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Development and Implementation of Water Quality Assessment Monitoring (WQAM) System using the Internet of Things (IoT) in Water Environment

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Abstract: Water quality monitoring (WQM) system is widely being explored as it is needed to prevent the problem of water contamination worldwide. Nowadays, there are various studies on WQM system that are being integrated with Internet of Things (IoT) concept for Wireless Sensor Network (WSN) technology implementation to get real time data measurement. Traditional ways of collecting the data are more time consuming and they lack real time changes in the quality of water. This paper presents the development and implementation of Water Quality Assessment and Monitoring (WQAM) system. The system development used WiFi enabled microcontroller to connect with the IoT environment and store the data in the IoT cloud server. The microcontroller used is Arduino UNO that interacts with three types of sensor probes which are pH, turbidity and temperature probe. All the data measurements is transferred using a WiFi module which is ESP8266. The IoT cloud used to utilize the data frame is ThingSpeak. This system was implemented on Bandar Perda Lake and Derhaka River in Pulau Pinang with two systems implemented at each location. The sensors were placed on the water surface for more accurate measurements. This system continuously measures the readings of pH, turbidity dan temperature on the lake/river for every 1 hour. Twenty readings were taken for every 1 hour within the first 20 minutes with 1 minute interval and the readings were stored in the IoT cloud server. The readings are accessible via ThingSpeak GUI. In conclusion, this system would benefit the authorities to take advantage of using the WQAM system with the aid of the IoT that is less time consuming, less cost and more reliable in real time data reading.

Keywords: Water quality assessment monitoring, Internet of Things, ThingSpeak.

1. Introduction

Mankind learns early in life that water is essential to the survival of all living creatures on this planet. Despite all that has been written and said on the importance of water, humans continue to pollute it. Water contamination is a serious global issue that necessitates continuous evaluation and change of the guiding principle of water resources at all levels, from the international level to individual wells [1]. Since they are exposed to a country's daily development, surface water such as lakes and rivers suffered the most degradation. Relevant examples of pollutant contamination in surface water include contaminants from mining, oil and gas exploration, and overall industrialization [2]. Multiple research attempts have been conducted to improve water quality by evaluating it and taking action based on the information gathered. However, these initiatives have not yet been incorporated into national-level structures [3].

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Recently in 2019, due to an illegal dumping in a river near Pasir Gudang, Johor, 111 schools in the Pasir Gudang district after almost 1,000 people, including school children, fell victim to gas poisoning [4]. Johor chief minister Osman Sapian quote “This was unexpected and regrettable” [4]. Ongoing river observation was carried out using the traditional method, which required on-site sampling to be sent to a laboratory for extensive analysis. The drawback is it consumes too much time to travel back and forth to the lab, thus non real time data was taken and if such a new type of contamination occurs, it would be too late to act on it.

Thus, a water quality monitoring system using an Internet of Things (IoT) platform is being built over time to tackle this issue ahead. According to M. A. Malek et al, there are various samples of parameters that can be measured in order to identify the quality of the water by observing the pH level, Dissolve Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH_3N), and Total Suspended Solid (TSS) [5]. The goal of implementing IoT platforms is to improve the manual or traditional methods of collecting water samples and analysing data to be more efficient. In addition, compared to the traditional way, gathering data using a wireless network would have benefits such as minimal workforce, remote monitoring, cheap cost, real-time data capturing, and fast network establishment.

Internet of Things (IoT) has become a powerful platform in the 21st century, not only for communication but also for gathering data, operating applications, and a diversity of other purposes. There are additional domains and environments where IoT can make a significant difference and improve our quality of life. Research [6] and [7] mentioned that these include transportation, healthcare, industrial automation, and emergency response. Furthermore, smart cities are becoming widely accepted around the world by incorporating IoT to control the urbanized environment as in [8] and [9].

There are a variety of projects involved in the WQM system that has been studied and published by previous researchers by using various ways in detecting the quality of water for the system. C. Z. Myint et. al. proposed a system that uses sensor probes such as ultrasonic sensor and carbon dioxide (CO_2) sensor, as well as a Radio Frequency (RF) module and a Field Programmable Gate Array (FPGA) board as the microprocessor to detect the quality of water [10]. Next, U. Shafi et al introduced a WQM system using IoT applications to detect surface water pollution using hardware and software applications [3]. Research [3] also ranked the water parameters with safe ranges based on the World Health Organization (WHO) recommendation [3].

