Monitoring System for Physical Water Quality Parameters and Automatic Control for Chlorine Dosing in a Aerator Treatment Plant

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Abstract. This work proposes the development and creation of an automatic monitoring and control system for the dosage of chlorine in the water treatment plant, purifying the vital liquid and avoiding the distribution and consumption of water contaminated by microorganisms. This is achieved by monitoring the physical parameters through the data sent by wireless sensors, acquiring them in a database, sending the data in real time to a web server, where they can be visible to the public, and generating automatic control in Based on the data obtained, this occurs in a water treatment pools. For this, a Raspberry Pi board is used, it acts as a data store, two Arduino Mega, acting as control nodes, a LAN server, and a PID control for the automatic control of chlorine dosage, thus achieving precautionary that the water is disinfected from any microorganism present.

1. Introduction
The World Health Organization (WHO) defines water as an essential aspect for life and all people must have an adequate supply (safe, sufficient and accessible) [1–4]. For this reason, one of the primary aspects emphasized by the WHO is the adequate supply of drinking water [5,6]. Monitoring and control of water quality is carried out from its source that is, in rivers, wells, springs; in addition, in the treatment stations together with the distribution network until it reaches the user [7]. Points of vital importance for taking samples that will later be used to analyze them in a laboratory. Technicians analyze the physical, chemical or biological parameters to find out if the water is suitable for human consumption [8,9]. Most common illnesses are related to drinking contaminated water. The contamination is produced by microorganisms or by chemical products. Microorganism contamination can be reduced by chlorination [10]. However, chlorine only works correctly if the water is clean. Chemical contamination is difficult to deal with and requires specialized knowledge and equipment. Given the importance of water, there is the Ecuadorian Technical Standard (NTE) INEN 1108 in force since 2014 where it establishes the optimal quality parameters for drinking water consumption. Access to drinking water is a primary need and therefore a fundamental human right, many of our populations...
are forced to drink from sources whose quality leaves much to be desired and produces endless illnesses for children and adults, generally these sources hydric are underground\[11,12\]. This paper evaluates the improvement achieved within the common chlorine dosing system compared to an automatic monitoring and control system; thus giving a stability in the amount of chlorine, supplied in the water that needs to be made drinkable. The prototype of the automatic monitoring and control system has been implemented and evaluated in a water management company for drinking water treatments.

This document is made up as follows: In section 1 the introduction to the proposed topic is indicated, then the work related to the proposed topic is analyzed, that is, section 2. Section 3 shows the materials and the methodology developed in the project, specifically describing its Hardware and Software. Section 4 shows the automation of the proposed system. Finally, the conclusions and future work of the project are established in section 5.

2. Related Work

The application of automatic chlorine dosing systems in water treatment plants can be evidenced in several investigations carried out worldwide, as shown below. In Haiyunnisa et al. [13] they analyze how water quality in aquaculture is influenced by various physical and chemical parameters; parameters that have a great effect on water quality. In Vijayakumar et al. [14] carried out a system that monitors in real time the water parameters such as temperature, PH, turbidity, conductivity, dissolved oxygen. The values measured by the sensors are processed to a raspberry PI B + central controller with a LINUX operating system, it also has an IoT module (USR WIFI232) that sends data to the cloud and through WIFI to mobile devices.

In Gopavanitha et al. [15] proposes to take various parameters for water quality such as PH, turbidity, conductivity, temperature and flow; which are connected to a central core, thus using the Raspberry PI where a gateway is configured, which is responsible for data analysis and transmission with the server. UDP (User Datagram Protocol) packets are generated at the gateway and encapsulate the sample data to be sent to the remote server. The server collects the UDP packets and stores them in the database.

With the stability of the sensors the solenoid valve is actuated to control the flow of water in the pipe that is carried out from anywhere in the world through the internet. Similarly, in [16] a monitoring system was carried out for rural areas due to the need for quality control of water parameters in real time using technology Wireless WSN uses five types of nodes that control different status required for agriculture and personal consumption; such as water quality, soil monitoring, routing node, dissolved oxygen node, and the gateway server. The ground monitoring nodes send the collected data to the gateway node through the wireless module directly, or through the routing gateway node to the gateway node; each node of the data collection unified by the GPRS module allow this process and then upload to a server.

