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Real-time Water Quality Monitoring System using IoT: Application at Melaka River, Malaysia

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ABSTRACT

The rapid development around the Malacca city has a huge impact on the environment. Among the effects that can be seen is water pollution along the Malacca River. To overcome the problem, Hydro Quality Monitoring System (HydroQS) has been built and is a co-developed product between Universiti Teknikal Malaysia Melaka (UTeM) and Perbadanan Pembangunan Sungai dan Pantai Melaka (PPSPM). This device acts as one of the solutions to continuous monitoring the river water quality in real time values such as pH, Dissolved Oxygen (DO), Total Dissolved Solid (TDS), Turbidity and Temperature via Arduino interface. Prior to conduct field test, the HydroQS will perform floating and sensors functionality test at laboratory environment. As a results, the HydroQS capable to float and the sensors able to capture the water quality data.

1. Introduction

Melaka is a state located in the southern part of Malaysia which has always been the focus of tourists from around the world because it is a historic city recognized by UNESCO on 07 July 2008. The rapid development in the state of Melaka has contributed many advantages and disadvantages to the locals. Among the effects that can be seen are the advantages through wider employment opportunities, business development, investment and more. However, a development can also bring adverse effects to the State of Melaka which will cause environmental pollution. One of the areas affected was Melaka River. This can be evidenced by the uncontrolled pollution of the Melaka River by Afroz & Rahman [1].

Rivers are one of the elements of nature that need to be preserved so that its function in the life of creatures remains awake and lasting. It also plays a major role in assimilating urban wastewater as well as in industry and agriculture. The river irrigation system can be affected if the waste disposal

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is direct or indirect. River pollution is not only caused by waste disposal but also caused by industrial pollutants released recklessly by nearby factories, accidental oil spills, deforestation, urbanization, vigorous agriculture. This will lead to pollution and impacts on aquatic animals, disrupt the landscape and the production of foul odors, and disrupt human relationships and the environment. Up to this point, river pollution has continued, and there has been no improvement in terms of positive outcomes [2-7].

The Melaka River also not excluded in the list of rivers in Malaysia that also receive the effects of water pollution. As seen in Figure 1, the river water becomes more polluted, blackish, and releases an unpleasant stench. The Melaka River is a popular tourist destination, thus this scenario quite terrible to present to tourists. In addition, due to the low levels of dissolved oxygen in the Malacca River, several examples of hundreds of wild marine and freshwater fish floating and dead in the river have been recorded as illustrated in Figure 2.

Fig. 1. Malacca River in blackish colour [8]

Fig. 2. Fish floating and dead in Melaka River [9]

Typically, water quality detection was conducted manually whereby the water samples were obtained and sent to the laboratories for examination which takes longer time to process, high cost and extra human resources [10-12]. This approach does not provide the water quality data in a real-time. Previous researchers also have come out with their own water quality monitoring device but lack of the establishment of IoT platform in real cases [13-24]. Therefore, the main objective of this study is to design and develop Hydro quality monitoring system (HydroQS) to monitor and evaluate water quality using Internet of Thing (IoT) in real environment condition. This system measures river water quality in terms of pH level, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), turbidity and temperature of the surrounding environment. All main five sensors that will be used are applicable to Arduino and can be linked and monitored through the online software at anytime and anywhere.

