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RIVER WATER QUALITY MONITORING SYSTEM USING LoRa DEVICES AND PSoC5LP

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ABSTRACT

This document presents the design and implementation of a wireless system to measure water quality parameters in rivers, using low-cost elements for its implementation. Modules LoRa is used for communication between nodes, which is a technology that has emerged with the increase of wireless sensor networks (WSN), the Internet of Things (IoT) and machine to machine communication (M2M). The LoRa modules have great characteristics due to their low power consumption, taking into account the distances they can cover and their low cost. Sensor nodes are built to monitor the following parameters: electrical conductivity, pH and temperature, plus a receiver node that is connected to a computer to display the data received through a graphical interface made in Java.

Keywords: LoRa, internet of things (IoT), water quality, wireless sensor networks (WSN).

1. INTRODUCTION

Little by little, humanity has realized that water is not an inexhaustible resource, that certain actions have affected, finished or made this resource unfit for consumption in a drastic way due to the growth of the human population, the expansion of industrial and agricultural activity and the threat of climate change as stated by the United Nations [1]. Apart from that, water has been the origin of many infectious diseases, so it is important to have control over it.

Monitoring water quality parameters such as pH (hydrogen potential), EC (electrical conductivity), and the temperature has become an essential process so that based on the measurement of these and other parameters correct decisions can be made regarding water control. In Colombia, the quality of drinking water is only determined by taking into account physicochemical and microbiological parameters [2].

Measuring the electrical conductivity of water allows indirect determination of total dissolved solids or dissolved salts. Although salinity in water is not a primary standard and by itself is not a cause of health damage, the use of this water can present problems in its use, can cause stomach disorders in people who ingest it and can damage bathroom and kitchen fittings and even damage the pipe that carries the water. If the salinity is very high, it is no longer advisable to consume it without prior treatment [3].

When you measure the pH, you have information about the acidity or alkalinity of the water, which allows you to know if the water is corrosive or fouling. Temperature is also an important parameter to measure; thermal pollution can cause disorders in aquatic systems. If the temperature increases, the concentration of dissolved oxygen (DO) decreases, if the DO is deficient, it can cause the death of aquatic species [3].

The implementation of modules that allow the wireless monitoring of these parameters facilitates the work of the personnel in charge of this monitoring, since they do not have to travel to the sites (which may be remote or difficult to access) to obtain samples and thus be able to make historical traces of the results obtained [4-6].

2. METHODOLOGY

For the design of the prototype, the three variables to be measured are taken into account: temperature, conductivity, and pH. The processor used for the implementation of the prototype is a PSoC5LP [7,8] device manufactured by Cypress Semiconductor that is in charge of reading the analog signals from the sensors, reading the digital temperature sensor and communicating using the LoRa specification. The summary of all elements that make up the sensor node is shown in the block diagram in Figure-1.

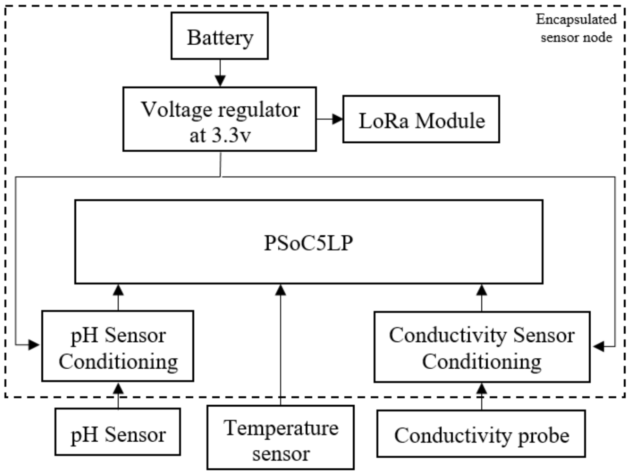

Figure-1. Block diagram of the sensor node.

As can be seen, conditioning circuits for pH and conductivity sensors are necessary. In the case of the temperature sensor, a digital sensor is not required, whose characterization is given by the manufacturer in his user's manual.

2.1 LoRa Module and Sensor Characterization

2.1.1 LoRa modules

Using LPWAN (Low-Power Wide-Area Network) wireless technology to develop IoT (Internet of

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Things) [9] and M2M applications. The LoRa modules used in the prototype are from the manufacturer Microchip reference RN2903, in Figure-2 you can see the diagram of the printed circuit board manufactured for the implementation of the prototype, which includes the connector for the antenna.

