Automated Water Storage Monitoring System for Rural Community in Malaysia Based on Arduino Microcontroller

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Abstract— **This project present a simple automated low cost water storage system in rural area intended to satisfy the demand of clean water and water shortage. There are still many rural areas in Malaysia that does not have the privilege to have clean water supply to satisfy the demand of water usage in daily life, such as in rural area in Kelantan, Sabah and Sarawak. The problem that they are facing is the water from the water well is not enough for the whole household at one time. Meanwhile, they still depend on the water sources such as self-dug water well. Besides that, these rural people are lack of infrastructure to monitor the level of water in order to use them in saving for daily life. So this project is developed to overcome the problem. Therefore, there are 3 important parts of this system defined as; water storage, filtering and monitoring system. The purpose of this project is to design automated low cost water storage system and the monitoring system which will characterized the sensors use based on real time data. As conclusion, the system capabilities to help storing clean water in rural area, thus solving clean water and sanitation issues while been monitored.**

Keywords— rural area; automated; water storage system; monitoring system

I. INTRODUCTION

Water is a fundamental component in keeping up life and required for all social and economic efforts [1]. It is not only meeting the current needs based on sustainable development of water resources, besides it is important for the future generation's needs, which has become a subject direction of many studies [2]. In support of Vision 2020, Malaysia will preserve and manage its water to ensure good enough and safe water for all. Two of the key purposes of the visions are water for people; to have an adequate supply of safe and good quality water supply is essential for the promotion of public health and water for food and rural development; provision enough water that will ensure countrywide food protection and promote rural improvement.

Despite of that, there are still many rural areas in Malaysia that does not have the privilege to have clean water supply to satisfy the demand of water usage in daily life, such as in rural area in Kelantan, Sabah and Sarawak. Almost of the rural area community still depends on the water sources from the self-dug water well. Based on analysis made in terms of percentage, there are several system that people in rural areas still used: 66% of them had gravity feed, 19.3% had rain water tanks, 9.7% had dug wells, 4% had mechanical pumps, and 1% had hydraulic rams[3]. The problem that they are facing is the water from the water well is not enough for the whole household at one time. Moreover, almost every home with a well has a pressure tank, however not every home with a well has a well water storage system [4]. This happened because the rate of the water usage is faster than the rate of the groundwater to recharge in the water well. Groundwater recharge is usually influenced by climate variability and human intervention and in Malaysia, groundwater level decreased day by day due to unnecessary withdrawal from irrigation sectors. Besides that, the groundwater is not clean enough as the water are mixed up with soil around the well causing the water to turn yellowish in colour and it is cannot be consumed especially for them to use for safe drinking [5] and cooking purpose. Unclean water consumed may causes some diseases risk of cancer and kidney toxicity because of the water contents of bacteria [6].

In order to overcome the problem faced by the rural community, this project will proposed an automated low cost water storage system. The water storage model will have three main parts. The water pumped system, water filtration system and the water storage unit. These three parts communicates using a microcontroller. The concept of the idea of this system is underground water usually rises only at a certain point. If there is no usage of the water, the water level will remain the same until someone uses it and it takes time for the underground water to recharge. By having this system installed, whenever the water well is not in used such as at night time, the water will be pumped automatically to the storage unit through the filtration unit. When it is recharged, it will be pumped again. This process will be continuously automatically control, until the storage unit is full and the water is sufficiently enough for the daily household usage.

II. METHODOLOGY

The methodology of this study was implemented through two stages. Firstly, starting with the sensors where they are the main component role in this system and controller development consists of microcontroller (Arduino) and Wifi module (ESP8266), the circuit was then developed to be a complete

system with monitoring module. The second stages involved with interfacing with monitoring system using Google Spreadsheets. The details of each development stage are explained in its respective sub-sections.

A. Sensor and Controller Development

1) Sensors

Fig. 1. Ultrasonic sensor

The first stages has been carried out by using this sensor as the main important role of whole system to work. The Figure 1 shows the ultrasonic sensor function as a device that can measure the distance to an object via usage of sound waves. It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is viable to calculate the distance between the sonar sensor and the object.

Hence, the algorithm uses for ultrasonic calculation or how the ultrasonic sensor does the calculation is:

$$\text{Distance} = (\text{duration}/2) / 29.1; \quad (1)$$

$$\text{If (distance} < 8)$$

This calculation is to determine the distance that ultrasonic sensor should sense. The value in the calculation is changes depends to the size of the storage tank and well. The distance equation should be focused on before start the program so that it will detect the correct distance.

