Development of Portable Water Quality Monitoring System Using Apps

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Abstract
Portable Water Quality Monitoring System Using Apps or better known as PWQMSA is a device for measuring and displaying the water temperature, water hygiene and pH value. The design of this innovation model is based on ADDIE model. Kodular Creator serves as graphical user interface while Firebase acts as a database. All the readings measurements acquired are stored in the Google Excel Spreadsheet. Apps that build using the Kodular Creator can be converted into apk format and downloaded by the user. Before innovation, fish pool operators will conduct water quality tests using pH strips to determine the pH value as well as using the hand to detect the temperature of the pool and see with the naked eye to determine whether the water is cloudy or clear. By using the PWQMSA, the measurement and monitoring process is now simpler, the value is readable, the information is automatically gathered in the Google Excel Spreadsheet and the system gives the owner the notification of water status. Moreover, the authentication process can be done by entering a password to prevent outsiders from accessing apps. The various hardware used in this innovation are Arduino Mega, NodeMCU, DS18B20 temperature sensor, humidity sensor, pH sensor and turbidity sensor. The greatest contribution is to contribute to the high accuracy in measuring pH values using the straight line formula y = mx + c. This model has been tested for its functionality by Energy High Tech Sdn Bhd that has certified qualifications in electrical and electronic field. However, for future planning, other parameters can be added such as Dissolved Oxygen, Ammoniacal Nitrogen, Biochemical Oxygen Demand and Total Suspenbed Solid.

Keywords: temperature, water hygiene level, pH value

1.0 Introduction

Water quality is the most important factor in everyday life. Water quality in Malaysia is regulated by the Department of Environment (DOE) using a standard known as the Water Quality Index (WQI). According to MESTECC (2018) and (Mei, et al, 2017) WQI is used to measure water quality in irrigation, domestic and aquaculture areas and is classified into 6 categories, Class 1, IIA, IIB, III, IV and V with Class 1 has natural water quality and class V is classified as poorly polluted water. For the aquaculture sector, water quality is a major element for fish growth. If parameters such as temperature, pH and turbidity are not accurate, then it will affect the survival of fish. The monitoring process needs to be done daily for temperature, pH and turbidity as the value will change daily.

In addition, some important information is to know the value of the tolerance range for fish species and the category of fish such as coldwater from 12 ° C to 18 ° C, coolwater with the range from 19 ° C to 24 ° C and warmwater from 25 ° C to 32 ° C as shown in Table 1, knowing the critical value of culture species and the way the information is delivered to the owner of aqualculture if the problem occurs. If the water temperature exceeds the ideal temperature value, the fish growth will be affected and will increase the operating cost to add the heating or cooling element. The quantity of hydrogen ions (H +) in water can determine acid or alkali conditions. The scale used to measure the pH value is pH scale. The pH scale is in range 1-14 where 1-6 will give acidic readings, 7 neutral and 8-14 will give alkaline readings. According to (Swann, 2000) and (Brown and Gratzek, 1980) the tolerance of pH value for the aquaculture sector is 6.5-7.5 while for the turbidity the tolerance range is within 0.5 NTU- 1.0 NTU.

Table1: Water quality tolerance by species

Species	Categories	Temp (°C)	pH	NTU
Salmon/Trout	Coldwater	7-20	6-7	0.5-0.7
Perch/Walleye		10-18	6-7	0.5-0.9
Baitfish	Coolwater	16-24	6-7	0.5-0.9
Catfish/Carp	Warmwater	18-27	6.7	0.5-0.7
Tropical Ornamentals		20-29	6-7	0.5-0.7
Mahseer		21-29	6-7	0.5-1.0
Tilapia		24-34	6-7	0.5-1.0