2. Methodology

2.1 Hydro Quality Monitoring System (HydroQS)

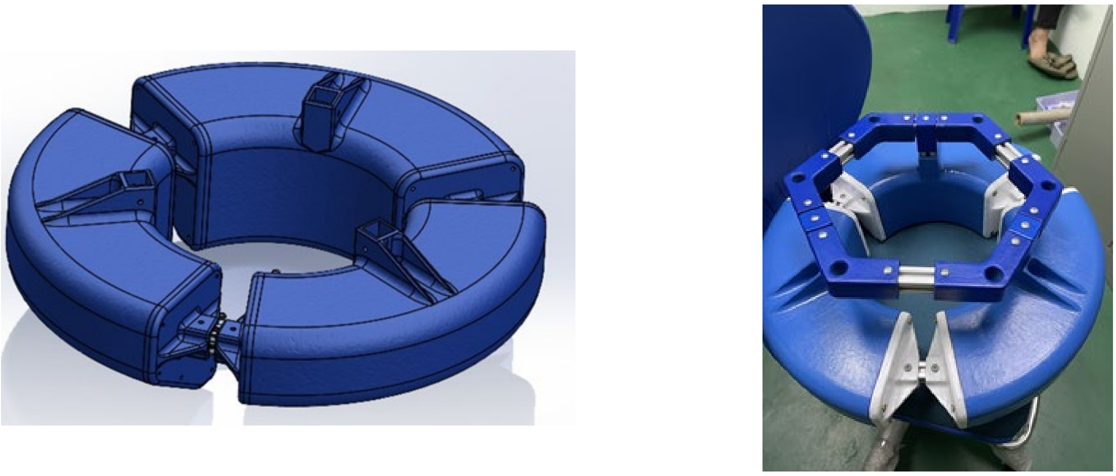
The HydroQS is a low-cost device that works to monitor river water quality. The device has been included with five sensors namely pH, temperature, turbidity, DO and TDS. Solar panels will absorb sunlight as an energy source to produce electricity and will supply the energy to the power bank. The device also integrates IoT as the latest technology that can transfer all the recorded data over the network with internet connection. The data will be sent to the cloud using sensors via Wi-Fi connection to the cloud for data storage. This system consists of mechanical and electronic components.

2.1.1 Mechanical parts

The HydroQS mechanical parts mainly casing is produced using the Farsoon SS402P machine and can categorize into 2 main parts. The first part as shown in Figure 3 (a) and (b) is the main body part of HydroQS, whereby this part is produced to store all electronics components such as sensors' Arduino, modem, power banks and batteries. Meanwhile, the second part is the buoy casing as illustrated in Figure 4 (a) and (b). This buoy casing is to ensure that the device can float on the water's surface. Additionally, all cases produced will be tested to ensure that each part can be matched without looseness.

(a) (b)

Fig. 3. Main body of the HydroQS (a) Design using software Solidworks (b) Printed casing using Selective Laser Sintering Machine



(a) (b)

Fig. 4. Buoy casing of the HydroQS (a) Design using software Solidworks (b) Printed casing using Selective Laser Sintering Machine and after painted

2.1.2 Electronics components

There are five sensors used to monitor river water quality. Firstly, is the pH sensor. This sensor used to measure the acidity and the alkalinity level of water. The type and model of pH sensor used is the industrial type of pH sensor, model H-101 which is manufactured by DfRobot Company, as shown in Figure 5. Secondly, is the temperature sensor. As illustrated in Figure 6, the DS18B20 temperature sensor is available in a waterproof form. This sensor is convenient for measuring anything from a distance or in rainy circumstances. The sensor can withstand temperatures of up to 125°C. Thirdly, is the Turbidity sensor. This sensor able to detect particles suspended in water by measuring the transmittance of light and the rate of scattering that varies with the number of total suspended solids (TTS) in the water. The turbidity rate will increase as the TTS increases. The sensor used in this study is a type of Arduino turbidity sensor F2A09 produced by DfRobot Company which has two analog and digital signal outputs, as shown in Figure 7.