Fig. 2. pH sensor with meter board

Another sensor used for this project is the pH sensor as shown in Figure 2. This sensor involved with meter board where the supply need is 5V to operate through pH probe. pH sensor is used to check the quality of water after being filter related to the pH scale where its range are between 0 to 14. If pH scale get below than 7, the water consider as acid state and not good for drinking purpose and health. While, if pH scale get over than 7, the water is in alkali state [7] where recommended to use suitable for human body health.

For pH sensor, the calculation uses as stated below:

$$\text{voltage} = \text{averagearray(pHArray, Arraylenth)}*5.0/1024; \quad (2)$$

$$\text{pHValue} = 3.5*\text{voltage}+\text{Offset}; \quad (3)$$

Equation (2) is function to get the voltage from the board where the value is usually around 5 since the board itself supply 5 volts. Therefore, in equation (3), the pH value is depending on the value of voltage times with 3.5 plus offset value which is set at 0.10.

2) Microcontroller

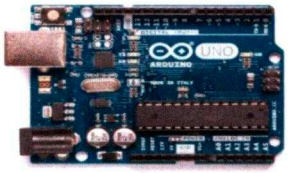


Fig. 3. Arduino UNO

Figure3 shows the Arduino UNO which is a microcontroller board based on the ATmega328.It has 14 digital input/output pins (6 of them can be utilized as PWM outputs), 6 analog inputs, a USB connection, a 16 MHz ceramic resonator, a power jack, an ICSP header, and a reset button [8]. It contains all needed to assist the microcontroller; essentially interface it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to begin. Moreover, the differs between UNO and all previous boards where it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

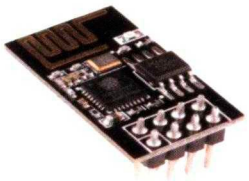


Fig. 4. Wifi module ESP8266

Figure 4 shows the ESP8266 series, or family of Wi-Fi enabled system on chip (SoC) module is developed by Espressif system. Besides that, it utilizes a 32-bit RISC CPU based on the Tensilica Xtensa L106 running at 80 MHz (or overclocked to 160 MHz). It has a 64 KB boot ROM, 96 KB data RAM and 64 KB instruction RAM. External flash memory can be accessed through SPI. Microcontroller communicates with ESP8266 module using UART having distinctive Baud rate. Moreover, this module accompanies 8 pins (2 GPIO pins). ESP-8266 being a first preference for implementing sensor networks and also low cost standalone wireless transceiver device in an IoT development [9].

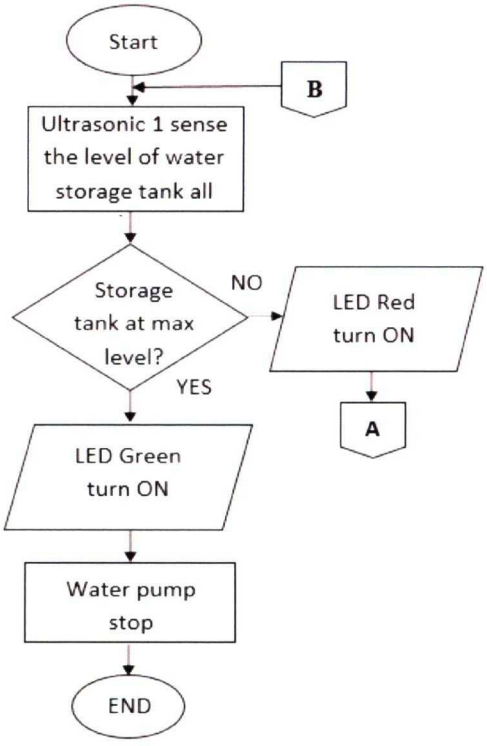
B. Database used for monitoring system

Fig. 5. Google Spreadsheets

Figure 5 shows Google Spreadsheets where basically it is a Web-based application that allows users to create, update and modify spreadsheets and share the information live online and at same time work with other people. Google Sheets is not only for consumers: it's used every day by businesses and schools to oversee spreadsheet data. With the new Sheets API v4 and Sheets add-ons, that data can be accessed by code as well as users. In addition, Microsoft Excel and CSV (comma-separated values) files is compatible with Ajax-based program. In this Spreadsheets, HTML also can be used to save.

Google's item offers typical spreadsheet features through the sheets API such as the ability to add, delete and sort rows and column, configure data validation, build and edit charts embedded in a sheet, create and manipulate pivot tables, control conditional formatting and others. The code can be access and update spreadsheets just like any other user by using API. Besides, the application allows multiple and topographically scattered users to collaborate on a spreadsheets in real time.