In terms of electrical characteristics, the module operates from 2.1V to 3.6V. The current consumption at 3.3V ranges from 0.0013mA (inactive) to 2.8mA. When in transmission mode it can reach up to 124.4mA [10]. Additionally, an external antenna of the manufacturer Pulse Electronics of reference W1063 was used.

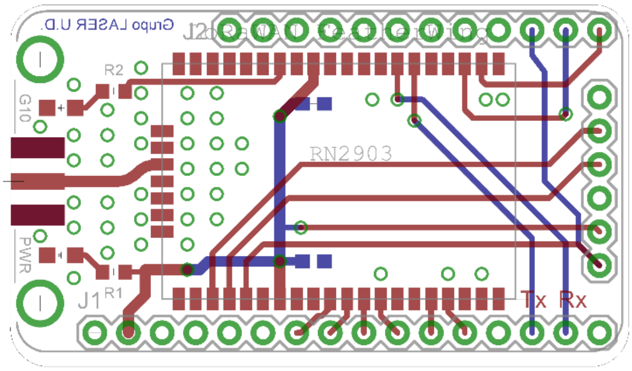

Figure-2. Printed circuit diagram of the LoRa RN2903 module.

The nodes in a LoRaWAN network are asynchronous and communicate when they have data ready to send either event-driven or scheduled, this type of pro-protocol is known as the Aloha method. In a bad or synchronous network, the node has to wake up to synchronize with the network and this consumes significant power, reducing the battery lifetime [11].

For your safety, LoRaWAN [12, 13] uses 2 layers of security: one for the network and one for the application.

- Network Session Key: Ensures that the authenticity of the node.
- Application Session Key: Ensures that the operator has permission to operate the network (see Figure-3).

AES-128 encryption is used along with key exchange using an IEEE EU164 Identifier.

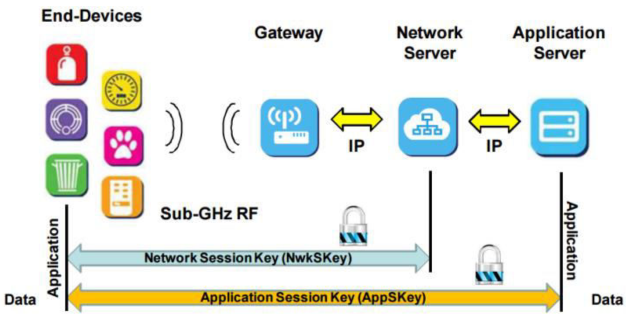

Figure-3. Security layers of a LoRaWAN network [14].

2.1.2 Conductivity sensor

Or the design of the probe that allows the measurement of the conductivity, different prototypes were created to find the most suitable one for the implementation of the project. Figure-4shows the three tested probes.

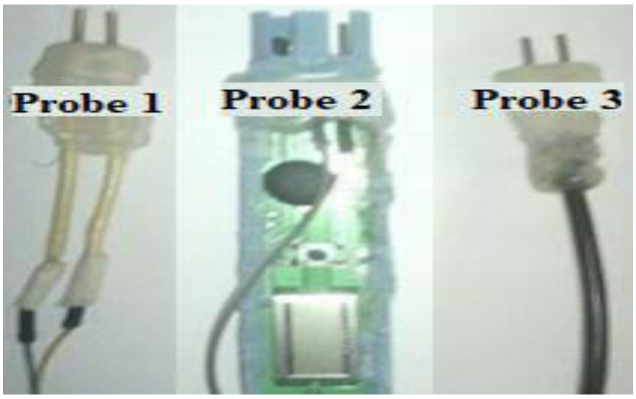

Figure-4. Manufactured probes for conductivity measurement.

Probe 1 was made from two AWG14 copper wires. Probe 2 was made from a TDS (Total Dissolved Solids) meter; finally, probe 3 was made from stainless steel of the same size as the copper wire. The circuit to measure with each of the sensors is shown in Figure-5, where the gain depends on the conductance of the substance in which the sensor is located.

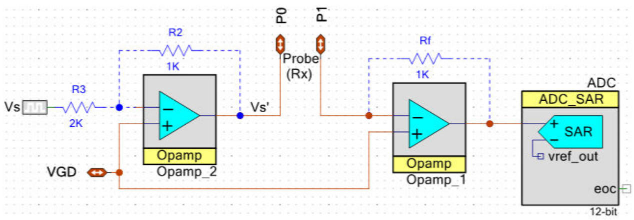

Figure-5. Circuit diagram of the conductivity sensor conditioning system.

