Real-Time Water Quality Monitoring System by Using Wireless UART Module

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Abstract— **The water quality plays an important role for everyone. It is not only affecting our ecosystem, but it can also give effect to the living things such as humans, animals and plants. The purpose of this project is to design a real time water quality monitoring using wireless networks. The monitoring system is a system used to determine the state of a parameter on certain times according to the needs. This monitoring system will be implemented at lake, pond and river. The sensor will be used to detect the water quality parameters such as pH and temperature of water. For the real time monitoring purpose, Global System for Wireless UART module is used to enable the system sends the data to the computer. Graphical User Interface (GUI) used to assist the monitoring operator by display the sensor reading on computer screen. The sensor has been tested in few water conditions and gives promising results and accurateness.**

Keywords— **Water Quality, pH, temperature, Real-time Monitoring, wireless, UART, GUI.**

I. INTRODUCTION

The development without limitation in industrial is the human achievement which can be proud of. However, the progresses in the industry today have been scratched by the impact of human behavior especially in environmental cleanliness. There are lots of pollution occurs such as air pollution, water pollution, soil pollution, noise pollution, radioactive, etc. The pollutions come from different sources with different effect to the environment. The pollution usually gives a bad effect not only to the environment, but it also affects every life on earth. Water pollution is one of the most dangerous forms of pollution

Water is very important for life. On earth, there are 71 percent of the earth's surface is covered by water. However, only a small portion of water that can be used. Without water, every living thing could not survive. Water is used for many things such as agricultural, household, environment, and industry. Water pollution is one of the serious environmental issues that face nowadays. In Malaysia, the water pollution caused by urbanization, domestic and industrial sewerage, effluents from livestock farms, manufacturing, solid waste, rubbish, organic pollution, and agro-based industries, suspended solids from mining, housing and road construction, logging and clearing of forest and heavy metals from factories [1].

In 2012, total of 473 rivers has been monitored in water quality program. From 473 rivers, there are 5083 samples taken at 832 manual stations (MWQM) and 10 continuous water quality monitoring stations (CWQM). Out of 473 rivers monitored, 278 rivers which are 59% were found to be clean, 161 rivers which is 34% slightly polluted and 34rivers which is 7% polluted [2].

Prevention is better than cure. Due to increasing water pollution, the real-time water quality monitoring system is needed. The Department of Environment (DOE) Malaysia has set the water quality index (WQI) and National Water Quality Standards for Malaysia (NWQS), as a basis for evaluation of water pollution. Water will be divided into five classes which are Class I, Class II (A and B), Class III, Class IV and Class V. Class I water use as a conservation of the natural environment, practically no treatment necessary and usually there will have a very sensitive aquatic species. Class II water needs a conventional treatment use as recreational that use body contact such as kayaks and usually there will have a sensitive aquatic species. Class III water required the extensive treatment and Class IV used as irrigation. Class V considered polluted. These classes depend on certain parameter such as color, electrical conductivity, dissolve oxygen, temperature, hardness, pH, turbidity, etc. [3-5].

The common method of water quality testing is to collect water samples manually. There are two ways to collect the water sample manually which are the examiner need to collect the water samples by hand at regular intervals and send them to a laboratory for analysis and be tested by their equipment to determine their characteristics. Other ways is the examiner need to bring the equipment to the tested place and getting a result in shortens time [6-9].

Based on the findings, the problems for the water quality testing are examiner needs to be present at the tested place and the device cannot provide a real time monitoring which reflects poor time management and expenditure. Thus, a fast acting, wireless and continuous water quality monitoring system is needed.

The objective of this project is to improve the traditional monitoring system with the real-time monitoring system that can monitor some of water quality measurements such as temperature and pH of water and develop a communication system based on a wireless UART modular as to receive data from sensors in real time.

II. METHODOLOGY

This project involved software and hardware development in order to develop the Monitoring System uses a wireless UART module. Arduino software is used to develop the programming to control the system in Arduino microcontroller and to interface the data from the microcontroller to the computer. The other software used in is a Matlab to display the sensor reading and visualize the input data on the computer screen.

For the hardware or sensor, it consists of sensor elements, signal conditioning circuit, microcontroller, transmitter and receiver.

