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Portable H2O Quality Monitoring and Cloud Reporting System

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ABSTRACT

In order to ensure the safe supply of drinking water the quality needs to be monitored in real time. For this purpose, IoT based" Portable H2O Quality Monitoring and Cloud Reporting System" has been proposed. In this paper, we present the design and development of a portable water quality monitoring system that monitor the quality of water in real time. This system consists of some sensors which are used to measure the physical parameters of water such as pH, turbidity, conductivity and temperature. The measured values from the sensors are read by the microcontroller and these values are sent to the cloud using ESP-8266 Wi-Fi module. The data from the sensors can be viewed in the GUI and reports are sent accordingly.
Keywords: pH sensor, Turbidity sensor, Temperature sensor, Conductivity sensor, Arduino Uno model, IoT, Water Quality Monitoring.

I. INTRODUCTION

Over the past decade, online water quality monitoring has been widely used in many countries known to have serious issues related to water pollution [6]. The water is limited and essential resource for industry, agriculture and all the creatures existing on the earth including human beings. Any imbalance in water quality would severely affect the health of the humans, animals and also affect the ecological balance among species [9]. The drinking water is precious and valuable for all the human beings so the quality of water must be monitored in real time. These days water quality monitoring in real time experiences difficulties because of global warming, inadequate water resources, increasing population, etc. Hence, there is a need for developing better methodologies to monitor the water quality parameters in real time.

The WHO (world health organization) estimated, in India, 844 million people are estimated to die each year from diarrhoea as a result of unsafe drinking water. WHO also estimates that 21% of diseases are related to unsafe water in India. Also, more than 1600 deaths alone cause due to diarrhoea in India daily. Therefore, various water quality parameters such as conductivity, pH, turbidity and temperature should be monitored in real time.

The water quality parameter pH measures the concentration of hydrogen ions. It shows whether water is acidic or basic. Pure water should have a pH value of 7. If it is less than 7, it indicates acidity and if it is more than 7, it indicates basicity. The normal range of pH is 6 to 8.5. In drinking water if the normal range of pH is not maintained, it causes irritation to the eyes, skin and mucous membranes. The conductivity indicates the ability of water to pass an electric current. It is the degree to which a specified material conducts electricity, calculated as the ratio of the current density in the material to the electric field which causes the flow of current. In water it is affected by various dissolved solids such as chloride, nitrate, sulfate, sodium, calcium, etc. Turbidity measures the large number of suspended particles in water that is invisible. Higher the turbidity higher the risk of diarrhoea, cholera. Lower the turbidity then the water is clean. It indicates the degree at which the water loses its transparency. It is considered as a good measure of the quality of water. Water temperature is one of the most important characteristics of an aquatic system, affecting dissolved oxygen levels. The solubility of oxygen decreases as water temperature increases. If the water is too warm, it will not hold enough oxygen for aquatic organisms to survive. The deterioration of water resources has become a common human problem [7]. The traditional methods of water quality monitor involve the manual collection of water samples from different locations. These water samples are tested in the laboratory manually. Such approaches are time consuming, tedious, prone to errors and hence no longer considered to be efficient. Moreover, the current methodologies include analysis of various water quality parameters such as physical and chemical parameters. Traditional methods of water quality detection have the disadvantages like complicated methodology, long waiting time for results, low measurement precision and high cost [8]. Therefore, there is a need for continuous monitoring of water quality parameters in real time.

By focusing on the above issues, we have developed and designed a low cost and portable water quality monitoring system that can monitor the water quality in real time using IoT environment. In our system water quality parameters are measured by the different water quality monitoring sensors such as pH, turbidity, conductivity and temperature. These sensor-values are processed by the microcontroller and these processed values are sent to the cloud using ESP-8266 Wi-Fi module. In this system, IoT module is used to access processed data from the core controller to the cloud. The processed data can be monitored through a GUI designed for this purpose.
The overview of the following sections of this paper is as provided here: Section II provides the Iot, Section III provides Arduino Uno, Section IV provides a literature survey of existing systems, Section V provides system components, section VI provides schematic circuit diagram with its working and section VII provides result and analysis of the system.

