Design and implementation of remotely monitoring system for pH level in Baghdad drinking water networks

Hussein A. Mohammed, Sura F. Ismail
University of Information Technology and communications, Baghdad, Iraq

Article Info

Article history:
Received Apr 14, 2020
Revised Oct 13, 2020
Accepted Oct 23, 2020

Keywords:
Arduino uno
Drinking water pollution
GPRS sim900
Measurement of pH sensor
Water quality monitoring

ABSTRACT

Many people in the recent days have suffering from number of diseases due to unsafe and impure drinking water, especially in rural areas. As typical laboratory experiments and official water quality tests take considerable amount of time to obtain results and due to non availability of a simple device that can measure such water quality parameters in real time, therefore in this paper a remote pH level monitoring system for Baghdad drinking water system is proposed. A PH level sensing and monitoring nodes are distributed at different location. These nodes are proactively measured pH level of water and send data to the maintenance center to give them overall picture about pH level via global position system (GSM). This proposed system gives a robust, low-cost and effective method for the drinking water maintenance center to measure and monitoring the water quality in real time environment.

1. INTRODUCTION

As known that water is a prime importance resource for the presence of life in the plant, therefore the availability water with high quality characteristics is an important factor for life survival [1]. One of the main quality parameters for water is ‘pH’, a chemical characteristic used to measure the acidity level of water. It is an indicator of contaminants in water as pH level varies according to the amount of native substances [2]. The pH of any solution can be measured by taking the negative common logarithm of the hydrogen ion as illustrated in (1) [3].

\[
pH = -\log (H^+) \tag{1}
\]

If the activity of hydrogen ion is approximately equal to the hydrogen ion concentration, then the solution is neutral [4]. Water with more hydrogen ions is acidity water, whereas water with more hydroxyl ions is alkaline. The range of pH is from 0-14, the water with pH 7 is being neutral; pH of less than 7 indicate acidity water while a water with pH of greater than 7 indicates alkaline water. The water with too high or two low pH value can hurt the aquatic organisms living within it and also not suitable for drinking. Figure 1 show some examples of everyday substances and their pH. PH can be affected by temperature, for any temperature degree above 25 °C a decrease in pH for about 0.45 occurs [5]. The pH of most drinking water lies within range 6.5-8.5 as shown in Figure 2.
Many standards for water quality are defined by authorized organizations with respect to usage of water [6]. Water quality monitoring is recommended in many situations. Water wells around factories and sites that dump hazardous waste should be regularly monitored [7] as well as water sources in agricultural areas [8, 9]. Moreover, soon after natural disasters such as floods, landslides, and tsunami, water sources in the affected area should be tested whether it is suitable for consumption or not [10, 11]. To assure the quality of water, tests can be performed on actual sites and in laboratories [12]. When few measurements are taken at sites, most of the tests are carried out in laboratories by collecting water samples from a particular site and transporting them into different locations. Taking readings in a different environment other than the native environment of the samples will produce error reports hampering accurate monitoring [13].

Therefore, many real time monitoring systems have been proposed. Zhenan et al. [14] presented an intelligent control system for water quality using wireless sensor networks and UAV control algorithm but this method is not efficient for controlling wireless systems. Barabde et al. [15] introduced a water quality measurement system based on zigbee and WSN. Rao et al. [16] presented an autonomous water quality monitoring system using GSM [16]. A water quality monitoring system based on IEEE 802.15.2.4 and solar energy is proposed by Fredrick et al. [17] but this system is expensive and difficult to deploy. Chandrappa [18] proposed a system for monitoring water quality using Raspberry Pi 2. Lai developed an image processing and fuzzy inference system for monitoring the water quality [19]. Thamarai and Anitha [20] introduced a real time monitoring and automated billing system for drinking water. Yu et al., [21] improve the power consumption and packet loss rate by proposing a rural drinking water monitoring system based on wireless sensor network. A robust sensor network that uses the mobile sensor technology and robust sensor placement model (RSPM) is proposed in [22] that can detect pollution events in water supply systems to ensure that the optimal sensor deployment scenario performs well in all achievable pollution scenarios. Jalal and Ezzedine [23] proposed water monitoring system that uses a new generation of wireless sensors to detect the chemical, physical and microbiological water parameters in Tunisian water resources. The proposed system in [24] examine the relationship between pH, total dissolved solids (TDS) and conductivity water quality parameters (WQPs) involved in the detection of hexavalent chromium contamination in the drinking water distribution system. Finally, Zennaro M et al. [25] present the design of a water quality measuring system and propose a prototype implementation of a water quality wireless sensor network (WQWSN) as a solution to water quality measurement in Malawi.