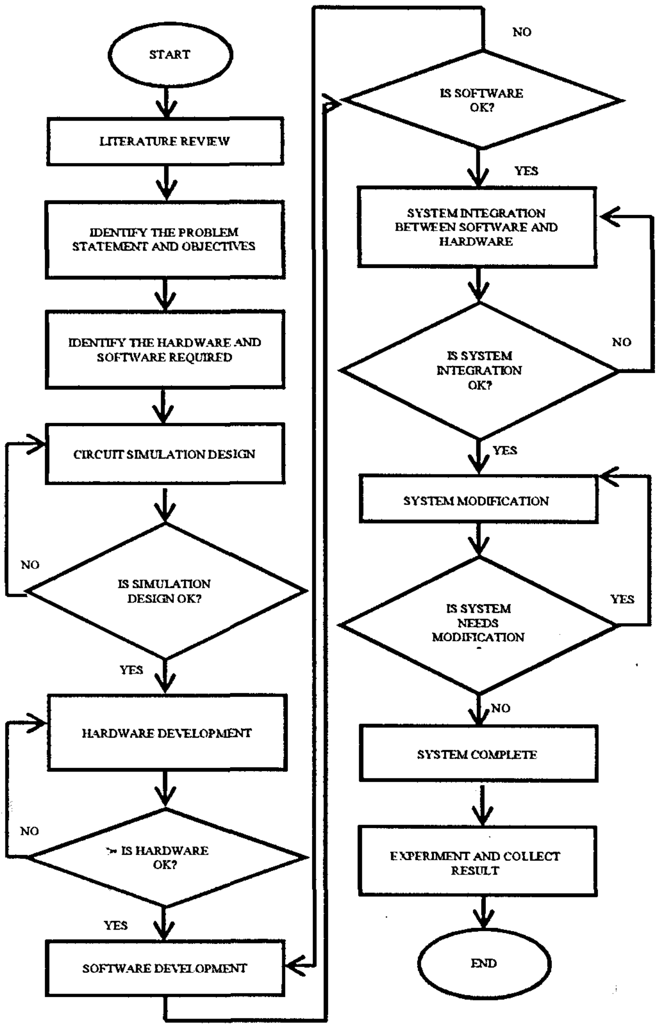

Figure 1 Flow chart of the overall system development

Based on flow chart of the project is illustrated in Figure 1, the project is started with the literature review, identify the problem statement and objective. This project requires hardware and software development then integrates the hardware and software to be complete.

1. Simulation

The signal conditioning circuit as shown in Figure 2 is used to amplify and modify the signal output in order to have a suitable output for operating the display. The signal from the sensor is very small which is between -0.414V to 0.414V, hence it needs to be amplified. The circuit has been simulated using PSpice software software which is the circuit analysis tool.

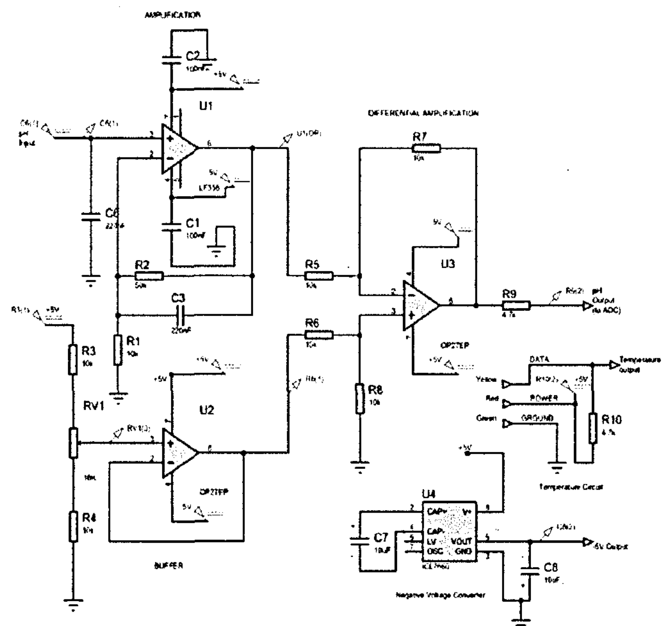

Figure 2 Signal Conditioning Circuit

2. Hardware

The hardware consists of five main parts, which are input, signal conditioning circuit, microcontroller, transmitter and receiver, and converter. The water quality monitoring system architecture is shown in Figure 3.

