Monitor Water: A Monitoring System Using NodeMCU ESP8266

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Abstract*—Water quality has big importance for all living beings. For human consumption, it is necessary for water to have drinking standards. However, in many institutions and homes, there is no information on the quality of the water being consumed, which can be harmful to health as there are several factors that change water parameters. In order to solve this problem, we developed a prototype to monitor pH, turbidity and temperature of water intended for human consumption. In this project, we used the NodeMCU ESP8266 microcontroller to read the sensors and send the values obtained to a database. In addition, we created a Web interface to consult this data according to the chosen date and we used Twilio webhook to notify through WhatsApp when some of the measured parameters were outside the standard of potability. The results obtained after the prototype tests were satisfactory, as the sensors showed stable and consistent readings and the data acquisition and monitoring system worked as expected.*

Keywords— Water quality, NodeMCU, water monitoring, potability.

I. Introduction

The Internet of Things (IoT) has been used in several applications, facilitating the communication, control and monitoring of devices. In other words, IoT facilitates activities that are essential in people's daily lives. One of these activities is related to the quality of water intended for human consumption. According to annex XX of Consolidation Ordinance No. 5/2017 by the Ministry of Health of Brazil, drinking water must comply with the microbiological and physico-chemical standards established by this ordinance [1]. Because of this, it is necessary that water parameters are monitored frequently to ensure that the water is suitable for consumption.

Water monitoring can be done directly with human intervention or using resources that make it automatic. When done automatically, the data is more accurate and it is possible to obtain a large number of samples at short intervals [2].

Therefore, the objective of this project is to present a low-cost embedded system, called Monitor Water, which using the IoT concept capable of monitoring the main physical-chemical parameters of water intended for human consumption, such as pH, turbidity and temperature and sending the obtained data to the user.

II. Theoretical Background

A. Water Quality

The term "water quality" is used to express a set of parameters that make it suitable, or not, for a given purpose [3]. Despite the existence of many important characteristics for qualitative water analysis, the proposed automatic monitoring will analyze three of the main physical-chemical parameters: pH, turbidity and temperature, as mentioned before.

The hydrogenionic potential (pH) consists of the intensity of the acidic or alkaline conditions of a liquid, through the concentration of hydrogen ions (H^+) [4].

Turbidity is the degree of interference with the passage of light through a liquid. The change in the penetration of light into the water is due to the presence of particles in suspension. In addition, turbidity influences the water disinfection processes, as the suspended particles act as a shield to pathogenic microorganisms, thus minimizing the action of the disinfectant [4].

Temperature is a factor that influences the variation of other water parameters. It has a great influence on the speed of chemical reactions, metabolic activities of organisms as well as on the solubility of substances in water [4].

In annex XX of Consolidation Ordinance No. 5/2017, in paragraph 1 of article 39 it defines that the standard of drinking water for human consumption is that the pH is in the range of 6.0 to 9.5 and in paragraph 1 of article 30 defines that the turbidity does not exceed 5 NTU (Turbidity Units) [1].

B. Internet of Things (IoT)

The Internet of Things is a set of physical and virtual objects integrated in networks connected to the Internet, thus allowing objects to collect, exchange and store a huge amount of data in a cloud, and when this data is processed and analyzed, it can generate information and large-scale services [5]. We use the term IoT when we have electrical or electromechanical devices connected to the internet and these devices communicate with each other. In general, smart objects consist of actuators and sensors, that is, any solution using IoT is either monitoring something or acting on a specific activity [11].

C. Databases

A database consists of a collection of information correlated with each other, where this data is stored in an organized manner in a table [6].

D. Web Programming

A web application is composed of two main parts: the front-end, which is responsible for interacting with the user and the back-end, which has control of the system and its database [7].

HTML (Hypertext Markup Language) is a text markup language used to structure a web page. Along with HTML it is possible to use PHP (Hypertext Preprocessor), which is the programming language widely used for back-end development [7].

JavaScript is a programming language that has many visual resources for implementation on web pages. With this language, it is easier to create buttons, graphics and animations, thus making the site more interactive and attractive to the user. Therefore, it is responsible for programming the front-end of the Web interface [8].