Measurement device is required to measure, verify and monitor water quality (Salim, et al., 2018) and (Vijayakumar and Ramya, 2015). According to (Madhavireddy and Koteswarrao, 2018), (Spandana and Rao 2018) and (Prasad, et al., 2015) measurement device for measuring this water quality has gone through several phases of technology ranging from the use of sensors controllers to wireless. Examples of sensors used to measure water quality in aquaculture or fish farming sectors such as pH sensor (F, 2019), water temperature sensor (Pule, et al.,2017), Ammonia (NH4) (Xie, et al., 2019), Nitrate (NO3-), Nitrite (NO2-) and Dissolved Oxygen (DO) (Yusuf, et al., 2019). For wireless systems, the protocol utilized is 802.11 IEEE wireless LAN standards where it will work as a wireless LAN with 1 or 2 Mbps data transmission and a frequency value of 2.4GHz using either Direct Sequence Spread Spectrum (DSSS) or Frequency Hopping Spread Spectrum (FHSS) (Yue and Ying, 2011). The power source used for portable water quality monitoring is battery or by using solar power. The battery used must be rechargeable (Nizar, et al, 2017) but there are some systems that use standard batteries Srivastava, et al, 2018).

In this paper a measurement device based on Apps is proposed. It can monitor real-time situations, fast data transmission rate, data can be stored in Google Excel Spreadsheet, can notify owner if parameters exceed ideal values, use low power consumptions, portable and rechargeable batteries. All of these elements will work in a Wi-Fi network. Using the network, all user can monitor the water quality simultaneously and the cost is lower. There are three quantitative parameters that will be measured at the same time, namely temperature, humidity and pH.

2.0 Methodology

The PWQMSA model is designed using ADDIE method, which involves five processes, section 2.1 analysis, section 2.2 hardware design and sensor, section 2.3 software implementation, section 2.4 result and analysis using the apps and section 2.5 comparison between manual methods and PWQMSA Google Spreadsheet.

2.1 Analysis

Analytical research focuses on the problems faced by fish pool operators using existing equipment. This process of analysis is done by interviewing the fish pool operators.

2.2 Hardware design and sensor

The hardware design comprises of Arduino Mega from Cytron (2019), which serves as the I/O ports, NodeMcu as the Wi-Fi module and three sensor nodes, namely the pH sensor, the turbidity sensor and the temperature sensor as shown in Figure 1. The hardware component connection is shown in Figure 2 together with Kodular Creator, Firebase and Google Excel Spreadsheet.