C. Flowchart



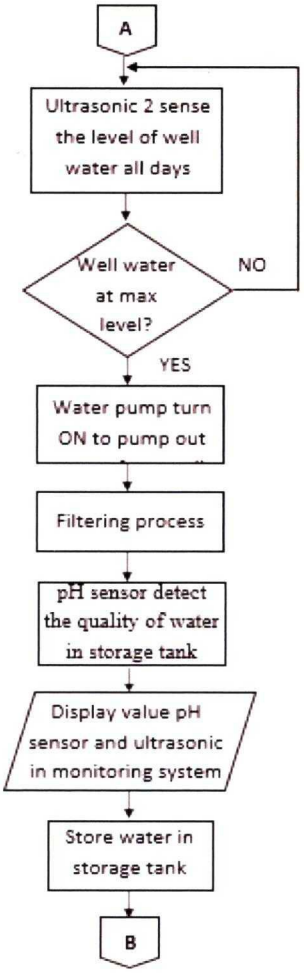


Fig. 6. Flowchart of the system

Figure 6 shows the flowchart of the overall system. Firstly, the water level will be sensed by an ultrasonic sensor 1 where it is placed on the top lid of storage water tank. This sensor will check either the water level in storage tank is full or not. If not, ultrasonic sensor 1 will triggered ultrasonic sensor 2 to be function as sense the water level in well. Basically, well water will increase at its maximum level in the middle of the night.

In the same time, LED will indicates as the current level in storage tank continuously. If LED green turn on mean the level of storage tank is full and if LED red turn on so the level of storage tank is not full yet and wait from water well. Next, ultrasonic sensor 2 detect the level of well water. In well, ultrasonic sensor 2 sense the water either the level of water at max level set or not to be transfer to the storage tank. If it is at max level, mean the water is ready to pump out. Back to storage tank, if the condition of water still not full, Arduino microcontroller will give a command to the water pump so that the water pump will turn on and start to pump out the water from the well. After that, the water will go to the next stage that is the filtering process. Water will be filtered at this stage before going to the storage water tank. Meanwhile, if the water in

storage tank is in full state, the water pump will stop immediately.

Next, the pH sensor will detect the pH value of the water that has been filtered where Arduino microcontroller will control the pH sensor so it will read the pH value in the water and the result will be shown on the monitoring system by using Wifi module. The data that collected will be monitored by person in charge in order to make sure this system work properly in a good condition. The water is ready to be use.

D. Hardware Design

Fig. 7. The prototype of the system

The figure 7 above shows the full prototype of the system. There are two tanks to indicate the storage tank and the well. The see-through tank as a well and the blue one is for storage tank. In between these two tanks there are two motors and filter system and connected to each other so that the water can be transferred from well to the storage tank without any problem. In the system, there are two filters that is located in the well and in between two tanks. Pipe nozzle is installed to the storage for people easy to use the water.

E. Block Diagram

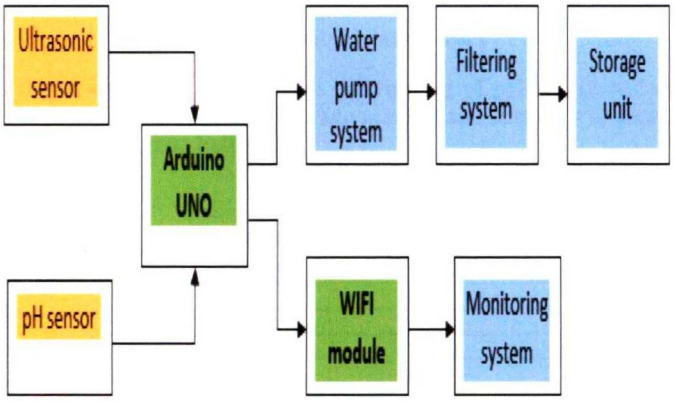


Fig. 8. Block diagram of the system

The main system that control overall of the system used consists of Arduino microcontroller and Wifi module as shown in figure 8. Wifi module is used as to receive all the data collected from the sensors and send it to the monitoring system through internet. Basically, the monitoring system will be displayed the distance level of storage tank, well and pH value.