Where VGD is a virtual ground created with the main purpose of the probe to receive an AC signal and is constructed using a follower a pair of series resistors of the same value, which will deliver a value close to 1.6V referred to the real ground. Since the prototype was powered by a single-pole source, the PSoC5LP's internal operational amplifier is used [7, 8].

The first operational amplifier is only responsible for reducing the voltage of the square signal generated in the PSoC5LP concerning the virtual ground. From there it is obtained (1).

$$V_S' = -V_S \frac{R_2}{R_3} + \left(\frac{R_2}{R_3} + 1\right) VGD \quad (1)$$

Since the signal Vs is a square signal and VGD is equal to 1.6V, there are two possible values as shown in (2).

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$$V_s' = \begin{cases} 0.8138V & , V_s = 3{,}2V \\ 2.3862V & , V_s = 0V \end{cases} \tag{2}$$

When analyzing the second operational amplifier, the output Vo is calculated with equation (3).

$$V_o = -V_s' \frac{R_f}{R_x} + \left(\frac{R_f}{R_x} + 1\right) VGD \tag{3}$$

By replacing (2) in (3), equation (4) is obtained.

$$V_0 = \begin{cases} \frac{0.8\,V * K\Omega}{R_x} + 1.6V & , Vs = 3.2V \\ -\frac{0.8\,V * K\Omega}{R_x} + 1.6V & , Vs = 0V \end{cases} \tag{4}$$

It's been known to:

$$G = \frac{1}{R} \tag{5}$$

$$k = G * K \tag{6}$$

So replacing (5) and (6) in (4) with Vs=0, we arrive at equation (7).

$$V_0 = -\frac{0.8V * K\Omega}{\mathrm{K}} * \mathrm{k} + 1.6V \tag{7}$$

Where.
k : Conductivity of the substance
K : Probe constant

From the behavior that can be seen in Figure-6, it is possible to calculate the constants of the probes, obtaining: K1=2.13 cm-1, K2=1.4169 cm-1 y K3=1.67329 cm-1.

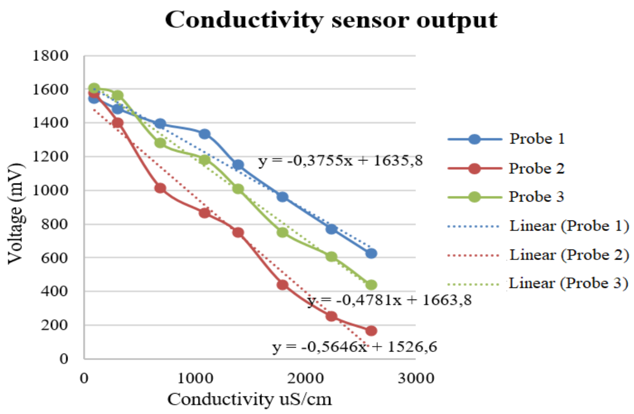

Figure-6. Response curves of manufactured conductivity sensors.

After this process, Probe 3 is selected because it has a more stable response and because of the stainless steel characteristic of the material.

2.1.3 pH sensor

For the pH sensor, the reference pocket pH meter KL-009(I) of the Kelilong Company was used. The main reason for the selection of the device was its low cost, which for the development of the prototype has sufficient characteristics, for example, the stabilization of the pH measurement is around 20 seconds [15].

For its characterization, a non-inverting gain amplifier 11 was used to obtain the response shown in Figure-7.

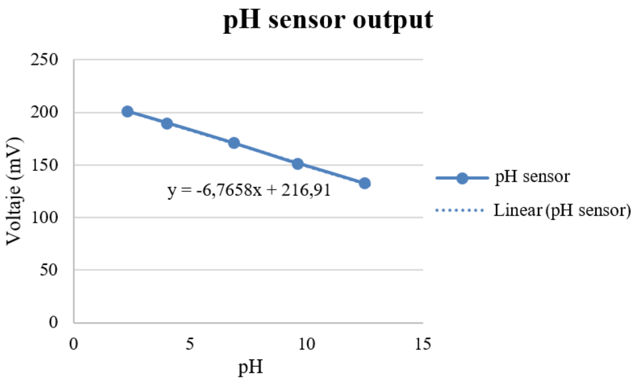

Figure-7. pH sensor response.