Fig. 5. H-101 pH sensor

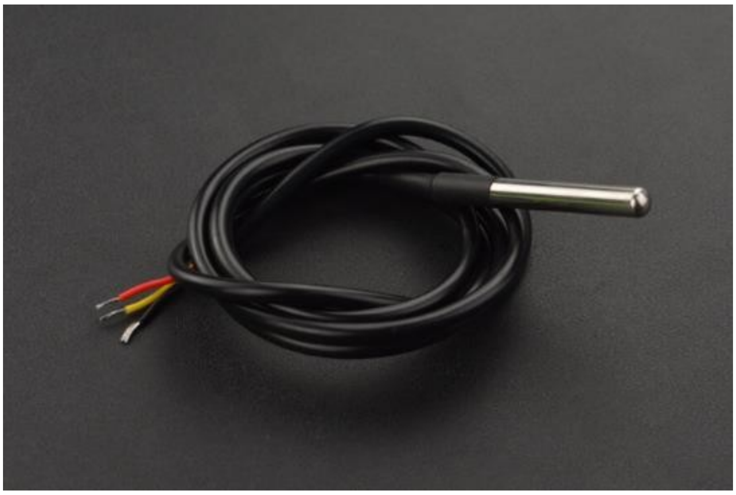


Fig. 6. Waterproof DS18B20 digital temperature sensor

Fig. 7. Analog turbidity sensor model F2A09

Fourtly, is the TDS sensor for determining the TDS value of water as well as the water purity as illustrated in Figure 8. The greater the TDS value, the more soluble solids are dissolved in water, and the less pure the water is. Lastly is the DO sensor. This sensor is used to measure the amount of oxygen in the water and, by extension, the quality of the water as shown in Figure 9. Another electronic component inside in the HydroQS are Arduino Uno, ESP32 with integrated Wi-Fi and Bluetooth connectivity, security camera, internet modem, powerbank and solar panel. The Figure 10 shows the arrangement of these sensors from the bottom view of the HydroQS. There is one empty slot for adding another sensor in the future if necessary.