Next, N. K. Koditala et al proposed a system where the water is monitored by using the applications of Global System for Mobile Communication (GSM) with the Internet of Things (IoT) application to detect the quality of water based on the water samples collected [11]. Research [12] presents a Surface Water Quality Monitoring (SWQM) system for aquaculture pond comprising a wireless mesh sensor system created using various wireless technologies, including an RF Identification (RFID) system, a wireless sensor system, and can access WSN-cloud databases via a mobile application and an IoT platform for devices [12]. There are also WQM systems that uses a PIC as the microcontroller and a wireless communication protocol based on the XBee-S2 series module to communicate were sensors and microcontroller to monitor the quality of water in remote areas as in [13].

In this project, a Water Quality Assessment and Monitoring (WQAM) system that used IoT platform is developed and implemented in real water environment. This system used ThingSpeak for the cloud data monitoring that make it available all the time. This system will measure pH, turbidity dan temperature on the water surface for every hour which will make sure the water condition is always up to date and useful for water quality monitoring. There were 20 readings taken within the first 20 minutes with interval of 1 minute. This system will improve traditional water assessment method which is based on the water sampling process that require in-lab measurement.

This paper is organized as follows which is Section 1 of this paper explained the introduction of the proposed project in detail including the previous research papers, journals and studies conducted by various researchers around the world. It serves as guidance for the writer when writing a solid literature review. Secondly, Section 2 of this paper is Methodology. It will focus on the project's flow with the help of a literature review connected to the project's title. Approximately, this chapter will explain in details on the development and implementation of the Water Quality Assessment and Monitoring (WQAM) system. Lastly, in Section 3 of this paper, it will summarize on the results attained from this project and conclude on the project’s overall performance for future recommendation respectively.

2. Methodology

This section is the main part of this paper in terms of methods and approach that must be achieved to proceed this project into the next stage. Demonstrates what and how the system will be used in real-life situations to convey the project concept discussed in this section. This project involves software and hardware applications with various types of sensor probes as the input sensors. It will further be explained later at this section.

2.1 System Overview

The proposed project system overview is shown as in Figure 1. Firstly, the WQAM system will be used to gather data on the surface of water in river or lake. Details on the sample that is to be taken for this project will be explain later in this chapter. For now, as the system has taken the samples, the system will store the gathered data on an IoT cloud platform. Cloud storage is more reliable in keeping data whereas it has larger capacity of memory and the chances of losing data is low. Therefore, choosing such method is more convenient because older data that has been stored before can be referred back to use as a comparison analysis. Next, the IoT platform will not just store the data, it will also display the gathered data to the user in real-time. User can choose how the data is to be displayed either in graph or chart, just to ease the monitoring activity. Method of displaying the data is by using either a personal computer (PC) or smartphone. Both devices can also show the data simultaneously without any delay showing how reliable this system is. One can access the stored data anywhere he is as long as their device are connected to the internet. This is because the IoT platform utilize the use of the internet to be access by accessing it using a link or URL of the system. Thus, to sum it all up, the system is going to be more portable and easier to access wherever and whenever the user needs it.