II. INTERNET OF THINGS

In the past decade, all human life changed because of the internet. The internet of things has been heralded as one of the major development to be realized throughout the internet portfolio of technologies [15]. The Internet of Things (IoT) is concerned with interconnecting communicating objects that are installed at different locations that are possibly distant from each other [11]. Internet of Things represents a concept in which, network devices have ability to collect and sense data from the world, and then share that data across the internet where that data can be utilized and processed for various purposes. IoT communication is quite different from the traditional human to human communication, bringing a large challenge to existing telecommunication and infrastructure [12]. Furthermore, IoT provides immediate information regarding access to physical objects with high efficiency. The concept of Internet of Things is very much helpful to achieve real time monitoring of sensor data.

Internet of Things (IoT) is a kind of network technology, which is based on information sensing equipments such as RFID, infrared sensors, GPS, laser scanners, gas sensors and so on, can make anything join the Internet to exchange information, according to the protocol, which gives intelligent identification, location and tracking, monitoring and management [13]. In proposing system we introduce cloud computing technique for monitoring sensor values on the internet. Cloud computing provides the access of applications as utilities, over the internet. The cloud computing characteristic and development approaches are explained in [10], [11], [12]. Cloud computing is a large scale processing unit which processes in run time and it is also a very low cost Technology based on the IP. The application area of IoT includes building and home automation, smart city project, smart manufacturing of various products, wearables, health care systems and devices, automotive etc.

III. ARDUINO UNO

Arduino Uno is the platform used in this project because of its simplicity and convenience. This microcontroller board has ATmega328P microprocessor. It includes 14 digital input/output pins (among them six can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a power jack, a USB connection, an ICP header and a reset button. It is simple to connect to the computer and program it as needed by the user. It can be powered in two ways, with battery by using power socket or just simply connecting through USB. Starting from A0 through A5, there are six analog inputs, and each pin has 10 bits of resolution. In total 14 pins are the digital pins, and they can be used as an input as well as output, using pinMode(), digitalWrite(), and digitalRead() functions in programming. These pins run at 5 Volts. Providing and receiving 20 mA current by each pin which is recommended operating condition and has an internal pull-up resistor of 20 to 50K ohm. With the intention of not damaging the microcontroller, 40 mA is the maximum current which must not be surpassed on any input and output pin. The Arduino Uno is possible to programme with the Arduino software. The Arduino Uno contains ATMega328 microcontroller which is already programmed with the bootloader to help with equipping programs in the system. For communicating it uses STK500 protocol. Bypassing the bootloader and program the microcontroller through the ICSP header using Arduino ISP or similar is possible as well. The software for Arduino is free to use and is easily available in the public domain. The ATmeaga328 contains 32 kB memory plus bootloader occupies 0.5 kB of memory. This has 2 kB of SRAM and 1 kB of EEPROM.

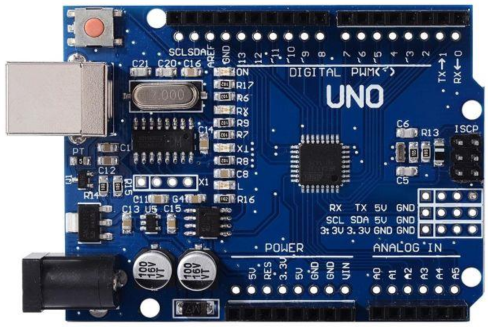

Figure 1. Arduino Uno

IV. LITERATURE SURVEY

Paper entitled “Water Quality Monitoring for Rural Areas-A Sensor Cloud Based Economical Project” by Nikhil Kedia, published in 2015 1st International Conference on Next Generation Computing Technologies (NGCT-2015) Dehradun, India. This paper highlights the entire water quality monitoring methods, sensors, embedded design, and information dissipation procedure, role of government, network operator and villagers in ensuring proper information dissipation. It also explores the Sensor Cloud domain. While automatically improving the water quality is not feasible at this point, efficient use of technology and economic practices can help improve water quality and awareness among people.[1]

Paper entitled “Real Time Water Quality Monitoring System” by Jayti Bhatt, Jignesh Patoliya This paper describes to ensure the safe supply of drinking water the quality should be monitored in real time for that purpose new approach IOT (Internet of Things) based water quality monitoring has been proposed. In this paper, we present the design of IOT based water quality monitoring system that monitor the quality of water in real time. This system consists some sensors which measure the water quality parameter such as pH, turbidity, conductivity, dissolved oxygen, temperature. The measured values from the sensors are processed by microcontroller and this processed values are transmitted remotely to the core controller that is raspberry pi using Zigbee protocol. Finally, sensors data can view on internet browser application using cloud computing.[2]