First the sensor will read the pH, which is in analog and temperature in digital. The data will be passed through the signal conditioning circuit to amplify and filter the data. Then, the microcontroller will set the data to be transmitted by the transmitter by a certain period of time that has been set on microcontroller programming. On the other end of the system, the receiver will receive the data. The data will be processed and displayed on the computer which enables the user to easily monitor the quality of water.

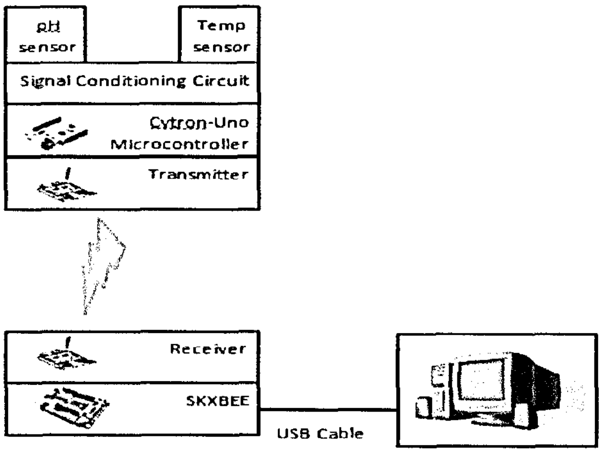

Figure 3 Architecture of Water Quality Monitoring System

Two different types of sensor are used in this project which is the pH sensor and temperature sensor. The pH sensor used is a pinpoint pH probe by American marine with the accuracy of +/-0.05pH. For the temperature sensor, a DS18B20 is used. This digital thermometer can be operated between -55°C and +125°C and for the temperature between -10°C and +85°C, it gives the accuracy of +/-0.5°C.

The circuit constructed based on a simulation diagram in PSpice and then implemented on printed circuit board (PCB). Figure 4 shows the signal conditioning circuit on the PCB. The circuit used two power supplies which are 5V and -5V.

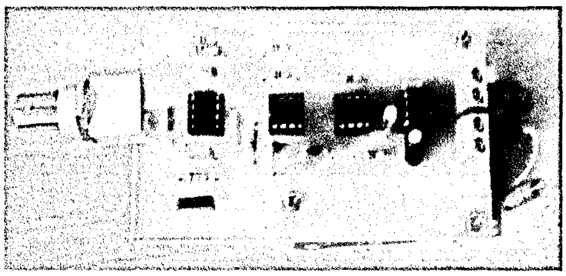

Figure 4 Signal Conditioning Circuit on PCB

A microcontroller is one of the most important devices used to control the device. Cytron-Uno microcontroller board is used in this project is based on the ATMEGA328. The microcontroller offer up to 14 digital input/output pins and six analog input pins. One of the analog input pin is used for pH sensor and three digital input/output pins are used for temperature sensor, transmitter and receiver.

The RFBEE-433MHZ transceiver is the wireless UART module used in this project. It can transmit the signal up to 500m in open space. SKXBEE is the XBEE starter kit that is stacked together with the receiver and the USB cable is used to connect the SKXBEE and computer.

3. Software

Matlab software is the high level language used to show and visualize the output of the system. This project used the Matlab to read the output from receiver and plot the graph from the output.

III. RESULT AND DISCUSSION

Table I shows the calculated PSpice and breadboard voltage output. As tabulated, we can see that the output voltage of the breadboard is almost accurate where the percentage of the inaccuracy is less than 5%.

Table I pH Signal Conditioning Output

pH	Voltage Output (V)		
	Calculated	*P-Spice*	*Breadboard*
0	0.016	0.016	0.06
1	0.370	0.370	0.34
2	0.724	0.724	0.70
3	1.078	1.078	1.06
4	1.432	1.432	1.43
5	1.786	1.786	1.75
6	2.146	2.146	2.08
7	2.500	2.500	2.47
8	2.854	2.854	2.87
9	3.214	3.214	3.19
10	3.568	3.568	3.54
11	3.922	3.922	3.92
12	4.276	4.276	4.24
13	4.630	4.630	4.66
14	4.984	4.984	4.99

In order to check the accurateness of the data, the pH sensor placed in pH4, pH7 and pH10 solutions and temperature sensor and mercury thermometer are placed in cold, room temperature and warm waters. The results of this experiment are shown in Figure 7 and Table II.