Figure-7 shows a linear response with offset; however, to take advantage of the full measurement range of the analog to digital converter, the conditioning circuit of Figure-8 is necessary to obtain a linear response without offset.

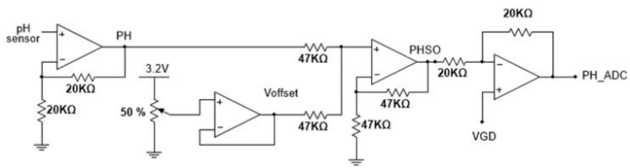

Figure-8. pH sensor conditioning circuit.

2.1.4 Temperature sensor

The selected temperature sensor is a probe type (designed to be immersed in water) with reference DS18B20 [16] shown in Figure-9.

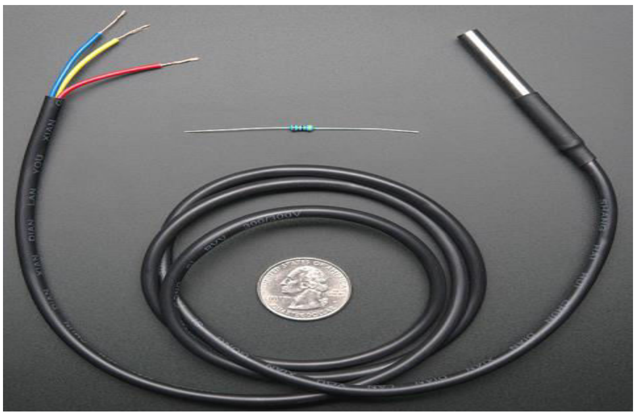

Figure-9. Probe type temperature sensor DS18B20 [16].

The output of the probe is digital and communicates with the PSoC5LP through the 1-Wire protocol where both transmission and reception are done by a single communications line.

2.2 Implementation of the Sensor Node

For the manufacture of the printed circuit of the sensor node, the free version of the Eagle CAD design tool was used, where all the components described above are designed and included (conditioning circuits, PSoC5LP, voltage regulator).

As the circuit must be above water, it is necessary to use floats and housing that protects the circuit from the water and for this purpose bottles are used as a form of recycling, and they also fulfill their function perfectly. The protection box will then have two bottles that will function as floats and another one that will function as protection, the structure manufactured is shown in Figure-10.

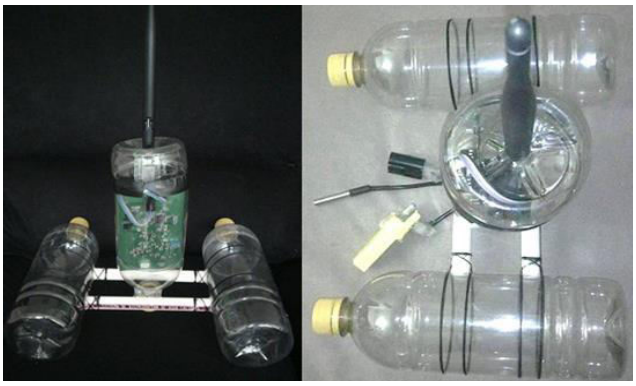

Figure-10. Sensor node terminated.

2.3 Receiving Node and Graphic Interface For Data Display

The receiver node is connected to the computer and will not have built-in sensors, so no microcontroller is required. This node will only receive the information from the sensor nodes, for communication with the LoRa module only a serial to USB converter will be needed that operates at 3.3V voltage values.

The program in charge of graphing the data taken from the two sensors nodes is designed in Java, which is a free object-oriented programming language. This program is in charge of graphing the data coming from the nodes, creating CSV files to save the data and configuring some parameters of the sensor nodes.

Its operation consists of opening a wire that will constantly monitor the information coming from the LoRa module, the flow diagram of this wire can be seen in Figure-11.

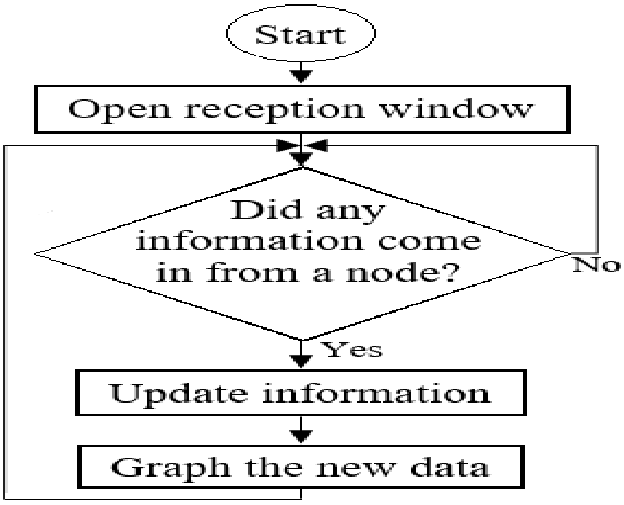

Figure-11. Thread in Java for the visualization of the received data.