III. USED METHODS

In the water monitoring system, we used three sensors that have the function of measuring the pH, turbidity and water temperature.

The turbidity sensor consists of an infrared light emitting diode (LED) and a photodiode sensor. The amount of light reaching the diode depends on the turbidity of the solution, the greater the turbidity, the smaller the amount of light reaching the receiver, that is, there is a decrease in voltage on the photodiode [9]. The calibration of the turbidity sensor was made from standard calibration solutions of 0.1 NTU, 0.8 NTU, 8 NTU, 80 NTU and 1000 NTU, in order to determine the relationship of the sensor's output voltage value with the value of the standard solutions used. The relationship found for the turbidity sensor is shown in (1), where V in the equation is the voltage value obtained by the sensor when placed in water, and from this we determine the turbidity value in NTU.

$$\text{Turbidity Value} = -183{,}93V^2 + 343{,}82 + 856{,}4 \quad (1)$$

The pH sensor measures the acidity of the water by relating a potential differential between two electrodes. That differential is measured by means of a glass membrane that is sensitive to H+ ions and the other one measures the electrical potential using a standard reference solution, KCl, thus generating a potential difference between two electrodes and this voltage is a metric of the H+ ionic activity, that can be converted into a pH value [10].

In order to obtain the correct values of the pH sensors it was necessary to calibrate it. The calibration was performed using standard calibration solutions of pH 4, pH 7 and pH 10. Similarly to the turbidity sensor calibration, we determined the relationship between the output voltage value of the pH sensor and the value of the standard solutions used. The relationship found for the pH sensor is shown in (2), so that V indicates the value of the sensor's output voltage, when it emerges in the water, thus we determine the pH value.

$$pH\ Value = 12{,}97V - 8{,}3045 \quad (2)$$

To read the temperature we use a DS18B20 digital sensor that uses the 1-wire protocol and provides temperature measurements from 9 to 12 bits in degrees Celsius and the temperature is converted to 12-bit digital word in a maximum of 750 milliseconds. [12].

The measurement error of the DS18B20 temperature sensor was defined using the measurement comparison between it and a sensor used for measurements in the laboratory, the PT100. To vary the water temperature, we used a TEKNA hot plate. The sensors were placed in a beaker with water. Depending on the heating of the plate, the water temperature variation allowed different temperature values to be measured that were compared between the sensors and the maximum error value obtained was 0.96% and the error value was compensated through the microcontroller programming.

In the Monitor Water system, to carry out the reading of the sensors we developed an electronic circuit shown in Fig. 1 composed of the signal conditioning module of the pH sensor DFROBOT and the turbidity sensor DFROBOT, temperature sensor DS18B20, NodeMCU ESP8266, LCD display 20x4, I2C Module (PCF8574) and two Push-Buttons to turn on the display and reset the system when necessary. In addition, we used the CD4051 integrated circuit due to the fact that we have two analog sensors and the chosen microcontroller has only one analog port.

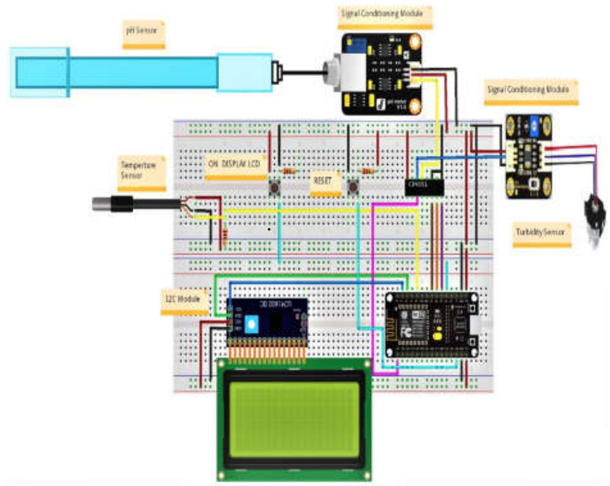

Fig. 1. Electronic circuit of Monitor Water.