Arduino microcontroller is used to perform ultrasonic sensors, pH sensors, water pump and LEDs. Ultrasonic sensor will operate when the sensor is triggered under certain circumstances. Besides, ultrasonic sensor will be placed in the well to detect the water level. When the ultrasonic sensor detects the water at a certain level, the motor pump will pump the water to the water filtration unit. Next, the water will be stored in the storage unit. In addition, pH sensor will be placed in the storage unit where it will detect the quality of water after being filtered. Then, another ultrasonic sensor that attach inside the storage unit will detect the water level and LED display will show the current water level for the user to know the current condition. Lastly, the monitoring system will take part to display the data collected in Google Spreadsheets database.

III. RESULT & DISCUSSION

A. Data analysis of ultrasonic sensor

TABLE I. TABULATED DATA

Actual distance (cm)	Distance measured 1 (cm)	Distance measured 2 (cm)	Distance measured 3 (cm)
5	5	5	5
10	10	10	11
15	14	15	15
20	19	20	19
25	25	24	24

TABLE II. ULTRASONIC ACCURACY

Actual distance (cm)	Average distance measured (cm)	Error (%)	Accuracy (%)
5	5.0000	0	100
10	10.3333	3.3330	96.67
15	14.6667	2.2220	97.78
20	19.3333	3.3335	96.67
25	24.3333	2.6668	97.33

Based on table II, the accuracy of the ultrasonic sensor has been calculated, test has been conducted using a ruler to ensure the accuracy of the distance measured by the system by taking several measurements on the sensor, we can say that the ultrasonic sensor accuracy is high. The highest accuracy was 100% when distance object is near within 5 cm to ultrasonic sensor, while the lowest 96.67% at some distance. The small signal loss might be coming from multiple reason due to the length of wire, the design parameters (directly angle), reduced sensitivity to glossy surfaces [10], reduced effectiveness to

detect objects in a small area (below 0.5m) [11] temperature reliance of sound speed. We can say that the system was accurate and efficient to used by this test. The efficiency calculate using;

$$Error\ (\%) = \frac{Actual\ distance - Average\ dist.measured}{Actual\ distance} X\ 100\% \quad (4)$$

$$Accuracy(\%) = 100\% - Error(\%) \quad (5)$$

B. Data analysis of pH sensor

In order to implement this project, the buffer solution of pH 4, 7 and 10 are used. Each of this sample solution is tested by using pH sensor by taking several measurement to compare the accuracy of this sensor that can be achieve.

Fig. 10. Tested with pH solution 4

Based on figure 10, it shows the reading of pH sensor tested with pH solution 4. The average reading and accuracy is taken as tabulated data below;

TABLE III. TABULATED DATA

Measured	pH reading
1	4.38
2	4.24
3	4.38
4	4.35
5	4.39
6	4.36
7	4.35

TABLE IV. PH ACCURACY

Actual pH solution	Average pH reading	Error (%)	Accuracy (%)
4	4.35	8.75	91.25

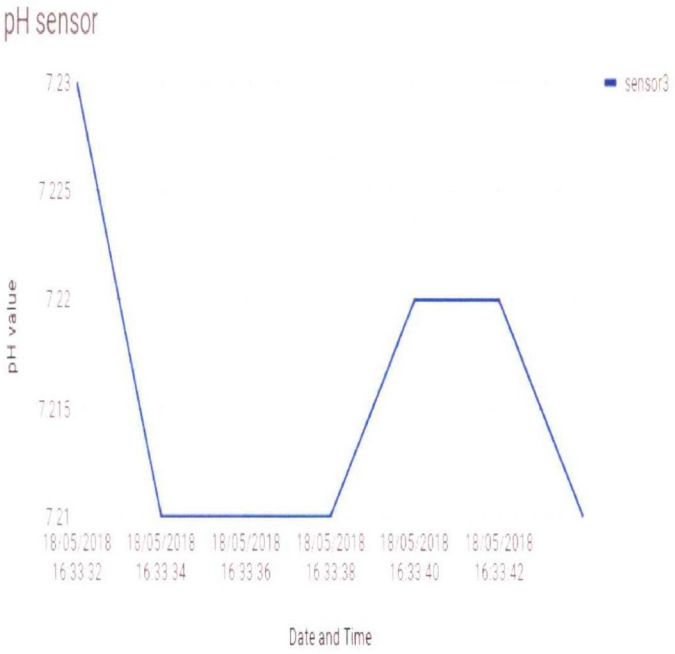


Fig. 11. Tested with pH solution 7

Based on figure 11, it shows the reading of pH sensor tested with pH solution 7. The average reading and accuracy is taken as tabulated data below;