Paper entitled “Industry 4.0 as a Part of Smart Cities” by Michal Lom, Ondrej Pribyl, Miroslav Svitek .This paper describes the conjunction of the Smart City Initiative and the concept of Industry 4.0. The term smart city has been a phenomenon of the last years, which is very inflected especially since 2008 when the world was hit by the financial crisis. The main reasons for the emergence of the Smart City Initiative are to create a sustainable model for cities and preserve quality of life of their citizens. The topic of the smart city cannot be seen only as a technical discipline, but different economic, humanitarian or legal aspects must be involved as well. In the concept of Industry 4.0, the Internet of Things (IoT) shall be used for the development of so–called smart products. Sub-components of the product are equipped with their own intelligence. Added intelligence is used both during the manufacturing of a product as well as during subsequent handling, up to continuous monitoring of the product lifecycle (smart processes). Other important aspects of the Industry 4.0 are Internet of Services (IoS), which includes especially intelligent transport and logistics (smart mobility, smart logistics), as well as Internet of Energy (IoE), which determines how the natural resources are used in proper way (electricity, water, oil, etc.). IoT, IoS, IoP and IoE can be considered as an element that can create a connection of the Smart City Initiative and Industry 4.0 – Industry 4.0 can be seen as a part of smart cities.[3]

Paper entitled “QOI-Aware Energy Management in Internet-of-Things Sensory Environments” by Zhanwei Sun,Chi Harold Li,Chatschik Bisdikian,Joel W.Branch and Bo Yang. In this paper an efficient energy management frame work to provide satisfactory QOI experience in IOT sensory environments is studied. Contrary to past efforts, it is transparent and compatible to lower protocols in use, and preserving energy-efficiency in the long run without sacrificing any attained QOI levels. Specifically, the new concept of QOI-aware “sensor-to-task relevancy” to explicitly consider the sensing capabilities offered by an sensor to the IOT sensory environments, and QOI requirements required by a task. A novel concept of the “critical covering set” of any given task in selecting the sensors to service a task over time. Energy management decision is made dynamically at runtime, as the optimum for long-term traffic statistics under the constraint of the service delay. Finally, an extensive case study based on utilizing the sensor networks to perform water level monitoring is given to demonstrate the ideas and algorithms proposed in this paper, and a simulation is made to show the performance of the proposed algorithms.[4]

Paper entitled “Adaptive Edge Analytics for Distributed Networked Control of Water Systems” by Sokratis Kartakis, Weiren Yu, Reza Akhavan, and Julie A. McCann. This paper presents the burst detection and localization scheme that combines lightweight compression and anomaly detection with graph topology analytics for water distribution networks. We show that our approach not only significantly reduces the amount of communications between sensor devices and the back end servers, but also can effectively localize water burst events by using the difference in the arrival times of the vibration variations detected at sensor locations. Our results can save up to 90% communications compared with traditional periodical reporting situations.[5]

V. SYSTEM COMPONENTS

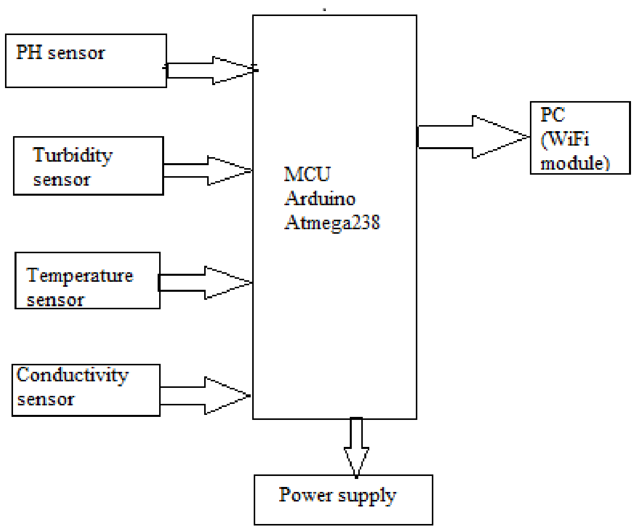

Figure 2. Block diagram of our system

Our system consists of several sensors (temperature, pH, turbidity, conductivity) is connected to microcontroller. The microcontroller access the sensor values and process them to transfer the data to the cloud using ESP-8266 Wi-Fi module. Arduino Uno is used as a core controller.