The traditional method for measure the quality of water is take samples of water to labs to be analyzed, but this method is not accurate method as well as not economical, reliable and time-consuming method. Therefore, a new accurate, robust and real time monitoring system is required. In this paper an effective, robust, low cost and real time system for measuring the pH level of the drinking water is propose. A distributed pH sensor at different locations in Baghdad are measured and monitored pH level. The output from pH sensors is fed to Arduino microcontroller which reads, processes and send the data to the maintenance center via via GPRS. The remainder of this paper is organized as follows: section 2 describes the proposed system in detail. The simulation results will be analyzed in section 3. And finally, in section 4 conclusions will describe.
2. **RESEARCH METHOD**

The proposed system consists of distributed pH sensors that automatically take water samples from tap water, pH sensor and send the measured information to Arduino microcontroller to be processing and then send periodic message about the status of pH level to the authorize center through GSM module. Finally the maintenance center mobile phone receives information about the level of pH and takes the correct action when the pH level is in the risk level; acidic (below 6.5) or alkaline (above 8.5). The proposed pH level water monitoring system block diagram is show in Figure 3.

![Figure 3. Overall proposed drinking water quality monitoring system](image3.png)

### 2.1. HARDWARE DESIGN

The proposed system consists of three parts; the first is controlling, sensing and processing part. The second part is responsible for transmitter operation. And the last part is the receiving part in the maintenance center.

#### 2.1.1. Controlling, sensing and processing tap water sample

Firstly, based on programming procedure a signal is sent from Arduino to relay. Then a relay makes a solenoid valve opening and a sample from tap water will sense by analog pH sensor. The sensing pH level is then processed by the microcontroller to take the correct action. The components; relay, solenoid valve, pH sensor and Arduino are illustrated in Figure 4.

![Figure 4. First part components](image4.png)
a. Arduino uno module

This module is the brain of the proposed system. This is a microcontroller board based on the ATmega328P that are used to controlling, processing and analyzing the pH of tap water. This microcontroller is suitable to the proposed system. The specifications of Arduino uno that used in this paper are describe in Table 1. Also, in this a paper we need Arduino shield to extend the features of Arduino. The Arduino shield that used here is shown in Figure 5. Every Arduino shield must have the same form-factor as the standard Arduino. They are circuit boards that mounted above Arduino module to instill it with extra functionality.

| Table 1. Specifications of Arduino Uno |
|----------------------------------------|
| Microcontroller | ATmega328 |
|------------------|-----------|
| Flash Memory     | 32 KB (0.5 KB from it used by bootloader) |
| EEPROM           | 1 KB |
| SRAM             | 2 KB |
| Operating Voltage| 5V |
| Input Voltage    | 7-12V |
| Input Voltage    | 6-20V |
| Analog Input Pins| 6 |
| Digital I/O Pins | 14 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Clock Speed      | 16 MHz |

b. Arduino relay

The second part in the propsed system is the relay that connected to Arduino board. It is actually an electrically switch operated by an electromagnet which activated with 5 volts from Arduino and it pulls a contact to make or break a high voltage circuit. It is controlled the valve of the water pipe. Figure 6 shows the circuit schematic of the relay module that represented as communication node between solenoid valve and Arduino.

c. Solenoid valve

The solenoid valve used for controlling water flow based on the signal came from Arduino through relay. The flow of water is received by pH sensor to read the level of the PH. Based on the sensed PH value, Arduino make the correct action. The valve should connect to tap water pipe at homes as shown in Figure 7.

d. Analog pH Meter (SKU: SEN0161) module

This meter has build-in, simple and convenient connection and particularly designed for Arduino microcontrollers. It must be noted that before the meter can be used and to obtain more accurate results, it must calibrate by the standard solution as shown below in the following steps:
- Firstly, equipment required for calibration is connected as shown in Figure 8.
- Under 25 °C environment temperature the pH electrode will put into a solution with pH value 7.0. And the result started to appear in the serial monitor of the Arduino IDE will record as shown in Table 2. If the reading on the serial monitor is close to the standard’s solution conductivity, then the calibration process was successful.
2.1.2. The transmitting part
In the transmitting part, GSM SIM900A module is used. This module is used for transmit notification about the level of pH that sensed from the home water pipe to the maintenance center to take the correct action. A picture for the connection of the GSM SIM900A module to the Arduino microcontroller is shown in Figure 9.