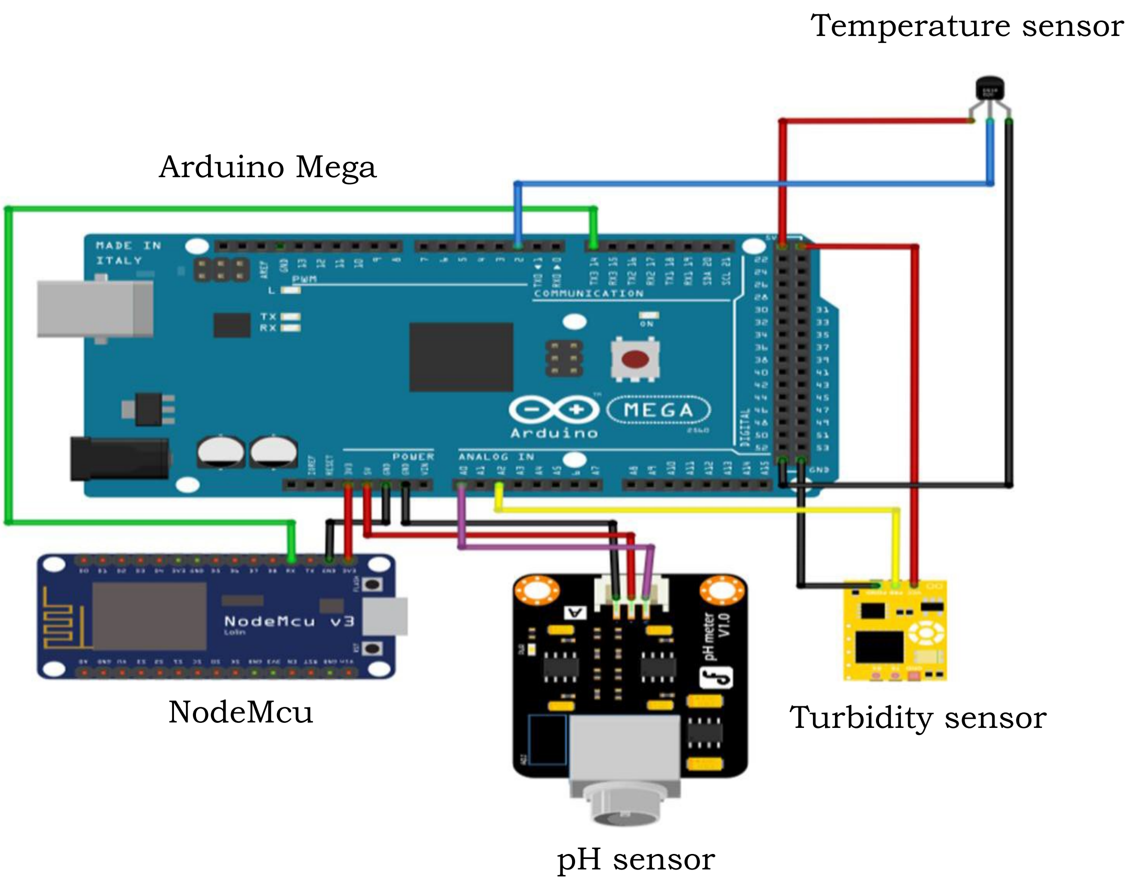


Figure 1: Hardware connection

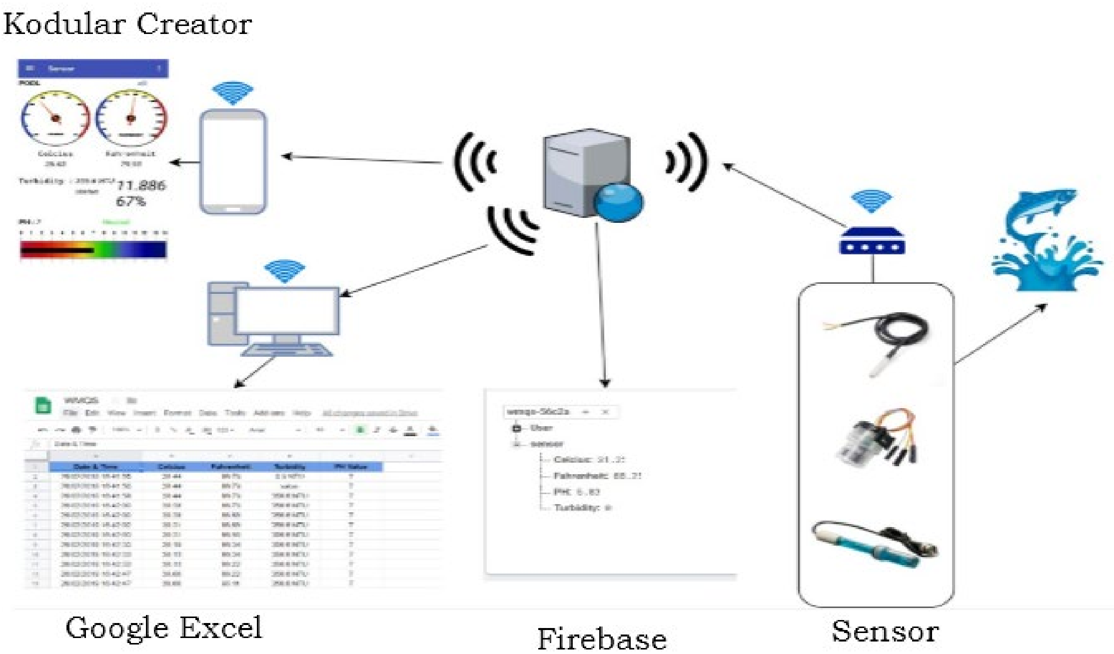


Figure 2: Complete system

A sensor is a device that detects changes in a given environment and sends the change information to the output or to the controller. In PWQMSA, three sensors were used to identify modifications in the three parameters, namely pH sensors for detecting pH parameters, turbidity sensors for measuring NTU values, and temperature sensors for obtaining present temperature measurements. Figure 3 shows DFRobot's Liquid PH0-14 Value Sensor Module with BNC PH Electrode Probe (2019). This pH sensor can detect pH variety from 0 to 14 and has less than 5 seconds of response time. This pH sensor operate at temperatures between 0 ° C until 80 ° C with the detection humidity 95% RH.