Parameters that we have chosen and their standard values are

Table 1

	PARAMETER	UNIT	QUALITY RANGE
1	pH	pH	6.5-8.5
2	Conductivity	µS/cm	500-1000
3	Turbidity	NTU	0-5
4	Temperature	^{0} C	0-100

pH sensor: The pH of a solution is the measure of the acidity or alkalinity of that solution. 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. It operates on 5V power supply and it is easy to interface with arduino.The normal range of pH is 6 to 8.5. pH is defined as the negative logarithm of the hydrogen ion concentration.

$$pH = -\log_{10}(H^+)$$

Figure 3. pH sensor

Turbidity sensor: Turbidity is a measure of the cloudiness of water. Turbidity has indicated the degree at which the water loses its transparency. It is considered as a good measure of the quality of water. Turbidity blocks out the light needed by submerged aquatic vegetation. Formula to measure turbidity in NTU,

NTU = a (TSS)b

NTU = Turbidity Measurement

TSS = Suspended solids measurement in mg/L

a = Regression- estimated coefficicent

b = Regression- estimated coefficicent

Figure 4. Turbidity sensor

Temperature sensor: Water Temperature indicates how water is hot or cold. The range of DS18B20 temperature sensor is -55 to +125 °C. This temperature sensor is digital type which gives accurate reading. Arrhenius equation is used to determine temperature dependence on reaction rates.

k = Ae-Ea/(RT)

k = Rate constant

T = Absolute temperature in Kelvins

A = Pre-exponential factor, a constant for each chemical reaction

Ea = Activation energy for the reaction

R = Universal gas constant

Figure 5. Temperature sensor

Conductivity sensor: Water conductivity sensors are used in water-quality applications to measure how well a solution conducts an electrical current. This type of measurement assesses the concentration of ions in the solution. The more ions that are in the solution, the higher the conductivity. Formula to calculate electrical conductivity,

EC = J/e = 1/r

J = Current density

e = Electric field intensity

TDS = 0.9 * EC

TDS = Total dissolved salts

EC = Electrical conductivity

Figure 6. Conductivity sensor

Wi-Fi module: The ESP-8266 Wi-Fi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP-8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP-8266 module comes pre-programmed with an AT command set firmware. The ESP-8266 module is an extremely cost effective board with a huge, and ever growing, community.

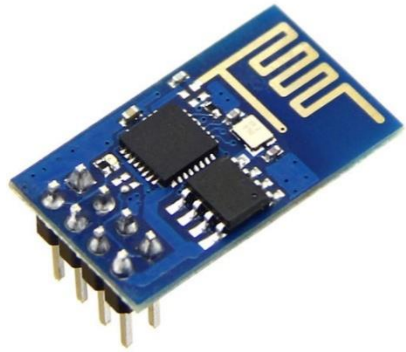

Figure 7. ESP-8266 Wi-Fi module

VI. SCHEMATIC CIRCUIT WITH ITS WORKING

The whole design of the system is based mainly on IoT. There are basically two parts included, the first one is hardware and the second one is software. The hardware part has sensors such as temperature sensor, pH sensor, turbidity sensor and conductivity sensor which help to measure the real time values, along with Arduino Uno microcontroller, ESP-8266 Wi-Fi module and LCD screen.

Each sensor is dipped in the water sample. The values read by these sensors are analog and continuous. Each sensor has its own comparator which acts as a communication medium between the sensor and the microcontroller. Since these values are analog, the Analog-to-Digital Converter(ADC) is used to convert them to digital and discrete values. The values are set and varied using Potentiometer which is present on each sensor. These digital values are displayed on the 2x16 LCD screen. ESP-8266 Wi-Fi module is used to give microcontroller access to

Wi-Fi network i.e., it gives connection between the hardware and software. When we supply AC using adapter, Arduino and Wi-Fi module turn on. There is a trigger button which when pressed pushes the values to the cloud.

Software part is designed using Microsoft Visual Studio Ultimate 2010. We have used NET framework for the GUI.