The other options will be event-driven when the GUI buttons are pressed and the determined actions are activated. The implemented GUI can be seen in Figure-12.

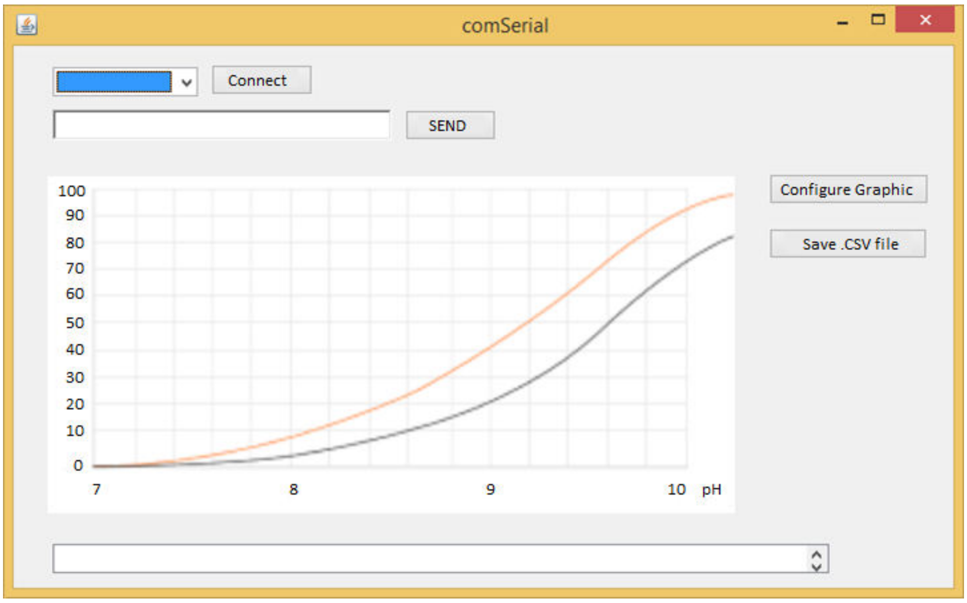

Figure-12. User interface for data reception.

3. TESTS AND RESULTS

To carry out the field tests, a point was taken from the Arzobispo River located in the city of Bogota (Colombia), the sensor node was located in the coordinates latitude 4.624 longitude -74.062. The receiving node was located approximately 360m away from the sensor node, thus checking the sending and receiving of data as shown in Figure-13.

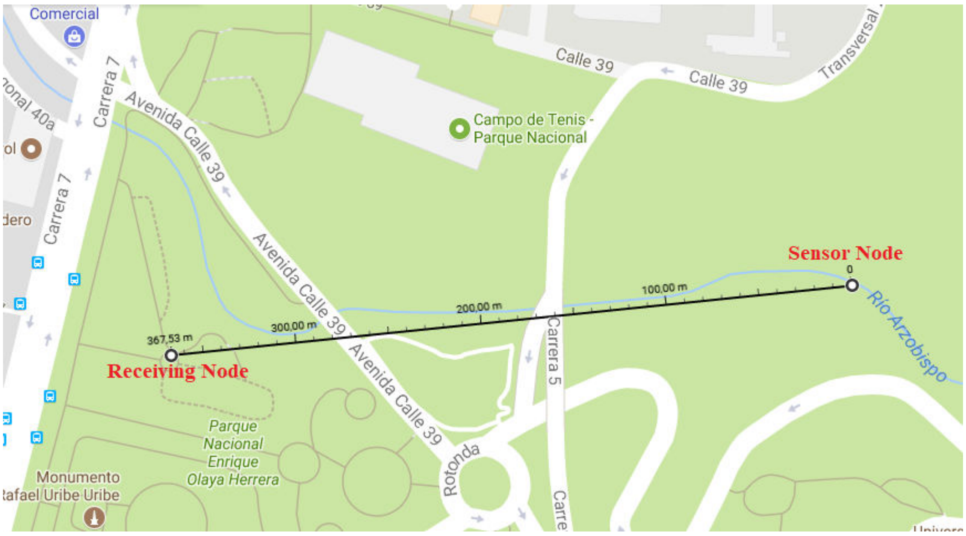

Figure-13. Location of the implemented prototype.