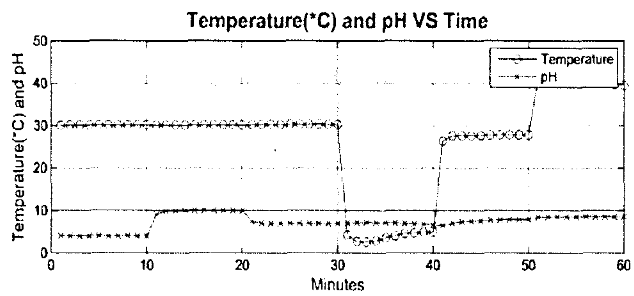

Figure 5 Accuracy experiment data

Table II Accuracy experiment data

Sample No.	pH			Temperature (°C)		
	pH 4	*pH 10*	*pH7*	*Cold Water*	*Tap Water*	*Warm Water*
1	4.01	9.06	7.48	4.25	26.44	41.75
2	4.02	9.82	7.03	2.75	27.69	41.81
3	4.02	9.97	6.99	2.63	27.69	41.56
4	4.02	10.02	7.01	2.94	27.69	41.25
5	4.02	10.02	6.99	3.56	27.75	40.94
6	3.99	10.04	6.97	4.06	27.81	40.63
7	3.99	10.02	7.00	4.63	27.87	40.38
8	4.02	10.02	6.99	4.75	27.87	40.19
9	3.99	10.02	6.99	4.94	27.87	39.94
10	3.99	9.99	7.00	4.94	27.87	39.63

To test the accurateness, the device should have less than 5% of the discrepancy. From the result, it shows the accuracy of pH is +/- 0.04pH and the accuracy of temperature by comparing the temperature sensor and mercury thermometer is +/-1°C which is within the allowable accurateness range.

Additional to the above, another experiment has been conducted with different type of drinking water which is mango cordial, tap water (for benchmarking purpose), sarsaparilla cordial and strawberry cordial. The data are taken by for 15 minutes for each type of water. The results show in Figure 6 and Table III.

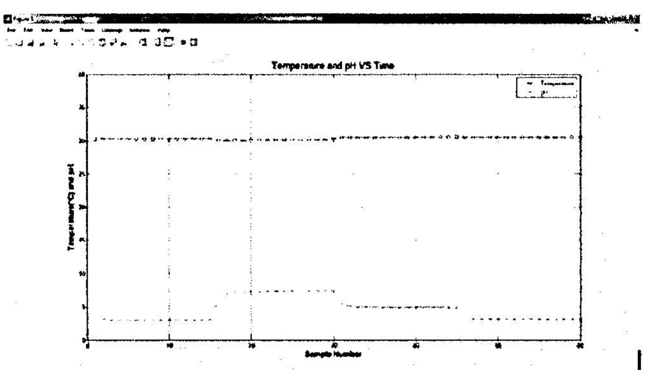

Figure 6 Different types of drinking water experiment data

In Table IV, we can observe that pH for mango and strawberry cordial is between 3.05 and 3.01 and between 3.09 and 3.05, respectively. This result reflects the nature of the fruits which is acidic. As for tap water, the result shows that the pH is between 6.90 and 7.44 which the similar to [10] that have a pH between 6.7 and 7.2.

Table III Different types of drinking water experiment data

No.	pH			
	Mango Cordial	*Tap Water*	*Sarsaparilla Cordial*	*Strawberry Cordial*
1	3.04	6.25	5.4	3.24
2	3.05	6.9	5.07	3.09
3	3.04	7.11	4.96	3.06
4	3.02	7.21	4.92	3.06
5	3.04	7.26	4.91	3.06
6	3.02	7.3	4.89	3.05
7	3.01	7.33	4.88	3.05
8	3.02	7.37	4.87	3.06
9	3.04	7.41	4.84	3.05
10	3.02	7.42	4.83	3.05
11	3.04	7.42	4.83	3.05
12	3.01	7.42	4.83	3.05
13	3.02	7.44	4.83	3.05
14	3.02	7.42	4.81	3.05
15	3.02	7.44	4.81	3.05

For practical purpose, the drain water quality has been tested based on the on-site and off-site experiments. For on-site experiment, the sensor has been placed in the drain and for off-site experiment; the water sample has been collected and tested in a room temperature. Figure 7 shows the on-site experiment data collected while. Figure 8 shows the off-site experimental data collected.

