MTSFB TR 002:2019

TECHNICAL REPORT

REAL-TIME WATER QUALITY MONITORING SYSTEM IN KETUTU FARMING

MTSFB TR 002:2019

Preface

Malaysian Technical Standards Forum Bhd (MTSFB) has awarded Sophic Automation Sdn Bhd the Industry Promotion and Development Grant to implement the Proof of Concept (PoC) through the Real-time Water Quality Monitoring System in Ketutu Farming. The duration of this PoC lasts for a period of 10 months starting May 2017.

The PoC is done at Profil Biofarm Sdn Bhd, Tampin, Negeri Sembilan. The key objective of this PoC is a real-time water quality monitoring system.

This Technical Report outlines objective, benefit, scope of work, methodology and result analysis.

Prepared by:

Sophic Automation Sdn Bhd (794994-D)

In collaboration with:

Profil Biofarm Sdn Bhd, Tampin, Negeri Sembilan and School of Computer Science, Universiti Sains Malaysia.

Published by:

Malaysian Technical Standards Forum Bhd (MTSFB)
Malaysian Communications and Multimedia Commission (MCMC)
Off Persiaran Multimedia, Jalan Impact, Cyber 6
63000 Cyberjaya, Selangor Darul Ehsan
Tel : (+603) 8320 0300
Fax : (+603) 8322 0115
Email : admin@mtsfb.org.my
Website : www.mtsfb.org.my

Contents

Abbreviations

BAS	Biological Aquaculture System
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPU	Central Processing Unit
DO	Dissolved Oxygen
GSM	Global System for Mobile communications
HDMI	High-Definition Multimedia Interface
HDPE	High-Density Polyethylene
HTML5	Hypertext Markup Language version 5
LAN	Local Area Network
M2M	Machine to Machine
MSE	Mean - Squared Error
PCIe	Peripheral Component Interconnect express
PHP	Hypertext Preprocessor
Sal	Salinity
SMS	Short Message Service
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USB	Universal Serial Bus
WQI	Water Quality Index

REAL-TIME WATER QUALITY MONITORING SYSTEM IN KETUTU FARMING

1. Introduction

Ketutu also known as ikan hantu, ketutu or soon hock and scientifically known as Oxyeleotris marmorata. It is one of the popular freshwater edible fish with high demand on the market. The ketutu farming managed by Profil Biofarm Sdn Bhd are equipped with Biological Aquaculture System (BAS) which is based on natural processes and adjustment of local conditions to enhance biological processes which involve biological water management to reduce fries mortality rate.

A real-time water quality monitoring system called PANTAU is installed to measure water quality parameters at pre-defined intervals and store the information on digital data loggers without the need for any operator intervention or M2M communication.

The compiled data from PANTAU were used to study the interrelationships among water quality parameters in BAS as predictive analytics.

1.1 Ketutu

Ketutu as in Figure 1, is cultured in ponds and cages in Southeast Asia, particularly in Malaysia, Thailand, Singapore, Indonesia and Vietnam and is exported to markets in Japan, China, Taiwan and Hong Kong. In Malaysia, commercialisation of this type of fish is not widely established. Demands are largely dependent on wild populations, thus fetching high prices in the market.

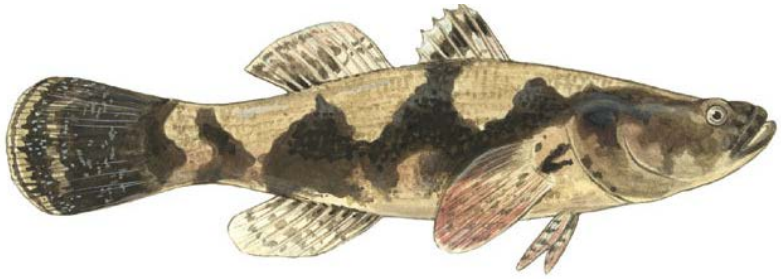


Figure 1. Ketutu

The extensive and intensive culture of the ketutu is limited by the short supply of larvae, which are obtained mainly from the wild. The problems related to ketutu culture include high mortality of larvae, its passive feeding behaviour, and preference for live feed and slow growth rate. The major food item of ketutu consists of small freshwater prawns and small wild fish and benthos.

1.2 Project site

There are 16 freshwater ponds connected to 96 bioreactors tanks i.e. 1 pond is connected to 6 bioreactor tanks. Each pond accommodates approximately 5 000 ketutu fries and is reared for a period ranging from 12 to 15 months to reach market size. The overall project site is shown in Figure 2.