The prototype was successfully tested on the Arzobispo River, 300 data were taken in five hours of testing which are shown below in Figure-14, Figure-15 and Figure-16.

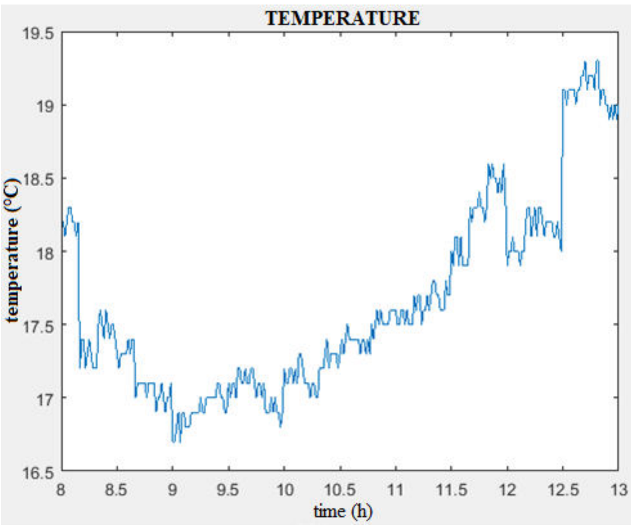

Figure-14. Temperature data - Arzobispo River test.

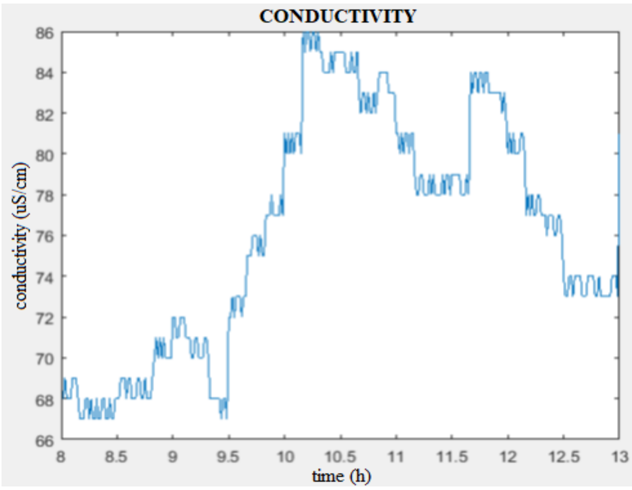

Figure-15. Conductivity data - Arzobispo River test.

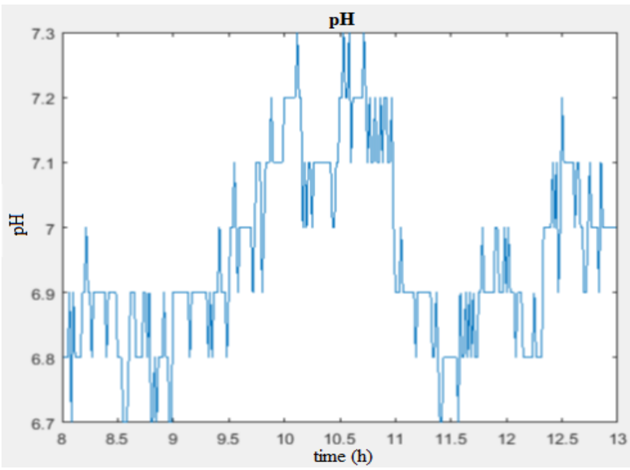

Figure-16. pH data - Arzobispo River test.

4. CONCLUSIONS

Effective communication depends not only on the communication modules and the devices to which it is connected but also on the medium in which it is transmitted; the distances reached by the LoRa modules in areas with high electromagnetic radiation are less than those obtained in non-urban areas.

Several parameters need to be adjusted to achieve a long-range with LoRa devices such as impedance coupling, a high gain antenna, choice of transmission power.

The Arzobispo River at the point where sampling took place has a pH and conductivity that are in the range of drinking water, although in the data corresponding to conductivity there were suspicious variations that may indicate an increase in dissolved solids.

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