There is a dropdown menu where we select "monitoring". We get directed to another page. When the "start monitoring" is clicked, the values displayed on the LCD is shown here. If the values are not in the specified range, an email is sent to the concerned authority in PDF format. If no action is taken even after a stipulated amount of time, these details are posted on the simulated social networking site which we have created for this purpose

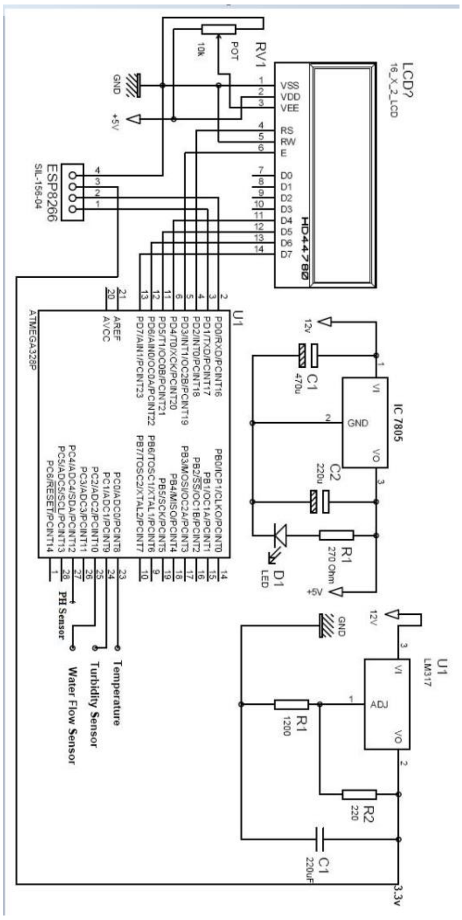

Figure 8. Schematic Circuit Diagram

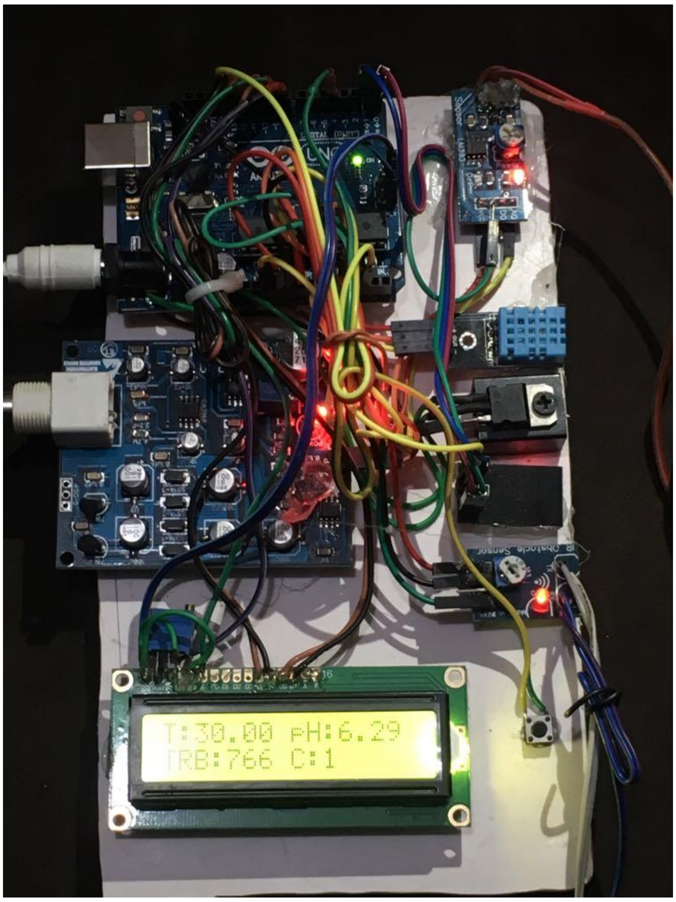

Figure 9. Hardware model

VII. RESULT AND ANALYSIS

  

(1) Tap water (2) RO water (3) Muddy water

 

(4) Salty water (5) Soapy water

Figure 10. Water Samples

We took five samples of water namely tap water, RO water, muddy water, salty water and soapy water and tested each of them individually with our device. In case of first sample, we observed that the pH was less than the normal range (6.5-8.5), conductivity was below normal range(500-1000) and turbidity was more than the specified range(1-5). Hence, this water is not suitable for drinking.

In case of second sample, we observed that the pH, conductivity and turbidity were in the normal range specified for drinking. So, this water is fit for drinking purpose.

In case of third sample, we observed that the pH was more than the normal range (6.5-8.5), conductivity was way above the normal range(500-1000) and turbidity was more than the specified range(1-5). Hence, this water is not suitable for drinking.

In case of fourth sample, we observed that the pH was above the normal range (6.5-8.5), conductivity was within the normal range(500-1000) and turbidity was slightly more than the specified range(1-5). Hence, this water is not that suitable for drinking.

In case of fifth sample, we observed that the pH was more than the normal range (6.5-8.5), conductivity was below the normal range(500-1000) and turbidity was more than the specified range(1-5). Hence, this water is not suitable for drinking.