Figure 2a. Project site

Figure 2b. Sensor node (front view)

Figure 2c. Sensor node (site view)

Figure 2. Overall project site

1.3 Biological Aquaculture System (BAS)

BAS is modular in design and permits flexibility in upscaling of pond operations. BAS production system modules as in Figure 3 comprise of a pond with the following specifications:

a) High-Density Polyethylene (HDPE) liner (dimensions 25 ft x 50 ft x 6 ft);

b) BAS bioreactors (stage 1);

c) BAS bioreactors (stage 2);

d) overflow sump;

e) sump pump;

f) concrete; and

g) submersible pump.

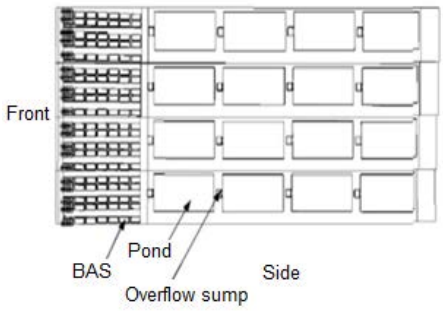


Figure 3a. Top view

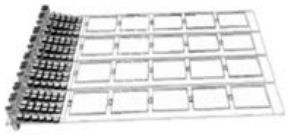


Figure 3b. 3D perspective

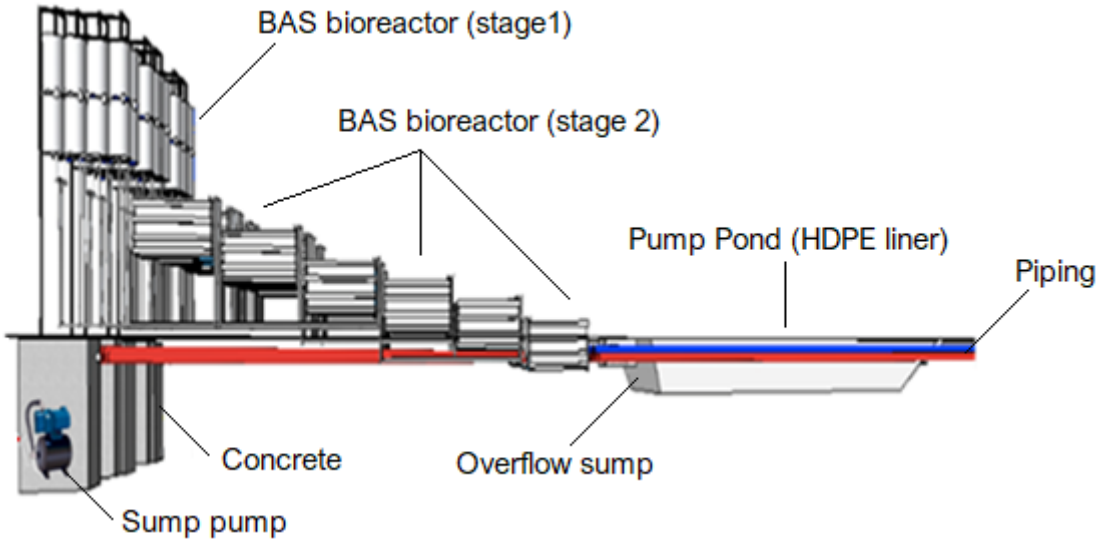


Figure 2c. Side view

Figure 3. BAS production system

1.4 PANTAU

PANTAU is a real-time web-based monitoring system that specialises in measuring water quality and able to measure 12 parameters.

PANTAU consists of automated data acquisition module for the collection of data from data loggers on site, expert analysis module for automated validation of data to reduce dependency on human validation, auto alert module for sending of alert via SMS and email, Integration module for integration with user portal and open data app, web portal module for users and reporting module.

2. Target groups and benefits

2.1 Profil Biofarm

The PANTAU has benefits Profil Biofarm in the following items:

a) identify ideal water quality index for ketutu farming;

b) shorten the breeding gestation period for ketutu farming;

c) determine and evaluate BAS biofiltration capacity and size of ponds optimisation; and

d) duplicate BAS for other freshwater species.

2.2 Universiti Sains Malaysia

Collaboration with School of Computer Science, Universiti Sains Malaysia on the data collection which the study of interrelationships among water quality parameters in BAS for ketutu farming can be utilised by other aquaculture researchers and replicate to other types of fish species.

2.3 Suppliers

Hydrolab DS5 (multi probes) from USA and Trios Opus (UV Analyser) from Germany are purchased from their exclusive distributor in Malaysia, HSA Asia Sdn Bhd.

3. Objectives

The objectives of the project are as follows:

a) to enhance the PANTAU; and

b) to study the interrelationships among water quality parameters in BAS.

4. Scope of work

The scope of work for this project is enhance PANTAU that is able to monitor water quality, provide an error log report and the efficient data recovery function of the ketutu farming.