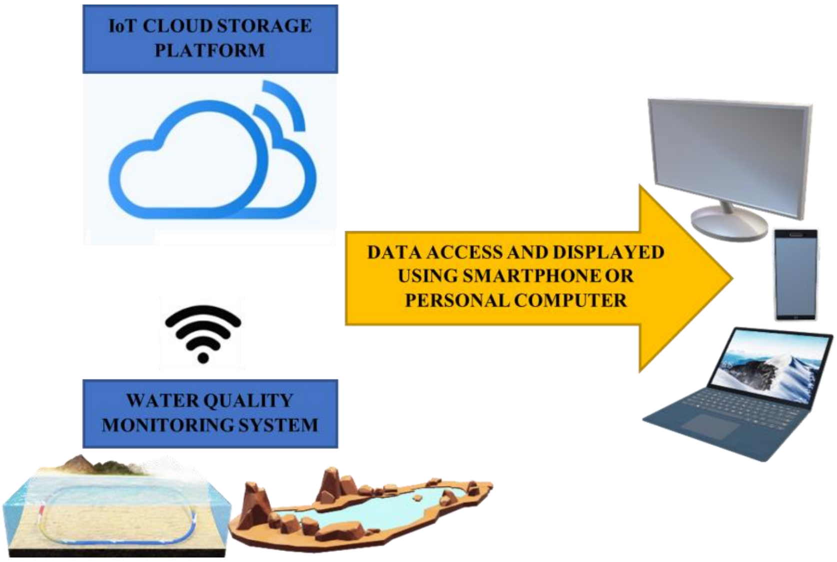

Fig. 1 - System overview

2.2 System Block Diagram

The system block diagram is shown in Figure 2. From the previous section, this block diagram is to explain further details of the hardware and software that will be used for this system. First, the brain of this system that will be use is Arduino UNO. Reason to choose such microcontroller is because of its affordable price and the size of it makes it easier to be bring or deploy at any place. Then, the input data that this system will measure is pH level, turbidity and temperature of the water source by using the sensors labelled in the figure. Choosing this data to tolerate whether the water quality is good or bad is reasonable because this project focus on creating a budget WQAM system so that others can try and used this type of system to be deploy near their premise. Next, data taken by the sensors are pass through the internet using the ESP8266 WiFi Shield. The module will be connected to an access point for it to connect to the internet. After that, data is stored in the proposed IoT cloud platform, ThingSpeak. Later, ThingSpeak can be access using a PC or smartphones anywhere using an internet browser by given address of the ThingSpeak cloud. The data is shown in a graphical manner that can be set up in the ThingSpeak platform. In addition, ThingSpeak can also notify the user by adding the status message widget also provided by ThingSpeak.

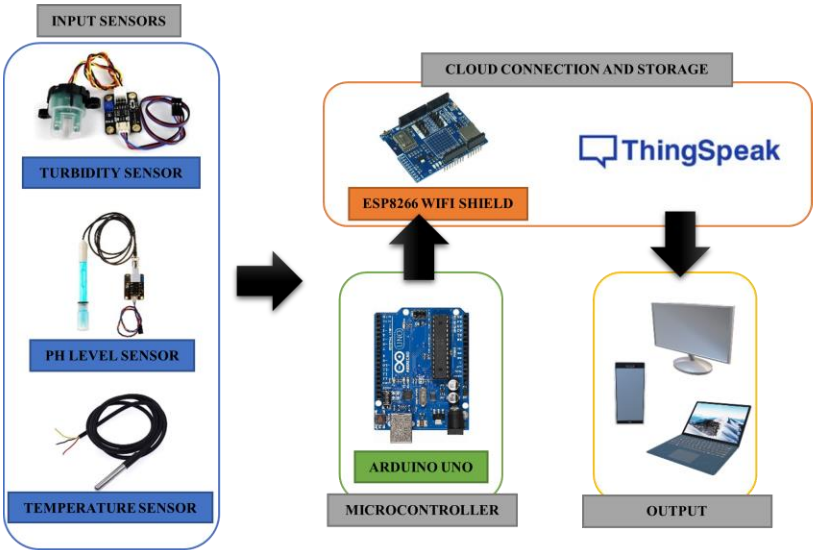

Fig. 2 - Proposed system block diagram

2.3 System Operation Flowchart

With the aid of the system operation flowchart shown in Figure 3 further details on how the system will operate can be describe. At first, the sensor probes that was described in the last section reads the data in the water of a lake or river. Temporary data that the probe gathered is then pass to the Arduino UNO. As the Arduino UNO stored the temporary data, it will pass it to the ThingSpeak cloud storage using the WiFi shield that has been connected to an access point near the system. All of the data that has been pass to the cloud is stored according to their field type which are pH level, turbidity level and temperature. Each data will show its graph accordingly in ThingSpeak so that one can ease the analysis that is needed to be taken. And the last additional function is that the value can be compared whether the water quality is in good terms or not can be notified to the user via status display in ThingSpeak. This system is repeatable such that it needs to continuously monitor the water quality. It can end depends on the decision made by the user whether the user want to move the system on to another place or has gathered enough data.