Figure 3: Liquid PH0-14 value sensor module with BNC PH electrode probe

The turbidity sensor, as shown in Figure 4, is the type of DFRobot's SKU turbidity sensor: SEN0189 (2019). According to (Kamaludin and Ismail, 2017), this turbidity sensor works to detect water quality based on turbulence using the transfer rate and light scattering techniques. Total suspended solids (TSS) are directly proportional to the quality of water in which TTS also raises the NTU value.The operating voltage is 5 V DC with less than 500ms response time. The output method can be used in analog and digital mode and working temperatures at 5 ° C to 90 °

Figure 4: SKU turbidity sensor: SEN0189

Figure 5 shows DFRobot's Waterproof DS18B20 Digital Temperature Sensor (2019) for Arduino operating at a temperature range of -55 ° C to 125 ° C and less than 750ms of query time [20]. The power used is 3.0V up to 5.5V and uses a 1-wire interface which requires only one digital pin for communication. This temperature sensor is protected by a stainless steel tube and has a 90cm cable length covered with PVC. Therefore, this enables the sensor to operate on the water base.

Figure 5: Waterproof DS18B20 digital temperature sensor

2.3 Software development

The hardware used by PWQMSA is programmed using the Arduino IDE. As shown in Figure 6, Arduino IDE is an open source software that can be used on Windows, Linux, and Mac OS X operating systems. This software can be used by any board compatible with Arduino like Arduino Mega and NodeMcu.

Figure 6: Arduino IDE

Data obtained from sensor will be sent to Firebase. This Firebase serves as an online database. The data in this firebase can be stored in the Realtime or Cloud Firestore database as shown in Figure 7.

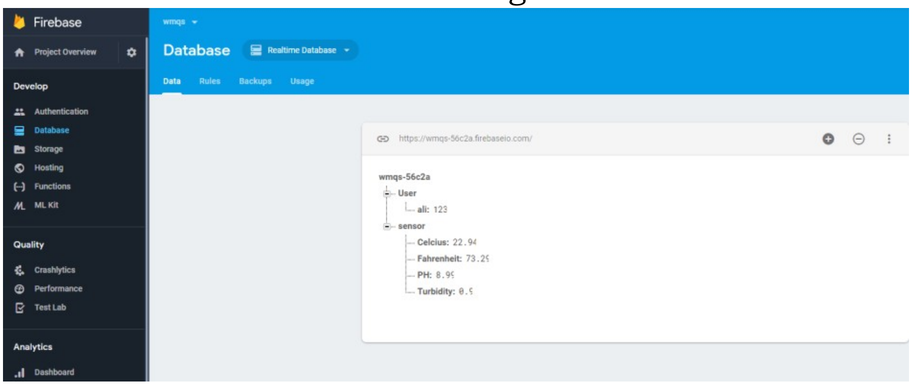


Figure 7: Firebase console

These data will then be sent to Kodular Creator to display value for sensors in PWQMSA apps. This code creator is an open source platform for MIT App Inventor- based creation of mobile applications that utilizes drag-and-drop block methods as shown in Figure 8.