3. Controller design

For the development of the automatic control of the servo valve for the chlorine delivery, a proportional and integral control is used, PI, which allows calculating the ideal opening angle for the passage of the respective chlorine, thus establishing the required measurement so that the Water found in the supply section can be made drinkable according to the quality standard. In the event that the control process does not notice abnormalities in the water from the 4 sensors connected in each pool, the standard measure for disinfection is established, helping to establish that the water, despite presenting the appropriate values, is made drinkable [17]. Depending on the amount of liquid and the contact time that the chlorine needs to proceed to disinfect the water.

Figure 1 shows the schematic of the closed loop proportional and integral control system. A discrete PI controller is characterized by the expression presented in the following formula, to establish the working equation used in programming

\[ \frac{1}{10.1088/1742-6596/1878/1/012065} \]

http://www.pudeleco.com/files/a16057d.pdf
The proportional and integral controller, PI, allows maintaining the set pH level set point to provide the same level at the outlet in the drinking water supply tank, eliminating the error caused by the external variations that the water covers in the concentration pools. A discrete PI controller is characterized by the expression presented in the equation (1).

\[ D(z) = k \frac{z + a}{z - 1} \]  

(1)

Where:
D(z) = transfer function.
E(z) = transformed Z.

Applying the Z transform in (1) and solving we have equations (2), (3) and (4).

\[ D(z) = k \frac{z}{z - 1} \]  

(2)

\[ \frac{zD(z) - D(z)}{z} = kE(z)z - akE(z) \]  

(3)

\[ D(z) - z^{-1}D(z) = kE(z) - akz^{-1}E(z) \]  

(4)

Then the inverse Z transform is applied to obtain the difference equation of the system (5).

\[ Z^{-1} \left\{ D(z) = kE(z) - akz^{-1}E(z) + z^{-1}D(z) \right\} \]  

(5)

Finally, the difference equation is obtained from the PI controller. The equation (6) is established within the programming in the Arduino IDE and allows automatic control of the required lighting level.

\[ D(n) = kE(n) - akE(n-1) + D(n-1) \]  

(6)

Calculation of “a” and “k” by the Forward method in (7) and (8).

\[ D(z) = k_p + k_iT \frac{z}{z - 1} \]  

(7)

\[ D(z) = k \frac{z + a}{z - 1} \]  

(8)

Then:

\[ k_p + k_iT \frac{z}{z - 1} = k \frac{z + a}{z - 1} \]
\[ k = k_p + k_i T \]

\[ a = \frac{k_p}{k_p + k_i T} \]

4. Hardware

4.1. Wireless Communication
It is one in which communication ends are not linked by a physical means of propagation, but modulation is used; are characterized by the use of air and radio waves as a communication support. This is presented in Figure 2.

![Fig 2 Wireless Connection](image)

**Figure 2.** Wireless Connection

4.2. Wireless Sensor Network
A wireless sensor network (WSN), consists of autonomous distributed devices using sensors to monitor physical or environmental conditions with low energy consumption; that allow performing data acquisition and communication tasks (Figure 3). With NRF technology, sensor nodes are also created and therefore the capacity that they have with the wireless signal provided is considered. Within this communication it is necessary to use a topology for communication, seeing the compatible ones such as Star, Tree and Mesh.

![Fig 3 NRF Communication](image)

**Figure 3.** NRF Communication.
4.3. **Drinking water supply systems**
The drinking water supply system consists of a set of works necessary to collect, conduct, treat, store and distribute water from natural sources, whether underground or surface, to the homes of the inhabitants who will be favored with said system.

4.4. **Water quality parameters**
The parameters of water quality are criteria or standards which allow knowing the nature of water to know if it is suitable for human consumption or at the same time for the activities carried out with it. These parameters can be affected by different reasons which alter their composition or natural condition due to an instantaneous or gradual degradation of their quality, until they are no longer suitable for the intended use.

4.5. **Parameters analyzed in the Project**
**Hydrogen Potential (pH):** It is a measure of acidity or alkalinity of a solution, it indicates the amount of hydrogen ions present in the water.
  - Temperature: It is a physical quantity that reflects the amount of heat, either from a body, an object or the environment. It is important to know the temperature at which the water is located, since too high a temperature facilitates the growth of bacteria in the water.
  - Conductivity: It is the measure of the capacity of a material or substance to freely pass the electric current. It is a simple measure to determine the quality of the water because, unlike the pH, it only has an upper limit, that is, if it has conductivity tending to 0, it is good quality and if it reaches a limit determined by regulations, it is no longer drinkable.
  - Turbidity: Hazy appearance of water due to suspended particles.