2.1.3. The receiving part
The mobile phone of maintenance control station will receive a periodically notification message about the pH level. The transmitted value is sensed by PH sensor and send by GSM module. The authorized persons in the maintenance station will record pH value corresponding to the location of the water pipe. The record the location corresponding to the phone number that implanted in GSM module in transmitting part.

2.2. Software design
The Software approach for the monitoring system of drinking water pH level is based on programming the Arduino Uno to communicating with GSM SIM900A module and analog pH meter. The Arduino Uno is programmed with the Arduino software. After measuring the level of PH, GSM SIM900A module send the PH value to the mobile phone of the maintenance center to take the correct action based on the sensed value. Figure 10 show a detailed flowchart about the proposed water pH level monitoring system.
3. RESULTS AND ANALYSIS

The prototype of the proposed pH level monitoring system is shown in Figure 11. We measured pH level of tap water at center and side locations in Baghdad as shown in Figure 12. Also, pH level of tap water in locations near the filtering and generating drinking water stations at different locations are measured as shown in Figure 13. This measuring information through pH meter is periodically sent to maintenance center through GSM module as SMS shown in Figure 14. The measured pH level will save based on phone number putting on GSM module for the monitored place, if the recorded pH value is lower than 6.5 (acidic water) or higher than 8.5 (alkaline water) the maintenance center should take necessary action to return the water to normal level (about 7.0).

It noticed from the measured results that range of pH in most locations is about 9. In spite of some studies said that drinking alkaline water may have benefits for people who suffer from high cholesterol, diabetes, and high blood pressure but it has some negative side effects such as decreasing the natural acidity level of stomach and the decreasing of free calcium in the body, which can affect bone health. Additionally, a high level of alkalinity in the body may cause skin irritations and gastrointestinal issues. Therefore, the monitoring center in Baghdad drinking water should treat of high alkalinity in drinking water and conversion to neutral water.
Figure 11. Proposed system overview picture

Figure 12. Measuring pH level

Figure 13. pH level at filtering and generating drinking water stations
4. CONCLUSION

One of the important things for human health is to consider the water quality. Therefore, in this paper a real-time pH level monitoring system for drinking water at consumer sites is presented. A number of sensing and controlling nodes are distributed at different locations to measure the pH level. These low cost, low power and lightweight distribute nodes is sense and process the measured data and send periodic message to the maintenance center mobile phone to give them overall picture about the pH level and if the level of pH is lower than 6.5 or higher than 8.5, then a warning message is sent to maintenance center to take an immediate action and return the level of pH to normal range (about 7). It noticed from the calculated results that the level of PH is in the alkaline level (above 8), therefore a water treatment system should apply to return the water to normal range.

ACKNOWLEDGEMENTS

The authors would like to thank the reviewers for their detailed comments on earlier versions of this paper.