So, our device can be used to check the quality of water and as well as monitor it in real time. Since it is not done manually, it is less likely to give erroneous values.

Operation is simple. Even a layman can operate it with ease without having any prior knowledge about it.

It reduces the total time spent in collecting the water samples, testing it and waiting for the results. Hence our system is useful for monitoring the water quality.

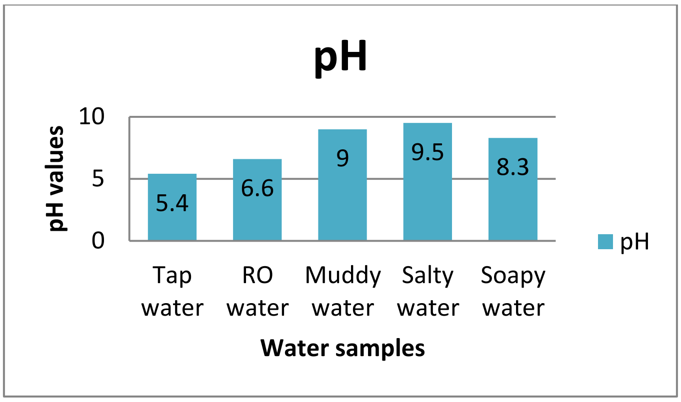

Figure 21. pH graph

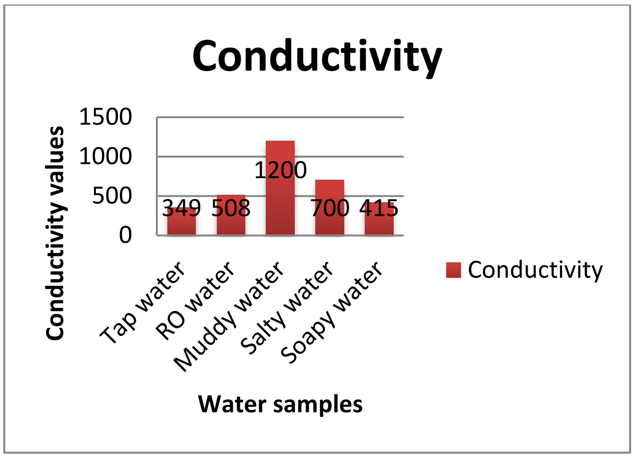

Figure 32. Conductivity graph

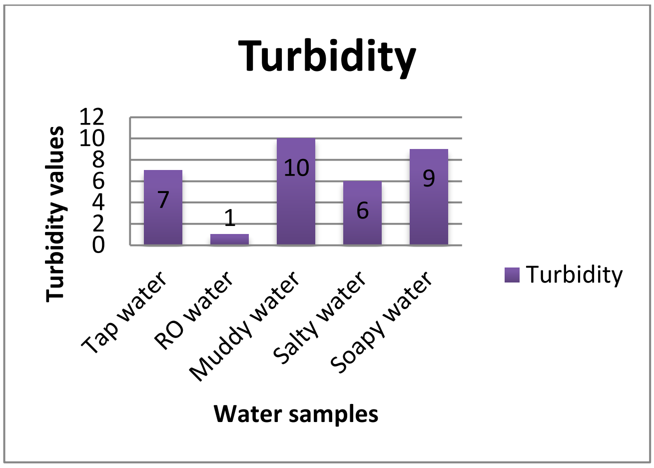

Figure 43. Turbidity graph

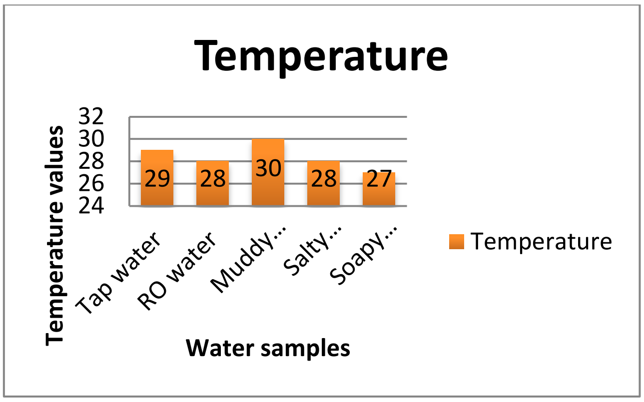

Figure 54. Temperature graph

VIII. ACKNOWLEDGEMENT

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