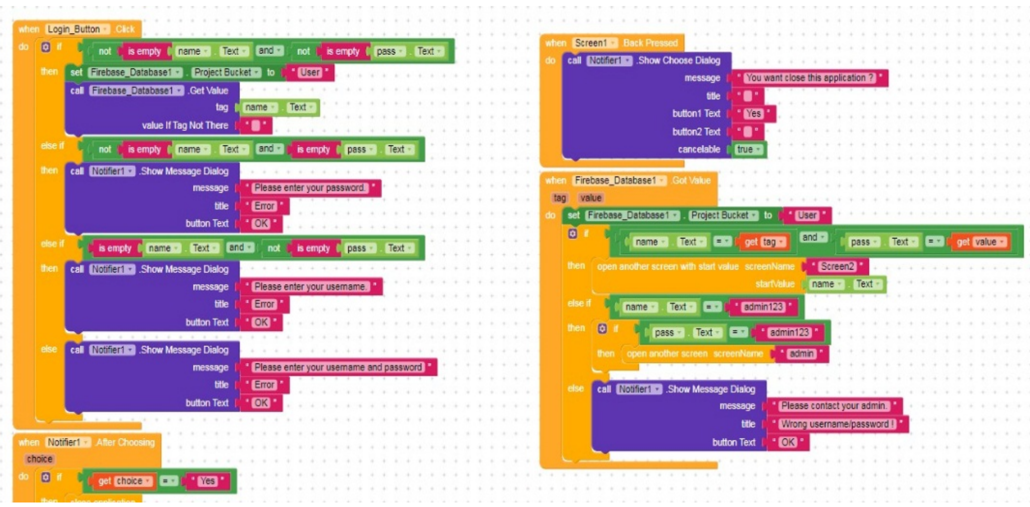


Figure 8: Drag-and-drop block

Figure 9 shows the login screen menu, the sensor menu that displays the sensor value and the side bar to select the desired pool either POOL 1, POOL 2, POOL 3 or POOL 4 and the side bar for the Welcome Screen containing About Us, Contact Admin and Exit apps. In the Code creator two login methods were created, namely admin and user. Using the admin login, admin can add or delete users, set each user's password and change the user's password as shown in Figure 10. If the admin adds the existing user to the database apps, it will issue a warning notification user already exist. However if a new user is added and the new user data is not in the database, a Registration Complete notification will appear. Admin can also view the client list and password enrolled in the PWQMSA applications. PWQMSA application also have function direct call to admin if has any problem.

The information is shown in an interactive form in the Sensor Menu. The temperature information is presented in Celsius and Fahrenheit values using the Gauge Meter. Data for this temperature are obtained from DS18B20 temperature sensor measurements with operating ranges from -10 to 90^{o}C and 0 to 150F. Turbidity values are presented in decimal and percentage. Clean condition will be displayed when the turbidity sensor readings are in range 0 to 5. If the measurements of the turbidity sensor are between 6 until 4000, apps will display Cloudy condition. The pH values are displayed in the form of interactive pH test strips where the pH meter moves to acidic fields if the pH detector detects values from ≥0 to ≤6.9 and gives a neutral reading from ≥7 to ≤7.9 and Alkaline when reading at ≥8 to ≤14. In PWQMSA Google Spreadsheet, each pool number will be separated into different sheets in order to store data read by the sensor as shown in Figure 11.

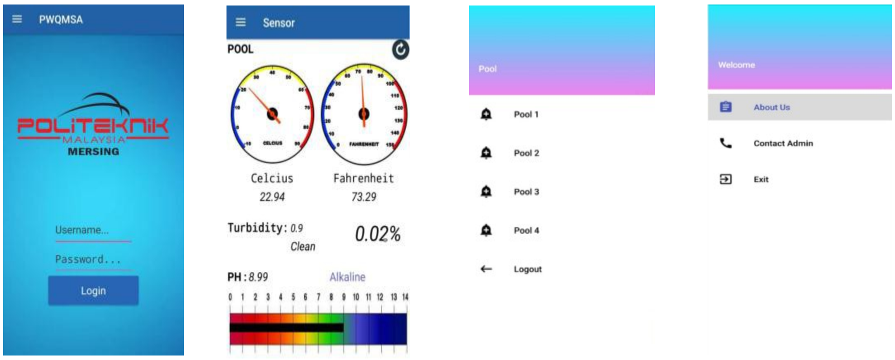


Figure 9: Menu on PWQMSA apps

Figure 10: Admin menu

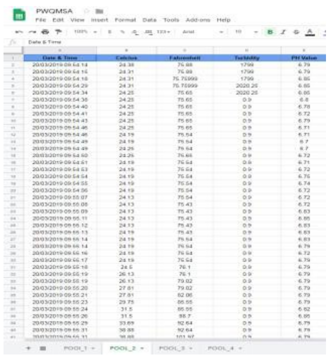


Figure 11: PWQMSA google spreadsheet

2.4 Results and analysis

The complete PWQMSA system is shown in Figure 12. PWQMSA's industrial partner, Far East Planet, located in Kampung Air Merah Mersing used this system. Far East Planet is Malaysia's biggest breeder and distributor of Mahseer fish or better known as kelah.