5. **Implementation of the proposal**
The general implementation scheme is presented in Figure 4, which is based on the elaboration of a summary set of what the project in general is, showing the possible sensors, communication and control that it is intended to present to the automatic monitoring and control of chlorine dosage in treatment plants.

![Figure 4. Main implementation diagram.](image-url)
5.1. Automatic control system for chlorine dosing

The implementation of an automatic electronic system allows to control the opening of the main valve which sends the chlorine to the vital liquid storage tanks within the water distribution network, managing to establish an automatic control of the amount administered at each moment of the execution of this process within the company [18].

The system guarantees the highest stability of the physical parameters of the water that are detailed in the Ecuadorian technical standard INEN-1108, comparing the values of pH, temperature, turbidity and conductivity of the water generated by the purification process with those mentioned in the standard. The prototype of the system for monitoring physical water quality parameters and automatic control consists of four blocks. In the first block, the measurement and acquisition of information is carried out with the help of pH, turbidity, conductivity and temperature sensors. The second block is in charge of conditioning and data processing, with the help of an Arduino Nano programmable board, thus establishing powerful wireless nodes. In the third block, the control part that the system performs is established, establishing the valve opening accordingly with the measured parameters and constant variables presented by the company system that works on a regular basis.

5.2. System Block Diagram

It displays 4 fundamental factors of the system, such as the acquisition of data from possible sensors, the conditioning of the processed values, the system that encompasses management and visualization, and the control system as the fourth stage. The system block diagram is described in Figure 5.

![Figure 5. System Block Diagram](image)

5.3. Instrument connection diagram

Connections that must have both the control, display and sensors part are shown in Figure 6; which are responsible for collecting the data to be processed, which will later be stored for the relevant action.
5.4. Wireless node Network connection
For the sensors, 2 nodes are established, which are in charge of capturing the data from the purification tanks and one that serves for the feedback of the system, thus forming 3 nodes (Figure 7).

5.5. Development of data monitoring and visualization systems
The physical structure of the prototype is shown in Figure 8. The installation of the LAMP server was carried out on a raspberry pi 3. The platform was designed with Dreamweaver, software developed for the design of web pages that offers a wide variety of customization of functionalities. An online template and HighCharts tools are used for the graphical display of collected data. Figure 9 presents the web interface developed. The monitoring system interface has 4 tabs in which it presents detailed information of the system as well as real-time data captured by the wireless sensor nodes, display of the latest data collected with time and date [19]. The different services with the a water company has, graphic diagrams of the values collected in each pool where the vital liquid is found, statistical graphs in chronological order of the measured values and tables where the values taken during the operation of the prototype within the company are appreciated.
6. Conclusions
The chlorine dosing systems found in a water management company are damaged, which does not guarantee the user that the quality parameters that govern the Ecuadorian technical standard are met, therefore the system does not give credibility of correct operation by the different changes that the water undergoes at all times. In the comparative analysis carried out, it can be seen how the values generated by the sensors are similar to the studies carried out each year by the company in the values of pH, temperature, turbidity and conductivity, although at different times of the day each value is altered by which triggers the need for continuous monitoring to determine how much chlorine is required at any given time. The operation of the automatic control goes hand in hand with the data from the sensors since thanks to these, the correct opening of the servo valve can be determined to allow the passage of chlorine correctly, taking into account the pressure of the pump, the time of operation of the pump and the amount of water to which the chlorine is directed having as an independent variable the pH which is the element that is in constant monitoring and allows to regulate the servo valve and send the required amount of chlorine.

The wireless sensor nodes provide a range with a line of sight of 1 Km but in the company due to the existence of construction, it is noted that the distance is decreased by 25% of its normal capacity but does not affect operation since the central node is not affected since it is located at a distance of 50 meters from each sensor. The web page has an information delivery response of only seconds to be able to observe the measurement parameters, the visual tools are general at the moment of entering and establishes the information in each window with a delay of 0.5 seconds for the installed local connection. The adaptation of an electrical network is required for the operation of both the wireless
sensors and the server that controls the automatic monitoring and control part. With the use of free hardware and software technology, a lower cost is established compared to industrial sensors and the ease of being compatible with each other with a low-level programming language that can be improved depending on the company’s requirements. This system is part of the municipal administration and the functional tests are still being carried out.

7. References

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