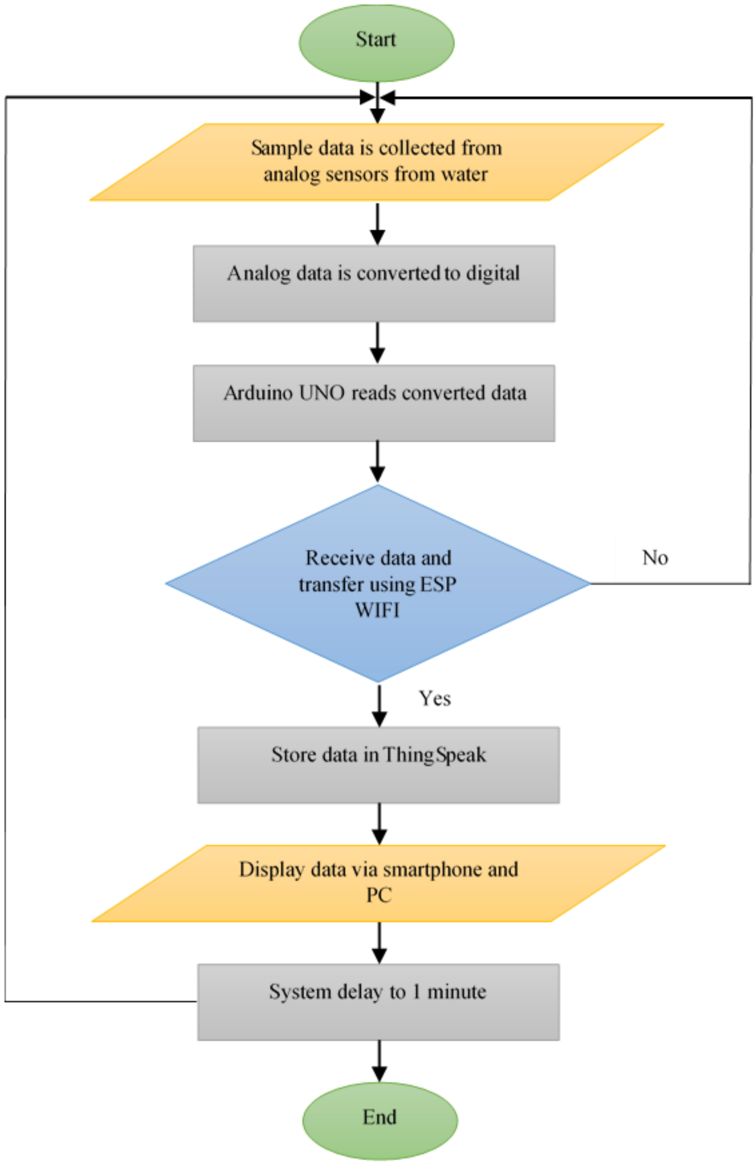

Fig. 3 - Operation flowchart of proposed system

2.4 Software Flowchart

Figure 4 shows the system software flowchart which explains the software set up for this system. It starts by setting up the public channel that can be access by anyone in the ThingSpeak platform. Then, the field where each data from different sample is created in the channel to be stored and displayed for the user. Once the platform settings is done, proceed to programming the microcontroller, which is Arduino UNO, by using Arduino IDE software in C language. The board is programmed to interact with all sensors and WiFi module. After completing the programming on the board, set up an access point for internet access. Access point can be either the mobile hotspot or nearest WiFi modem. Then test the WiFi connection for the board. If it is not connected, redesign the programming code that involves in connecting to the WiFi module to the internet then try connecting it again. If it is successful, therefore it can be guarantee that the data can be send to ThingSpeak cloud. Access ThingSpeak using the public URL that has been created before to observe the data taken. If there is a reading, then it is functional while if not, start over to troubleshoot any programming mistakes to fix the issue.