REFERENCES

[1] Diersing, Nancy, “Water Quality: Frequently Asked Questions,” Florida Brooks National Marine Sanctuary, Key West, FL, 2009.
[2] Chapman D., “Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring,” CRC Press, 2nd Edition, 1996.
[3] Sigdel B., “Water Quality Measuring Station: pH, Turbidity and temperature measurement,” Degree Programmed in Electronics Thesis, Helsinki Metropolia University of Applied Sciences, Finland, 2017.
[4] World Health Organization, “PH in Drinking-water,” Geneva, 2007.
[5] APHA, “Standard methods for the examination of water and wastewater,” American Public Health Association, Washington DC, USA, 1989.
[6] World Health Organization, “Guidelines for drinking-water quality: recommendation,” World Health Organization, 1993.
[7] Wimalasuriya et al., “In situ water quality and economical leachate treatment system for Gohagoda dumping side,” Journal of Society for Social Management, pp. 1-10, 2011.
[8] Noble A., “Review of Literature on Chronic Kidney Disease of Unknown Etiology (CKDu) in Sri Lanka,” Working paper, 2014.
[9] Premalal W., Jayewardene D., “Effect of Low pH of Groundwater in Rathupaswala Area, Sri Lanka: A Case Study,” In Proceedings of the Research Symposium of Uva Wellassa University, 2015.
[10] Villholth K.G. et al., “Tsunami impacts on shallow groundwater and associated water supply on the East Coast of Sri Lanka,” Report from the International Water Management Institute, IWMI, Colombo, Sri Lanka, 2005.
[11] Ferretti E. et al., “A case study of sanitary survey on community drinking water supplies after a severe (post-Tsunami) flooding event,” Annalidell’Istitutosuperiore di sanità, vol. 46, no. 3, pp. 236-241, 2010.
[12] Christiansen V. G. et al., “Real-time water quality monitoring and regression analysis to estimate nutrient and bacteria concentrations in Kansas streams,” Water Science & Technology, vol. 45, no. 9, pp. 205-219, 2002.
[13] Cotruvo J. et al., “Providing safe drinking water in small systems: Technology, operations, and economics,” CRC Press, 1999.
[14] Zhenan L. et al., “Sensor-Network based Intelligent Water Quality Monitoring and Control,” International Journal of Advanced Research in Computer Engineering & Technology, vol. 2, no. 4, 2013.
[15] Barabde M., Danve S., “Real Time Water Quality Monitoring System,” International Journal of Innovative Research in Computer and Communication Engineering, vol.3, no. 6, 2015.
[16] Rao A.S. et al., “Design of low-cost autonomous water quality monitoring system,” IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2013, pp.14-19.
[17] Ishengoma F. R., “A Novel Design of IEEE 802.15.4 and Solar Based Autonomous Water Quality Monitoring Prototype using ECHERP,” International journal of Computer Science & Network Solutions, vol. 2, no. 1, 2014.
[18] Chandrappa S., Dharmanna L., “Design and Development of IoT Device to Measure Quality of Water,” IJ. Modern Education and Computer Science, vol. 4, pp. 50-56, 2017.
[19] Lai C., Chiu C., “Using image processing technology for water quality monitoring system,” IEEE International Conference on Machine Learning and Cybernetics (ICMLC), 2011, pp. 1856-1861.
[20] Thamarai D. S., Anitha S.R., “Potable Water Quality Monitoring and Automatic Billing System,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 4, no. 4, 2015.
[21] Yu J., et al., “Design of Real Time Monitoring System for Rural Drinking Water Based on Wireless Sensor Network,” 2017 International Conference on Computer Network, Electronic and Automation (ICCNEA), 2017, pp. 281-284.
[22] Hu C.et al., “Robust Placement of Mobile Wireless Sensors in an Uncertain Water Distribution System,” 2020 39th Chinese Control Conference (CCC), 2020, pp. 1667-1672.
[23] Jalal D., Ezzedine T., “Toward a Smart Real Time Monitoring System for Drinking Water Based on Machine Learning,” 2019 International Conference on Software, Telecommunications and Computer Networks (SoftCOM), 2019, pp. 1-5.
[24] Krishnan K., Bhuvaneswari P., “Multiple linear regression-based water quality parameter modeling to detect hexavalent chromium in drinking water,” 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), 2017, pp. 2434-2439.
[25] Zennaro M., et al., “On the Design of a Water Quality Wireless Sensor Network (WQWSN): An Application to Water Quality Monitoring in Malawi,” 2009 International Conference on Parallel Processing Workshops, 2009, pp. 330-336.

BIOGRAPHIES OF AUTHORS

Dr. Hussein A. Mohammed has 10 years of experience in the publishing Water and air pollution, with expertise in digital strategy for authors. In additional he is an Assistant Professor in university of information technology and communications in Baghdad, Iraq

Sura F. Ismail M.Sc. degree in computer engineering from the University of Baghdad, Iraq, in 2014. B.Sc. degree in computer engineering from the University of Baghdad, Iraq, in 2011. Currently, she is working as a lecturer at University of Information Technology and Communications (UOITC). Her current research interests include machine learning, Internet of Things, remote controlling and network security. E-mail address is: sura.fawzi89@uoitc.edu.iq.