Figure 12: PWQMSA system

This pH experiment was performed by using pH Powder Buffer Calibration Sachet pH4.01/ pH6.86/ pH9.18 250 ml as shown in Figure 13.

Figure 13: pH Powder Buffer Calibration Sachet pH4.01/ pH6.86/ pH9.18 250mL Solution

The pH solution has an accuracy of ± 0.01pH. Table 2 shows the acidic, neutral and alkaline values of this pH solution tested using pH sensor PWQMSA.

Table 2: Acidic, neutral and alkaline experimental result using PWQMSA

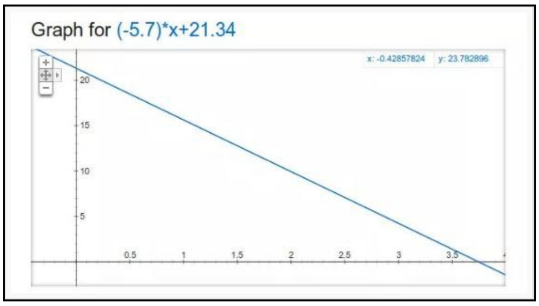
Acidic experiment results		Neutral experiment results		Alkaline experiment results	
pH Solution	**PWQMSA**	**pH Solution**	**PWQMSA**	**pH Solution**	**PWQMSA**
4.00	4.03	6.86	6.90	9.18	9.20
	4.02		6.90		9.22
	4.01		6.94		9.16
	4.02		6.90		9.24
	4.01		6.92		9.26

Table 3 shows the percentage accuracy for acidic, neutral and alkaline by using the accuracy formula $100 - [\frac{average\ measurement\ value - actual\ value}{actual\ value}]$x100%.

Table 3: Percentage of pH accuracy using PWQMSA

pH solution powder	% Accuracy
Acidic	99.55%
Neutral	99.24%
Alkaline	99.61%

This percentage of accuracy can be improved by using the staright line formula in the programming code, y=mx+c where y=pH value, m=gradient, x=volt, c=intercept of y-axis as shown in Figure 14.




```
float pHVol=(float)avgValue*5.0/1024/6;
float phValue = -5.70 * pHVol + 21.34;
```

Figure 14: Straight line formula

The turbidity value collected by the turbidity sensor requires external control for AD conversion to achieve a corresponding turbidity environment. The unit for turbidity measurement is NTU. The rates of water hygiene are directly proportional to NTU values where water becomes less volatile as NTU values increase. Using refined drinking water, the calibration turbidity sensor process provides 0.1 NTU reading. Next, this sensor's turbidity will be tested for different water turbidity. This sensor has a maximum turbidity range of 3000 NTU. The programming code uses formula NTU = -1120.4 * square (volt) + 5742.3 * volt-4353.8 to convert the voltage value to NTU value.

2.5 Comparison between manual methods and PWQMSA google spreadsheet

Workers conducted manual readings for each of the Mahseer fish pool at the Far East Planet company. Each measurement of temperature, pH value and turbidity is conducted only 3 times a day and this method of evaluation will only be reported on a piece of paper as shown in Figure 15.