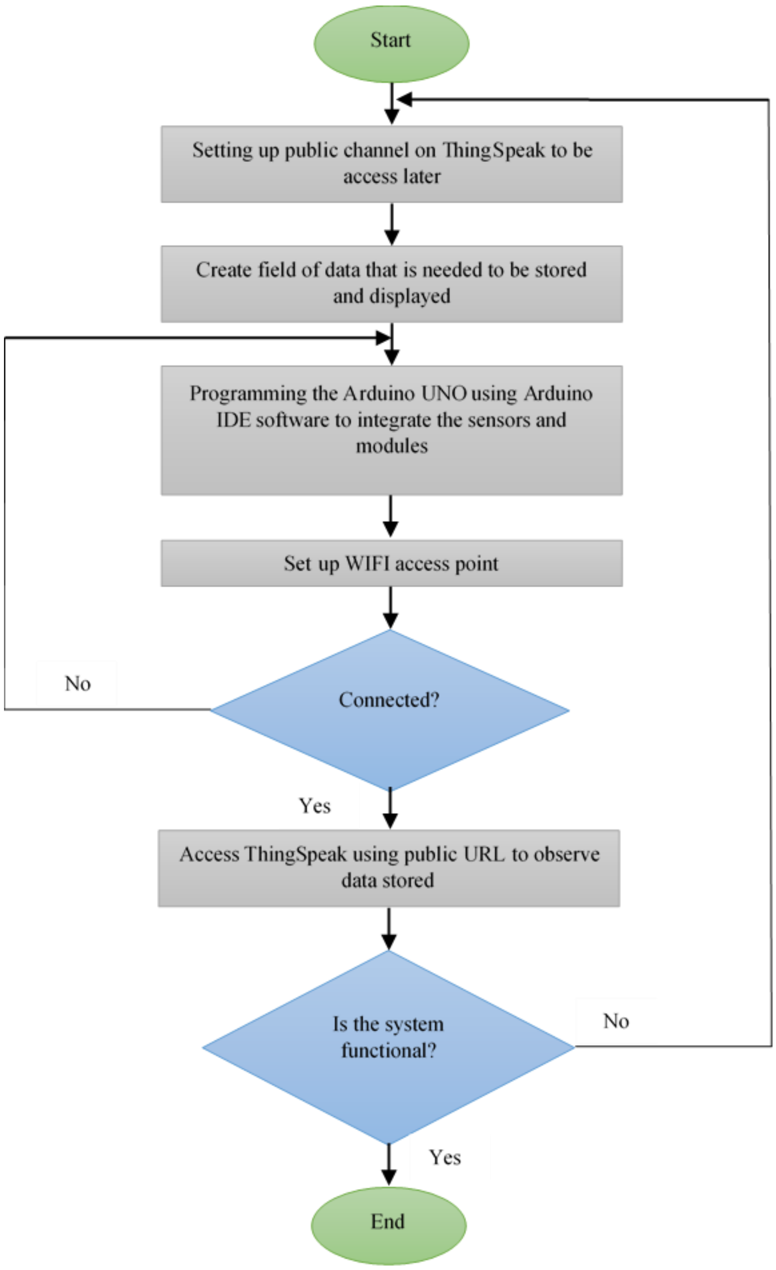

Fig. 4 - Software flowchart

2.5 System Implementation

This system was placed one time for five hours at two locations in Pulau Pinang which are at Bandar Perda Lake, Bukit Mertajam and Derhaka River, Seberang Perai. The real environment placement for the two locations were shown in Figure 5. One particular reason to choose two different places was to relate the result findings with the flow of water from both water surface. Such that the water flow more vigorously in river than of that in the lake, therefore there should be some hypothesis can be made according to both situations.

(a) (b)

Fig. 5 - Real environment test location (a) Bandar Perda Lake, Bukit Mertajam; (b) Derhaka River, Seberang Perai

For the hardware, it was setup in a polystyrene type material that is designed to equip the system for it to float on the water surface. The sensors position was at the bottom side of the polystyrene material. When the polystyrene placed on the water surface the sensor will automatically submerged in water at depth 1.5 cm from the water surface. Shown in Figure 6 is the hardware setup for this system. The system is much more portable such that it uses a battery power source. In addition to that, there is an additional set of the same system was placed at each locations (bandar Perda Lake and Derhaka River). The first set was placed further away from the lake/river bank while the second set placed near the lake/river bank. The purpose is to test whether the first and second set of the system can update simultaneous data on the ThingSpeak channel. Another reason to have two sets of system with the same function was to observe if there is any reading difference between the two places of the same location. Different of readings recorded by the two places will indicates that there is no or small flow of water at that location. The first set of the system is labelled as WQAM System A while the second set is labelled as WQAM System B as shown in Figure 6. Other than that, the result for this test was monitored using a smartphone using ThingSpeak Graphical User Interface (GUI) shown in Figure 7. The result on the smartphone includes the real time sensors measurements for pH, turbidity and temperature. Maximum of 20 measurements for each sensor displayed on the smartphone for one hour. The measurement is performed within the first 20 minutes for every one hour.

Fig. 6 - Hardware setup

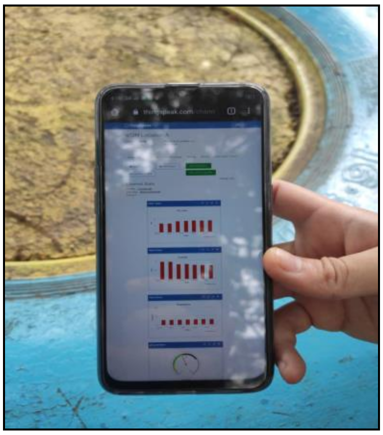

Fig. 7 - System GUI accessed using smartphone

Shown in Figure 8 is the WQAM System A that was placed further away from the lake bank while the WQAM System B was placed near the lake bank.