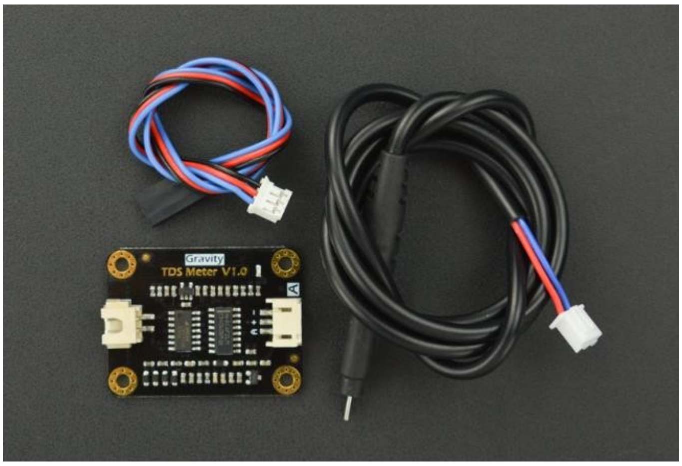


Fig. 8. Analog TDS Sensor

Fig. 9. Analog DO Sensor

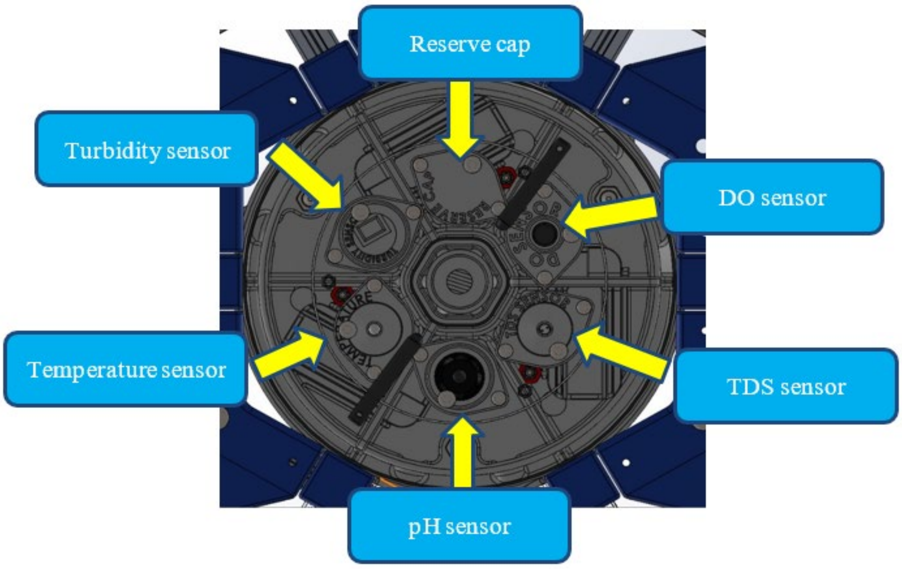


Fig. 10. The position of each sensor for water quality monitoring

3. Results

3.1 Pre-testing

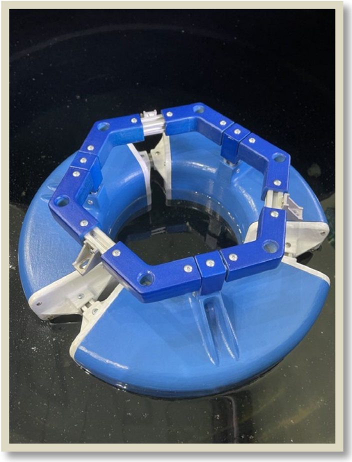
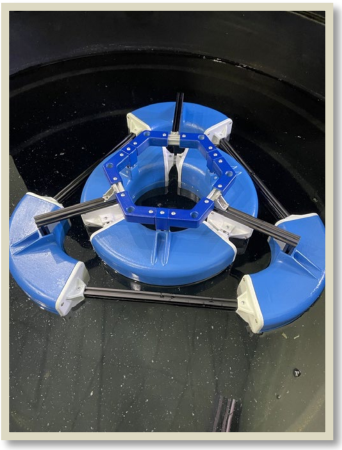
Pre-testing is carried out on the HydroQS device to ensure that it can work properly before being tested on the actual condition. Among the pre-testing processes are leakage and buoyancy tests. This is very important to ensure that the entire device can float well on the water and will not sink. In addition, pre-testing of electronic system is also a priority to ensure that all sensors can record water quality readings and can be monitored from the Home Assistant application software. The data will be recorded and will be displayed in the form of value and graph.

The floating test uses a bucket filled with water weighing 8 kg and a piece of acrylic weighing 1.35 kg as shown in Figure 11 (a) and (b), respectively. A piece of acrylic acts as a balanced liner to ensure the HydroQS buoy area does not get scratched. The total weight borne by the buoy area is 9.35 kg. Based on Table 1, initially, buoy first design cannot support weight and was unstable. Thus, the design was improved by increasing the length from the center device to increase the stability of the buoy area. The design improvement, which is the second design, was stable and can float properly.

(a) (b)

Fig. 11. Weight measurement (a) Bucket filled with water (b) A piece of acrylic plate

Table 1
Floating test

Buoy area version	Design	Test	Degree
1			Approximately 30 degrees (unstable)
2			90 degrees (stable)

The leaking test is done in two different area which is the HydroQS main body and the buoy parts. If the water leak occurs, the repair or improvement process is done first to prevent water from getting into the device and can damage the electronic components. Table 2 shows the initial leaking test and modification made to prevent leakage at device and buoy parts.

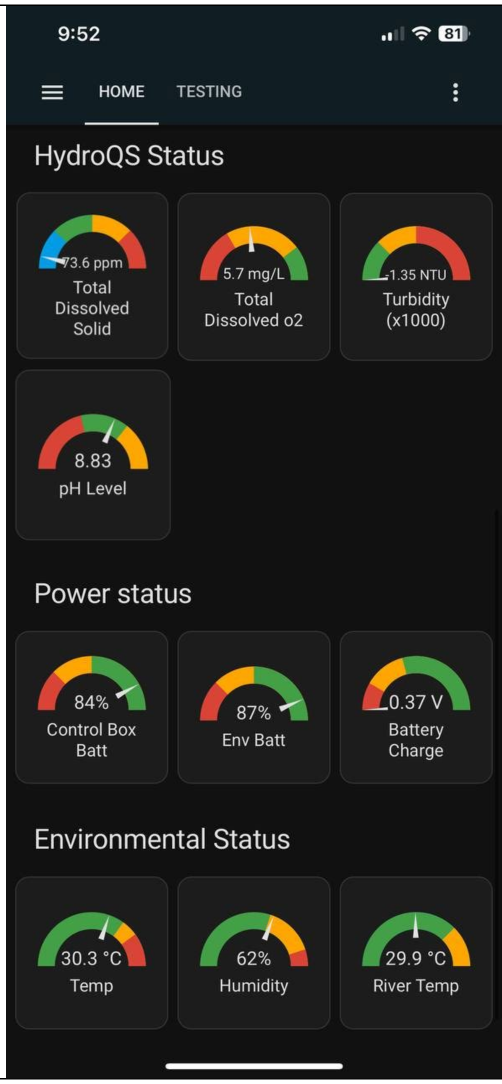
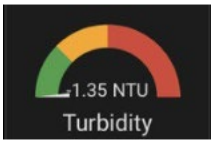
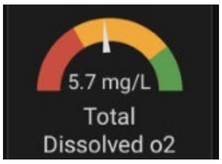
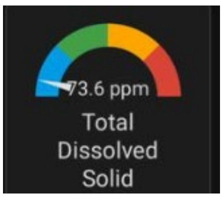
Table 2
HydroQS main body and buoy parts leaking test and improvement result

Part	Initial test result	Improvement and result
Main body part	Water enters the path of the sensor holder and slowly through the pores of the bottom wall. 	Apply rubber gaskets on the sensor holder, the screw part, and silicon to prevent water from entering the device. No leakage.  
Buoy part	Water slowly enters the pores of the buoy parts.	Inserting foam into the buoy compartment. No leakage. 