FAR EAST PLANET
EST. 2014

POOL: POOL 1

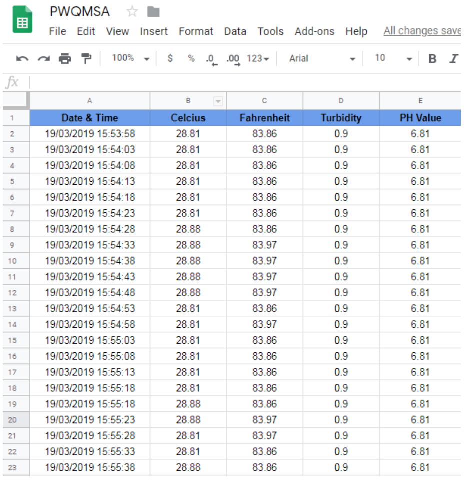
Time Start: 8 am

Date: 19/3/2019

Time	Celcius	Turbidity	pH value
8 am	28^{0}C	0.9	6
1 pm	30^{0}C	0.8	7
4 pm	31^{0}C	0.9	8

Figure 15: Manual reporting method

The data displayed in the apps will be stored in the PWQMSA Google Spreadsheet as shown in Figure 16 containing information on test dates and times, temperature values in Celsius and Fahrenheit, turbidity values and pH values.



	A	B	C	D	E
1	Date & Time	Celcius	Fahrenheit	Turbidity	PH Value
2	19/03/2019 15:53:58	28.81	83.86	0.9	6.81
3	19/03/2019 15:54:03	28.81	83.86	0.9	6.81
4	19/03/2019 15:54:08	28.81	83.86	0.9	6.81
5	19/03/2019 15:54:13	28.81	83.86	0.9	6.81
6	19/03/2019 15:54:18	28.81	83.86	0.9	6.81
7	19/03/2019 15:54:23	28.81	83.86	0.9	6.81
8	19/03/2019 15:54:28	28.88	83.86	0.9	6.81
9	19/03/2019 15:54:33	28.88	83.97	0.9	6.81
10	19/03/2019 15:54:38	28.88	83.97	0.9	6.81
11	19/03/2019 15:54:43	28.88	83.97	0.9	6.81
12	19/03/2019 15:54:48	28.88	83.97	0.9	6.81
13	19/03/2019 15:54:53	28.81	83.86	0.9	6.81
14	19/03/2019 15:54:58	28.81	83.97	0.9	6.81
15	19/03/2019 15:55:03	28.81	83.86	0.9	6.81
16	19/03/2019 15:55:08	28.81	83.86	0.9	6.81
17	19/03/2019 15:55:13	28.81	83.86	0.9	6.81
18	19/03/2019 15:55:18	28.81	83.86	0.9	6.81
19	19/03/2019 15:55:18	28.88	83.86	0.9	6.81
20	19/03/2019 15:55:23	28.88	83.97	0.9	6.81
21	19/03/2019 15:55:28	28.81	83.97	0.9	6.81
22	19/03/2019 15:55:33	28.81	83.86	0.9	6.81
23	19/03/2019 15:55:38	28.88	83.86	0.9	6.81

Figure 16: Sensor values recorded into PWQMSA google spreadsheet

Temperature and pH values differ significantly between manually recorded information and the use of applications. This mistake happened during reading owing to a human error. This is because by using the manual method, Far East Planet company will take one parameter reading at a time instead of using PWQMSA, all sensors have been integrated into PWQMSA board and will have simultaneous sensor value readings and the value of this sensor will be recorded automatically into PWQMSA Google Spreadsheet.

3.0 Conclusions

The PWQMSA was developed to measure water quality for aquaculture purposes. With this PWQMSA, data will be more reliable as sensor values will be read every 5 seconds, save time, cost-effective as there is no use of pH strips which are disposable, more accurate sensor readings and data can be recorded automatically and real- time. Based on the apps recorded, the Mahseer fish pool readings of temperature, pH value and turbidity value meet the Fishery Class IIA Water Quality Index (WQI) for the sensitive aquatic species aquaculture sector released by the Department of Environment (DOE). Using this PWQMSA, Far East Planet owners can easily monitor their worker activities as well as temperature, pH and turbidity values. This PWQMSA acts as a dedicated app and implements a security feature where this system can only be used by users who have apk files, registered in the PWQMSA database and connect to the specific WiFi. The PWQMSA admin is responsible for the user's add, delete and change password process. These apps support dual mode, either log in as an admin or user. PWQMSA acts as a portable device where it can be carried anywhere and uses the power bank as a power supply and admin can monitor the quality of water at any time and anywhere.

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