(a) (b)

Fig. 8 - Real testing setup at the lake bank (a) Far from lake bank; (b) Near lake bank

Figure 9 shows the WQAM System A that is placed further away from the river bank while WQAM System B placed near the river bank.

(a) (b)

Fig. 9 - Real testing setup at the river bank (a) Far from river bank; (b) Near river bank

3. Results and Analysis

Figure 10 shows the result for system that is stored in the IoT cloud and viewed using ThingSpeak GUI that can be accessed by the public URL of ThingSpeak website. Field 1 chart shows the readings of the pH level taken every one hour. There were 20 readings taken within the first 20 minutes for every 1 hour with 1 minute interval between each reading. Sometimes there was no reading recorded due to undetected signals by sensors as happened at time 17:01-17:05, 20 readings per hour is set to avoid zero readings per hour. The readings for turbidity and temperature were shown in Field 2 Chart and Field 3 chart respectively. For the pH measurement, there is also a gauge shown that is used to inform the user whether the pH level is still safe or not. In the gauge, the safest pH level is shown in green while the yellow and blue indicates that the water pH level is at risk of harmful chemicals exists. Data of the result can be exported from the ThingSpeak cloud into excel format to be used for analysis purpose.

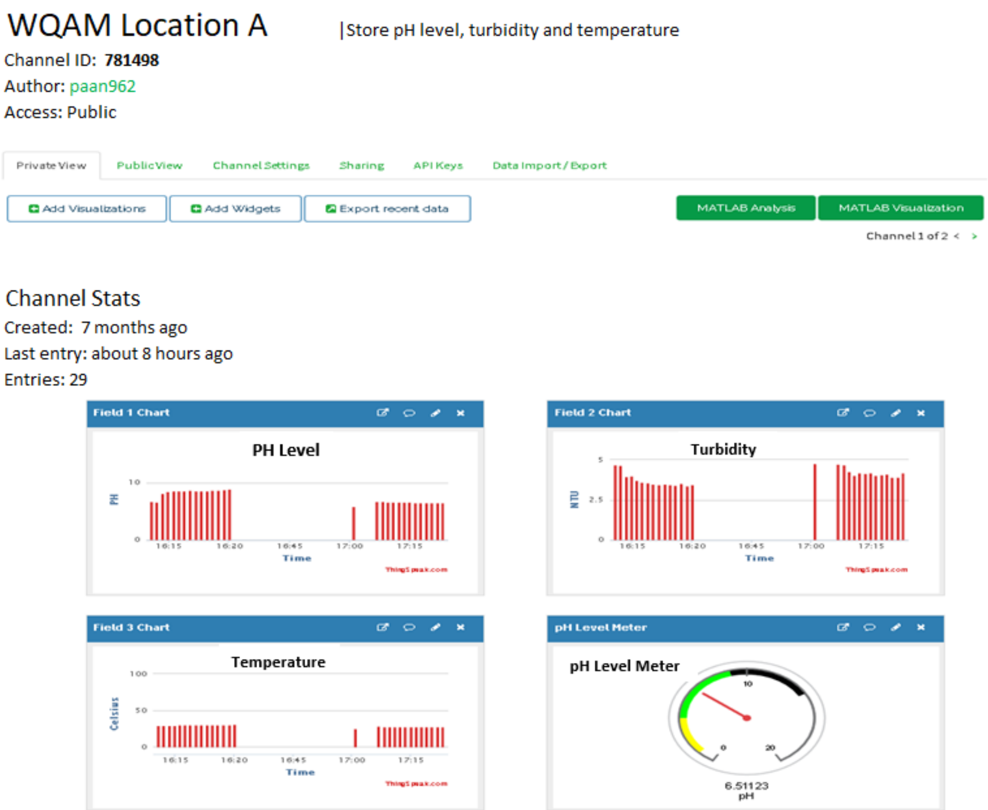

Fig. 10 - Result in ThingSpeak GUI

The sensors' readings for the two systems (WQAM System A and WQAM System B) placed in Bandar Perda Lake were tabulated in Table 1. Only 10 readings (out of the 20 readings) are tabulated in the table. The average results shows that there are obvious difference between the readings of WQAM System A and WQAM System B on the average value taken for the pH and turbidity. However, the temperature recorded a few differences. For the pH level readings, it shows that the location further away from the lake bank consists of an alkaline substance while the location near to lake bank recorded neutral reading. As for turbidity, the lower the value of NTU, the higher the number of suspended particles. From the result, the location further away from the lake bank can be said to have more suspended particles than the location near the lake bank