After completing the floating and leaking test of the HydroQS device, all the sensors need to calibrate and ensure can working correctly before being taken to the river for actual field testing. The sensor calibration process especially pH sensor is used pH meter calibration liquid. The pH sensor value read the approximately same value of three calibration liquid values such as 4.0, 7.0 and 9.2. The HydroQS is placed in a water tank in the SLS laboratory that contains clean water, as shown in Figure 12. The results of the recorded data are shown in the Home Assistant application software as shown in Table 3. The pH sensor reading shows a value of 8.83. The turbidity sensor reading is 1.35 NTU, showing the logical turbidity value because the water in the tank is clear. Furthermore, the temperature sensor reading is 29.9 Celsius. The Dissolved Oxygen (DO) sensor reading is 5.7 mg/L, and the Total Dissolved Solids (TDS) reading is 73.6 ppm.

Fig. 12. Sensor functionality test check at SLS faculty laboratory

Table 3
Sensor functionality test and results

<table>
<tr><th>Sensor type</th><th>Individual results</th><th>Full results on Home Assistant application software</th></tr>
<tr><td>pH sensor</td><td></td><td rowspan="5"></td></tr>
<tr><td>Turbidity Sensor</td><td></td></tr>
<tr><td>Temperature Sensor</td><td></td></tr>
<tr><td>Dissolved Oxygen Sensor</td><td></td></tr>
<tr><td>Total Dissolved Solid Sensor</td><td></td></tr>
</table>

3.1 Field Test

After completing the pre-testing tests, the field test is carried out for 24 hours at the Melaka River near the Taman Rempah, Melaka as shown in Figure 13. All sensor readings can be monitored remotely through the Home Assistant application software. All readings will be recorded every second and a graph will be displayed. Users can monitor changes in readings that increase or decrease dramatically directly. To analyse the obtained sensor data, an interval of 15 minutes will be set accordingly. Table 4 shows the data analysis for each parameter to find out the average, maximum and minimum values in 24 hours.

Fig. 13. Field test at the Melaka River near the Taman Rempah, Melaka

Table 4
Data analysis in 24 hours

Parameter (unit)	Average value	Minimum value	Maximum value
pH	9.11	8.38	9.40
Turbidity (NTU)	30.94	25.60	36.50
Temperature (degree Celsius)	26.90	24.80	28.50
Dissolved oxygen (mg/L)	8.91	8.26	9.81
Total dissolved solid (ppm)	239.33	230.67	316.96

The data of each parameter obtained will be compared with the National Water Quality Standard (NWQS) issued by the Malaysian Environment Department. This comparison aims to determine the status or condition of the water in Malacca River, whether it is in a normal state or polluted. The Table 5 shows the data of each parameter recorded and the standard readings set by the Department of Environment.

Table 5
Data comparison with NWQS

Parameter (unit)	HydroQS data range	NWQS range parameter for clean water (Class 1 and 2)	Melaka River water class based on data comparison
pH	8.38 – 9.40	>7	Class 1
Total dissolved solid (ppm)	230.67 – 316.96	< 500 ppm	
Dissolved oxygen (mg/L)	8.26 – 9.81	> 7 mg/L	
Temperature (degree Celsius)	24.80 – 28.50	-	
Turbidity (NTU)	25.60 – 36.50	< 50 NTU	Class 2

Based on the parameter data recorded and analyzed, the water condition of Melaka River is still under control, where it is still at a level not exceeding class 1 or 2.

4. Conclusions

This study concludes that river water parameters such as pH, turbidity, total dissolved solids, dissolved oxygen, and temperature can be monitored for 24 hours. Next, pre-test the HydroQS body leaking, HydroQS buoy part, and sensor calibration to ensure the device has no issue during the field test. Finally, the data result was collected and compared with NWQS to know the condition of the river water. The result for the dissolved oxygen parameter is the most critical parameter to monitor. This is because, as is known, living things need sufficient oxygen to live. In addition, the pH parameter is also an important parameter that readings are taken to monitor in this study. The pH reading for Melaka River water shows a non-acidic reading where the reading exceeds 7 during the field test.

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