The data processing of the sensors is done through the NodeMCU ESP8266 microcontroller. In this project, it has the purpose of sending the sensor data to the database and sending alerts to the user when some of the parameters are out of the potability standard.

To make the sensor data available to the user, we created a web interface based on IoT. In the development of this interface it was necessary to create the web server and the database. In order to reduce project costs, a Raspberry Pi 3 was chosen and the Raspbian NOOBS 4.19 operating system was installed to act as the server for the developed system.

As a database administration tool, phpMyAdmin was used, after creating a MySQL login and password using PHP scripts. We created two tables for storage in an orderly way: "Registration" and "Monitoring". In the “Monitoring” table, data from the sensors are received from the NodeMCU microcontroller, using the GET method, and in the “Registration” table, data are received after filling out a form through an HTML page of the web interface.

In the development of the interface, we used PHP to create the backend and to carry out communication with the project's database, JavaScript to create the dynamic aspects of it, coming from the frontend, and HTML to structure the pages.

In summary, the connection between the system and the server is made through a fixed IP of the server that is pre-defined in the microcontroller programming, to which it directs the data packets through the TCP/IP protocol to Raspberry, which for in turn manages the packages in order to make their data available to the user on the web pages.

To notify the user that the water parameters are out of the standard, we chose to use the Twilio webhook, which offers several free services, such as sending messages via WhatsApp. We used the Twilio PHP auxiliary library to concatenate names and numbers recorded in the database by the user through the web page, so that all registered numbers receive alert messages. The values considered out of the standard in this system are: 6 > pH > 9.5, turbidity > 5 NTU and Temperature < 40 ° Celsius.

The Monitor Water was encapsulated through the use of a box to couple the circuit and the display so that they do not come into contact with water as shown in Fig. 2 and for the sensors, we made a Styrofoam buoy to gather the three sensors and prevent critical parts from coming into contact with water as shown in Fig. 3.

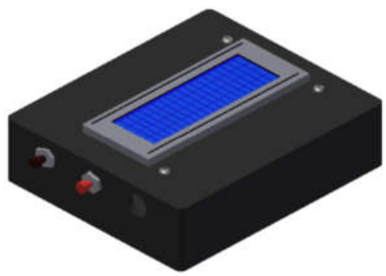

Fig. 2. Circuit encapsulation.

Fig. 3. Styrofoam buoy in top view.

IV. Results

A. Prototype Structure

In Fig 4, we have the result of the prototype together with a container used in order to simulate a water tank and inside it we placed the system sensors.

Fig. 4. Final prototype structure.

B. Web Interface

The interface developed for water monitoring consists of three pages: the homepage shown in Fig 5, the page for registering WhatsApp numbers shown in Fig 6 and the dashboard for viewing the data explained below.

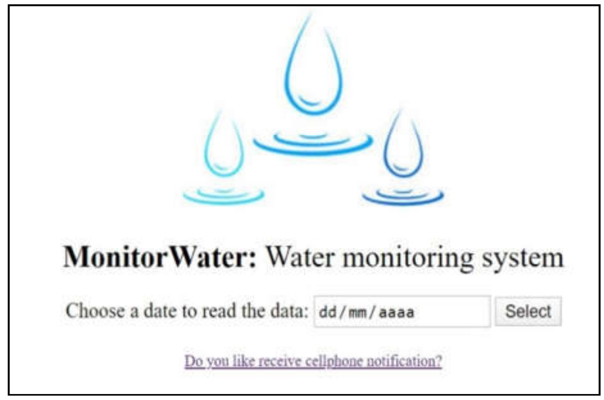

Fig. 5. Initial page of monitoring system.