TABLE V. TABULATED DATA

Measured	pH reading
1	7.23
2	7.21
3	7.21
4	7.21
5	7.22
6	7.22
7	7.21

TABLE VI. PH ACCURACY

Actual pH solution	Average pH reading	Error (%)	Accuracy (%)
7	7.2157	3.08	96.92

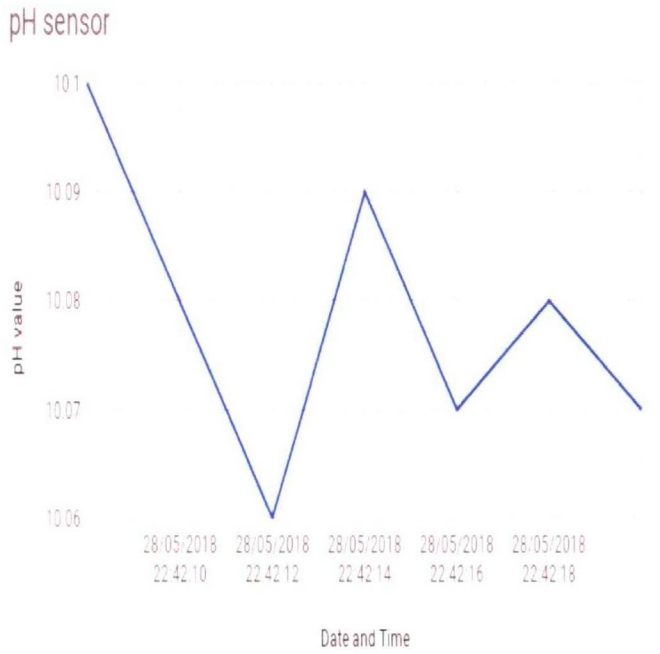


Fig. 12. Tested with pH solution 10

Based on figure 12, it shows the reading of pH sensor tested with pH solution 10. The average reading and accuracy is taken as tabulated data below;

TABLE VII. TABULATED DATA

Measured	pH reading
1	10.1
2	10.08
3	10.06
4	10.09
5	10.07
6	10.08
7	10.07

TABLE VIII. PH ACCURACY

Actual pH solution	Average pH reading	Error (%)	Accuracy (%)
10	10.0786	0.786	99.214

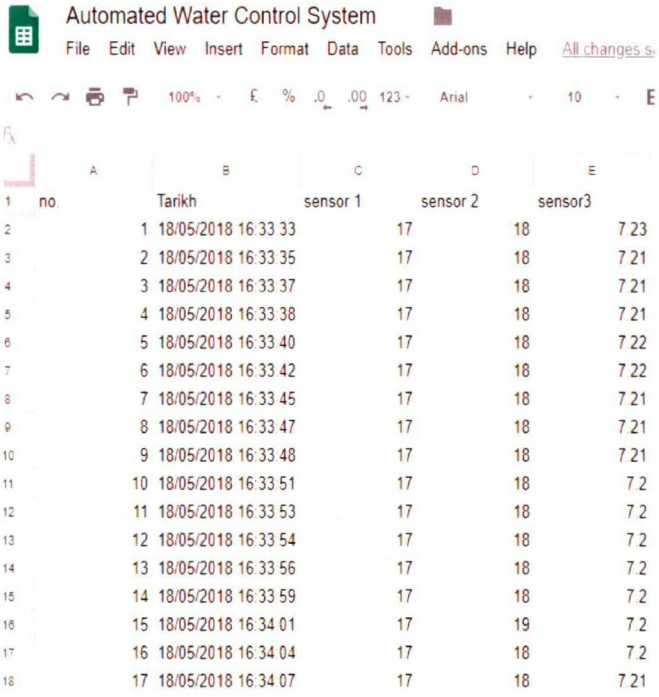
Based on the table IV, VI and VIII, the accuracy of pH sensor has been calculated. Test has been conducted by using buffer solution to ensure the accuracy of the pH value measured by the sensor whereby taking several measurements on the solution, we can say that the accuracy of pH sensor is quite near to the actual pH solution. Error is detected might be due to the supply at pH board itself produces different voltage, temperature behavior of the solution pH, not using contemporary pH analyzers and many else. The accuracy is calculated by using;

$$Error(\%) = \frac{Actual\ pH\ solution - Average\ pH\ reading}{Actual\ pH\ solution}\ X\ 100\% \quad (6)$$

$$Accuracy(\%) = 100\% - Error(\%) \quad (7)$$

C. Iot system

In this part focus on the data that has been collected from the ultrasonic sensor and pH sensor. Both of these sensor will updated the data into Google Spreadsheets for every 2 seconds continuously.