Table 1 - Sensors's readings for Bandar Perda Lake

No. of reading	WQAM System A			WQAM System B		
	PH	*Turbidity*	*Temperature*	*PH*	*Turbidity*	*Temperature*
1	8.17	3.94	28.81	6.97	4.32	29.81
2	8.45	4.00	29.50	7.18	4.34	30.00
3	8.58	3.72	30.44	7.18	4.32	29.75
4	8.57	3.61	30.44	7.14	4.34	29.88
5	8.61	3.56	30.44	7.12	4.32	29.88
6	8.63	3.49	30.44	7.13	4.32	29.81
7	8.60	3.47	30.44	7.13	4.29	29.94
8	8.59	3.50	30.50	7.15	4.31	29.88
9	8.60	3.46	30.50	7.19	4.30	29.82
10	8.68	3.40	30.44	7.18	4.29	29.94
Average Value	**8.55**	**3.62**	**30.20**	**7.14**	**4.32**	**29.87**

As for the sensors' readings for the two systems (System A and System B) placed in Derhaka River, the data is tabulated in Table 2. The same number of 10 readings (out of 20 readings) tabulated in the table. The average values shows that there are only small differences recorded for location further away from the river bank and location near the river bank in terms of the pH, turbidity and temperature. The small differences indicate the water in the river was having a good flow which recorded almost uniform readings at the two locations. As mentioned before, river water flows more frequent than lakes which makes them dissipate both temperature and suspended particles much faster compared to lakes which suspends the water flow such that it acts as a water reservoir.

Table 2 - Sensors's readings for Derhaka River

No. of reading	WQAM System A			WQAM System B		
	PH	*Turbidity*	*Temperature*	*PH*	*Turbidity*	*Temperature*
1	6.70	4.68	27.81	6.68	4.31	27.94
2	6.65	4.27	27.81	6.67	4.31	27.88
3	6.61	4.04	27.88	6.67	4.32	27.75
4	6.60	4.19	27.88	6.66	4.32	27.94
5	6.59	4.15	27.88	6.65	4.32	28.00
6	6.59	4.19	27.81	6.65	4.31	27.81
7	6.56	4.04	27.81	6.65	4.31	27.94
8	6.56	4.08	27.81	6.65	4.31	27.88
9	6.56	4.11	27.81	6.65	4.32	27.88
10	6.55	3.90	27.88	6.67	4.31	27.94
Average Value	**6.60**	**4.17**	**27.84**	**6.66**	**4.31**	**27.90**

The graphical comparison between WQAM System A dan WQAM System B of for the two locations were presented in Figure 11 and Figure 12. Figure 11 compared the average pH, turbidity and temperature for location Bandar Perda Lake for WQAM System A (further away from the lake bank) and B (near the lake bank) while Figure 12 compared the average pH, turbidity, temperature location Derhaka River for WQAM System A (further away from the river bank) and B (near the river bank).