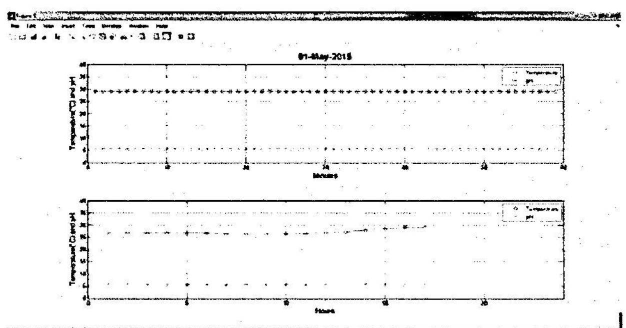

Figure 7 On-Site experiment data

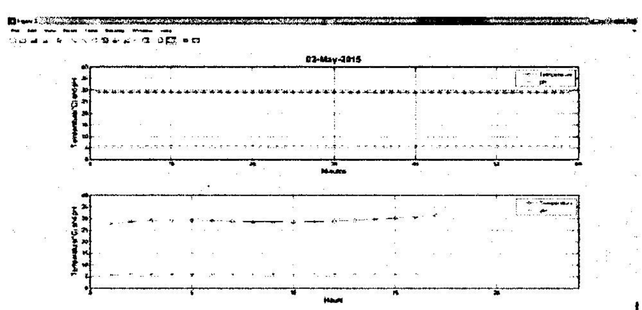

Figure 8 Off-Site experiment data

Table III shows the comparison between on-site and off-site data. The maximum temperature for on-site and off-site experiment is 29.06°C and 31.44°C where the minimum temperature is 26.62°C and 27.94°C. The pH for on-site and off-site is slightly deviated which are the maximum and minimum for on-site experiment is 5.93 and 5.65 where the maximum and minimum for the off-site experiment is 6.09 and 5.76.

The difference of these two experiments is because the experiments are conducted in two different days, which might have different weather and water condition. Besides that, for the on-site experiment, the pH of the soil and organisms that live in the drain such snails and tadpoles might affect the water quality. For the off-site experiment, the pH becomes more natural which is close to pH7 because the water and the soil have been separated according to how long the water in the test bottle.

Table IV On-Site and Off-Site experiment data

Time	Temperature (°C)		pH	
	On-Site	***Off-Site***	***On-Site***	***Off-Site***
1AM	26.87	27.94	5.85	5.76
2AM	26.81	28.75	5.82	5.82
3AM	26.69	29.12	5.73	5.79
4AM	26.69	29.19	5.65	5.83
5AM	26.62	29.19	5.67	5.84
6AM	26.62	29.12	5.74	5.88
7AM	26.44	28.94	5.67	5.91
8AM	26.37	28.81	5.65	5.97
9AM	26.37	28.69	5.7	6.01
10AM	26.37	28.56	5.69	6.05
11AM	26.56	28.75	5.66	6.01
12PM	26.81	28.87	5.66	6.05
1PM	27.25	29.25	5.78	6.01
2PM	27.81	29.81	5.81	6.02
3PM	28.56	30.37	5.93	6.02
4PM	29	30.87	5.93	6.06
5PM	29.06	31.44	5.93	6.09

IV. CONCLUSION

This project is successfully achieved all the objectives. Monitoring system is successfully developed and has at least 95% accurateness.

The monitoring system is to detect the parameter from the sensor and display the reading on the computer monitor. The system can help to monitor the quality of water.

V. FUTURE RECOMMENDATION

There are two recommendations for the future development. First, the monitoring can be done by using smart phones and can be used everywhere and at any time with a nice display. To monitor the system through a smart phone, the software should be developed as android application.

The second recommendation is the power supply. The high efficiency solar panel is needed so it can continuously recharge the battery which can reduce the cost and become energy saving product at the same time.

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