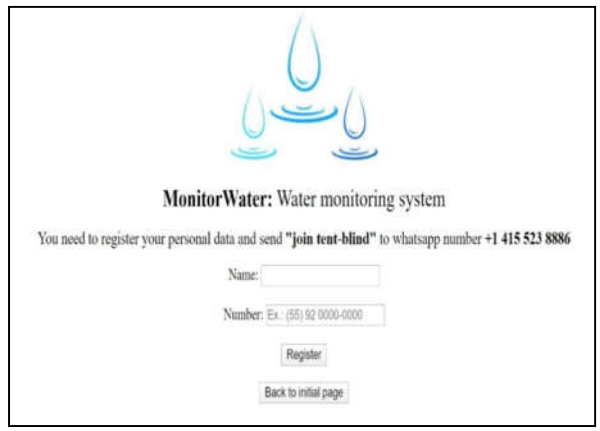

Fig. 6. Register to receive notifications.

Figure 7 shows the receipt of alerts by WhatsApp. The user receives the information that the value is above the standard and the value that was read by the sensor.

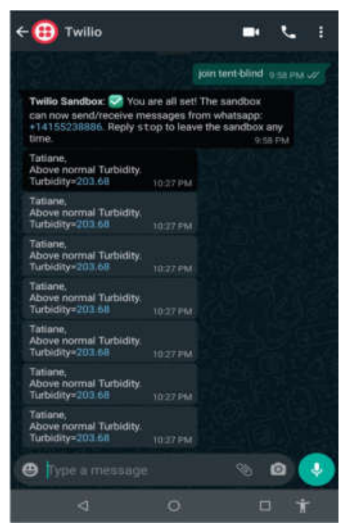

Fig. 7. Receiving notifications on WhatsApp.

C. Static Test

In the static test, the monitoring process was performed using sensors that we placed in the prototype container in mineral water for an interval of 2 hours. The dashboard graphs are shown in Figs. 8, 9 and 10. In Fig. 8, the water turbidity level was within the standard.

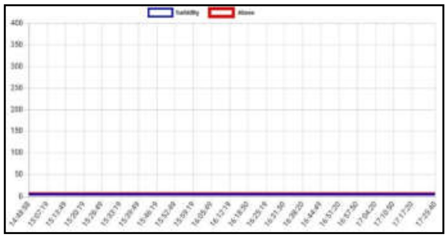

Fig. 8. Result of turbidity monitoring.

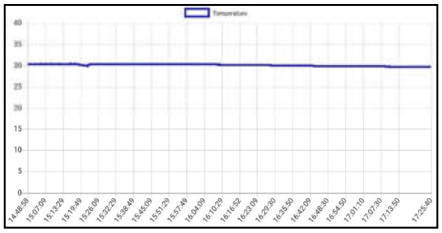

Fig. 9. Result of temperature monitoring.

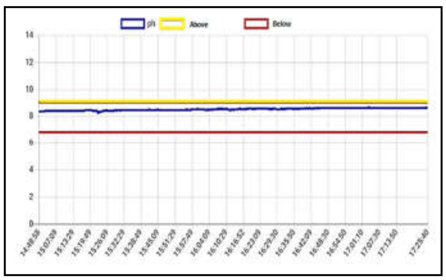

Fig. 10. Result of pH monitoring.

The results obtained in the static test show that the data acquisition was done correctly and there was stability in the measured values. In addition, these values were within the standard of potability.

V. CONCLUSION

The results of Monitor Water were satisfactory, as we achieved the main objective of building a device for monitoring water quality at a cost of R$ 691.76, which we consider to be low cost compared to existing water parameter meters available. The temperature, pH and turbidity sensors proved to be stable and together with this device, we implemented a system for storing data in a database. So, we created a client-server system and a database, in which Raspberry was used as the system server, and it met the needs of the project.

The monitoring system developed does not yet guarantee that the water is drinkable, as it monitors only three of the main water parameters, and it is necessary to monitor microbiological aspects and other physical-chemical parameters. However, in relation to the main physical-chemical parameters of water, the prototype that we have developed already meets the needs of monitoring and can contribute to the development of new projects aimed at the application of IoT related to water quality.

Therefore, as a suggestion for future works, more sensors can be added to the Monitor Water, such as electrical conductivity sensors, dissolved oxygen and TDS (Total Dissolved Solids), in order to carry out a more complete analysis of the water.

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