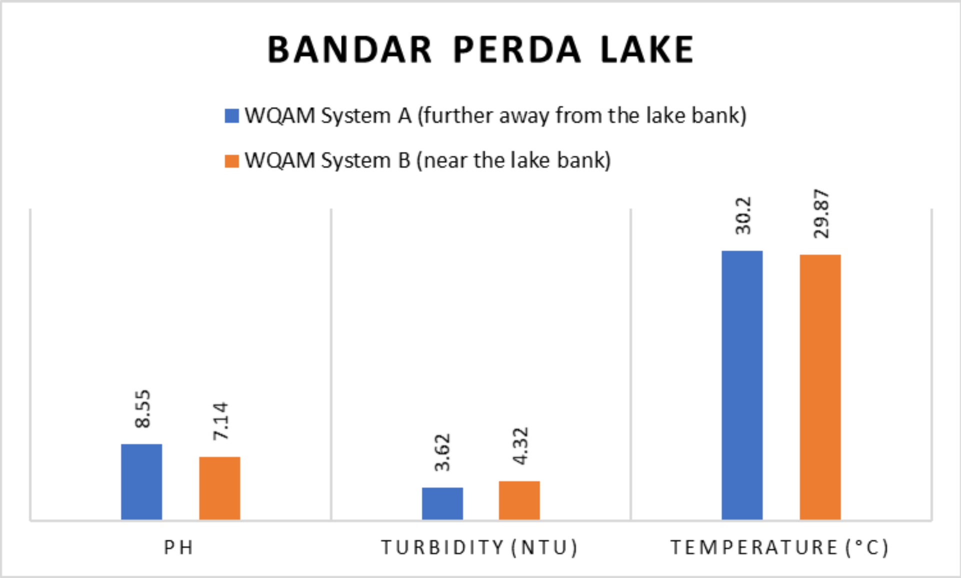

Fig. 11 - Comparison on average readings for Bandar Perda Lake

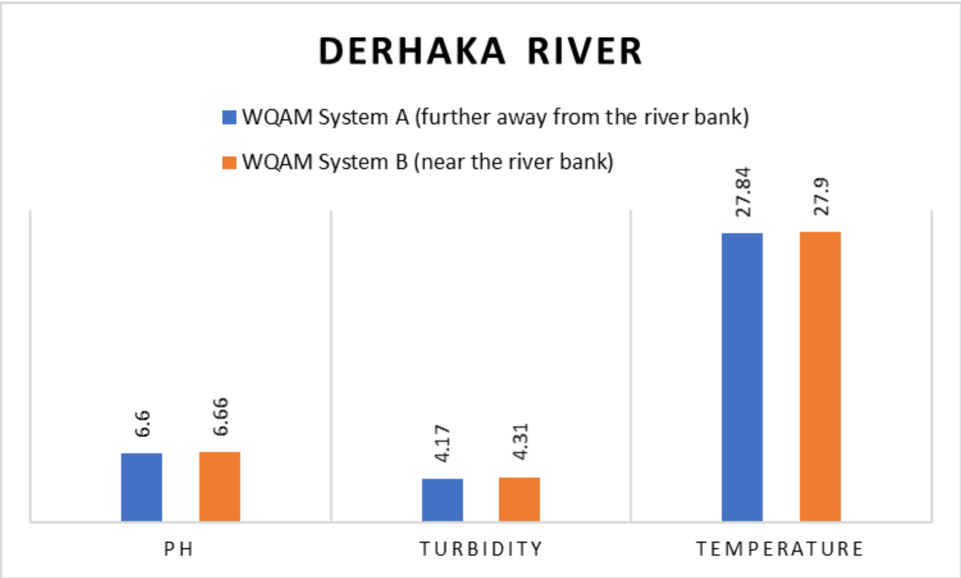

Fig. 12 - Comparison on average readings for Derhaka River

For the pH level, the average result for further away from the lake bank is higher compared to near the lake bank, it is more neutral near the lake bank. While the average pH for river is almost same for further away from river bank and near the river bank caused by a good flow of water. Next, for turbidity, when comparing the result for near and further to the bank in lake, it shows that the suspended particles are more in the center of the lake rather than near to it. Next, for turbidity, when comparing the result for near and further to the bank in lake, it shows that the suspended particles are more in the center of the lake rather than near to it. As for comparing to the river, it shows slight difference but still the suspended particles are much lower in river. The probability of suspended particles coagulate at the center of the lake would be the cause of this readings. While for the temperature, it shows almost the same average results for both lake and river for near and further away from lake or river bank. However, the lake's temperature is much higher of that in the river. The same hypothesis can be said for the temperature where the flow of water can be seen to have an effect on the readings. Therefore, to sum up the findings, there is a possibility that the flow rate of the water surface can gives difference in readings for all measurements such that the elements that exists in the water are moving with the water current to be transported to another locations. That is how the pollution in the water surface works by spreading harmful particles that are inside of it by using the flow of the water itself.

4. Conclusion

This system can be said that it is much more reliable than of those traditional ways of collecting water quality sample because of the implementation of the IoT is presented to gives real time data monitoring. Moreover, compared to other types of WQM system, this proposed system is less complicated when it comes to assembling it. It is also more portable with the use of external power source whereas this system is able to be deployed onto the water surface itself rather than placing it fixed near the banks. Ever so slightly, the system is limited to the source of internet network to be access. The system would not properly be deployed in an area that is situated at rural residence where there is not much network signal can be accessed. Therefore, this system would be more reliable at an urban residence. As a conclusion, the system is applicable to be added with other types of sensors that can detect other chemical residue that is being absorb by the water. Besides that, the future work that will be done for this study is taking the result in different time of the day and compare the difference. What is meant by this is that this system takes readings of the water surface in the morning, evening and night time. Later, the result is then to be compared with the time taken to analyze if there is any difference in readings for each time of the day. This could lead more findings on the water behavior during the difference time of the day whether the quality of water can have any relationship between it. Next, the system would be embedded with a machine-to-machine (M2M) protocol to automatically help acts on the data taken. For this, the system will ease more work for the user so that faster actions to tackle water pollution can commence.

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