	A	B	C	D	E
1	no.	Tarikh	sensor 1	sensor 2	sensor3
2	1	18/05/2018 16:33:33	17	18	7.23
3	2	18/05/2018 16:33:35	17	18	7.21
4	3	18/05/2018 16:33:37	17	18	7.21
5	4	18/05/2018 16:33:38	17	18	7.21
6	5	18/05/2018 16:33:40	17	18	7.22
7	6	18/05/2018 16:33:42	17	18	7.22
8	7	18/05/2018 16:33:45	17	18	7.21
9	8	18/05/2018 16:33:47	17	18	7.21
10	9	18/05/2018 16:33:48	17	18	7.21
11	10	18/05/2018 16:33:51	17	18	7.2
12	11	18/05/2018 16:33:53	17	18	7.2
13	12	18/05/2018 16:33:54	17	18	7.2
14	13	18/05/2018 16:33:56	17	18	7.2
15	14	18/05/2018 16:33:59	17	18	7.2
16	15	18/05/2018 16:34:01	17	19	7.2
17	16	18/05/2018 16:34:04	17	18	7.2
18	17	18/05/2018 16:34:07	17	18	7.21

Fig. 13. Result in the Google Spreadsheets

Figure 13 shows the result displayed in the Google Spreadsheets. There were three types of data has been monitored using Google Spreadsheets which were sensor 1 represent as the data for distance (cm) of ultrasonic in storage tank, sensor 2 as the data for distance (cm) of ultrasonic in well and sensor 3 as the data for pH sensor that placed in storage tank. All of these data were automatically updated in form of listed table. Besides, there also a column where the date and time were shown for real time monitoring.

IV. CONCLUSION

As for the conclusion, the project achieved successfully where each of the objective of the project is accomplished. The system could provide enough water for them to do all the chores without lack of water. The water that stored into the storage is clean enough for them to use it as a drink water instead of using it for housework.

The system could transfer the water from the well to the storage tank without any problem since the monitoring part is being installed together so that the rural people can alert in

using water for daily life by saving it. Besides, they do not have to worry whether the system is working or not because this system will be monitor by person in charge.

For future recommendation, implement water flow sensor between pipe so that it can determine how much water can be flown by motor while check the system if there any problem such as clogged in pipe. Besides that, this system also can be add up with boiler to boil up the water so that the water is more secured to drink as this method can remove chlorine.

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REFERENCES

[1] F.Ahmed and C. Siwar, "Concepts, Dimensions and Elements of Water Security", *Pakistan Journal of Nutrition*, vol. 13, no. 5, pp. 281-286, 2014.

[2] Dongjian Li, Lihua Zhang, W. Z, Bo Zhang, "ARM-based Design And Realization of Water Well Monitoring Terminal," 2015.

[3] S. H. A. Kiyu, "Functioning and utilization of rural water supplies in Sarawak,Malaysia," *WHO Bulletin OMS*, vol. 70(1), pp. 125-128, 1992.

[4] N. Chan, "Managing Urban Rivers and Water Quality in Malaysia for Sustainable Water Resources", *International Journal of Water Resources Development*, vol. 28, no. 2, pp. 343-354, 2012.

[5] Lei Xiao-ling, W. J., Wang Hai-Yan,Jiang Tao, "Current Situation of Safe Drinking Water in Rural Area of China and Its Solutions," 2012.

[6] D. Loucks, "Water resources and environmental management: issues, challenges, opportunities and options", *Water Science & Te*

[7] A. V, "Development of Automated pH Monitoring & Control System through USB Data Acquisition," 2014.

[8] M. Banzi, Getting Started with arduino: " O'Reilly Media, Inc.", 2009.

[9] Di Nisio, A., et al. "Design of a low cost multipurpose wireless sensor network." Measurements & Networking (M&N), 2015 IEEE International Workshop on. IEEE, 2015.

[10] Dobashi H., Tajima T., Abe T., Nambo H., Kimura H.: „Improvement of Abnormality Detection System for Bathers Using Ultrasonic Sensors", Electrical Engineering in Japan, Vol. 179, No. 3, 2012.

[11] Toledo F.J., Luis J.D., Tom L.M., Zamora M.A., Martinez H.: „Map building with ultrasonic sensors of indoor environments using neural networks", Systems, Man and Cybernetics, IEEE International Conference on Volume:2, 2000.