5. Methodology

5.1 System architecture of PANTAU

PANTAU is a combination of hardware and software that creates a dedicated computer system that is able to perform specific, predefined task which is encapsulated within the device it controls. The hardware involves embedded PC (Advantech ARK), serial port (RS232 cables), Hydrolab DS5 and Trios multi-water parameters probes, data logger and acquisition device (Advantech EKI), Global System for Mobile communications (GSM) module, Machine to Machine (M2M) sim card and antenna as shown in Figure 4.

The programming language are written in visual studio C# programming, AT commands, cloud server, mailbox emailing, Ajax, JavaScript, and Hypertext Preprocessor (PHP) for web page development.

All of these hardware and software are fully utilised to enable the system to collect data from the sensor through RS232 serial communication, analyses the raw data and interpret into scientific data, upload the data into the cloud server, web page to display real-time data, exporting tools such as csv, pdf, words and excel for data logging and data visualisation such as line graph.

Data are recorded every second at the data logger and transmitted to database every minute. All data can be viewed real-time at the website and mobile phones.

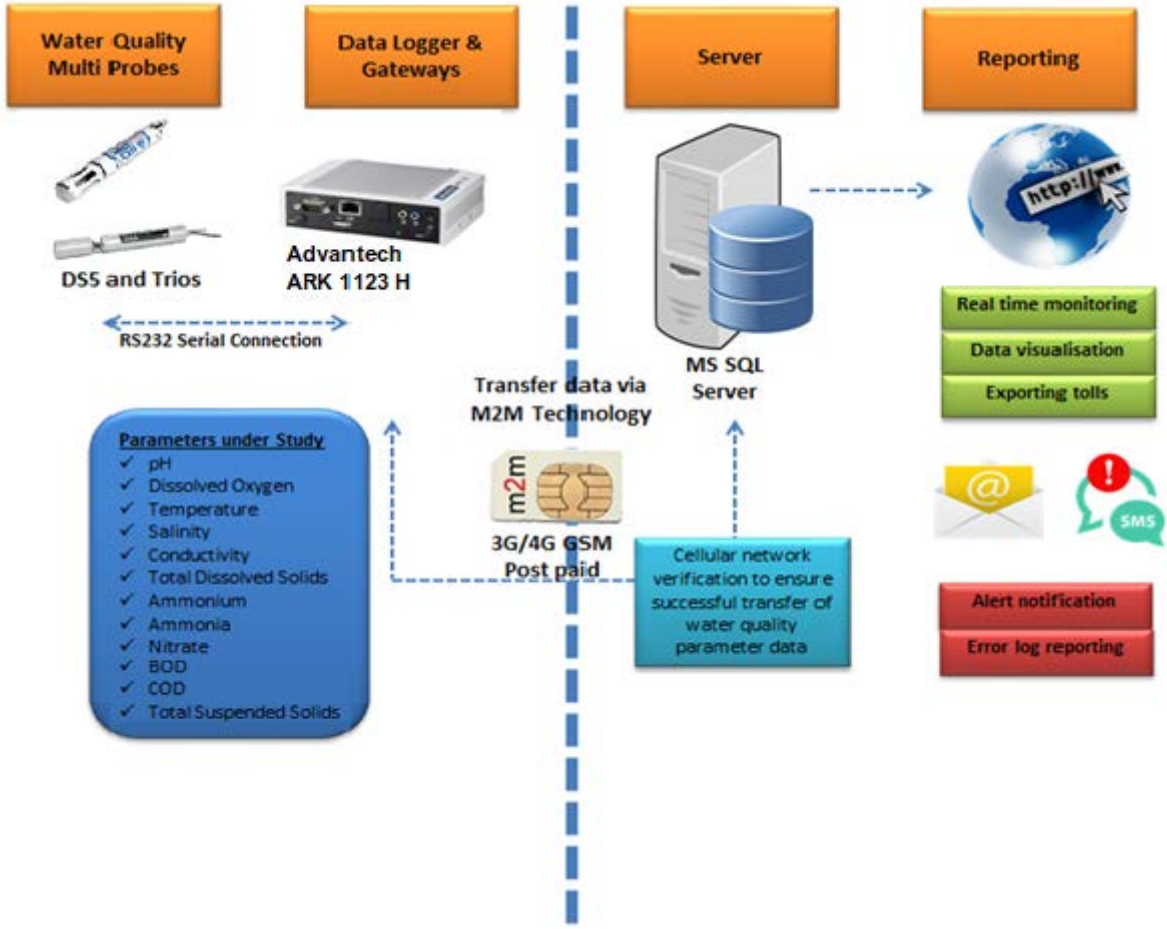


Figure 4. System architecture of PANTAU

Figure 5 illustrates the PANTAU flow chart.

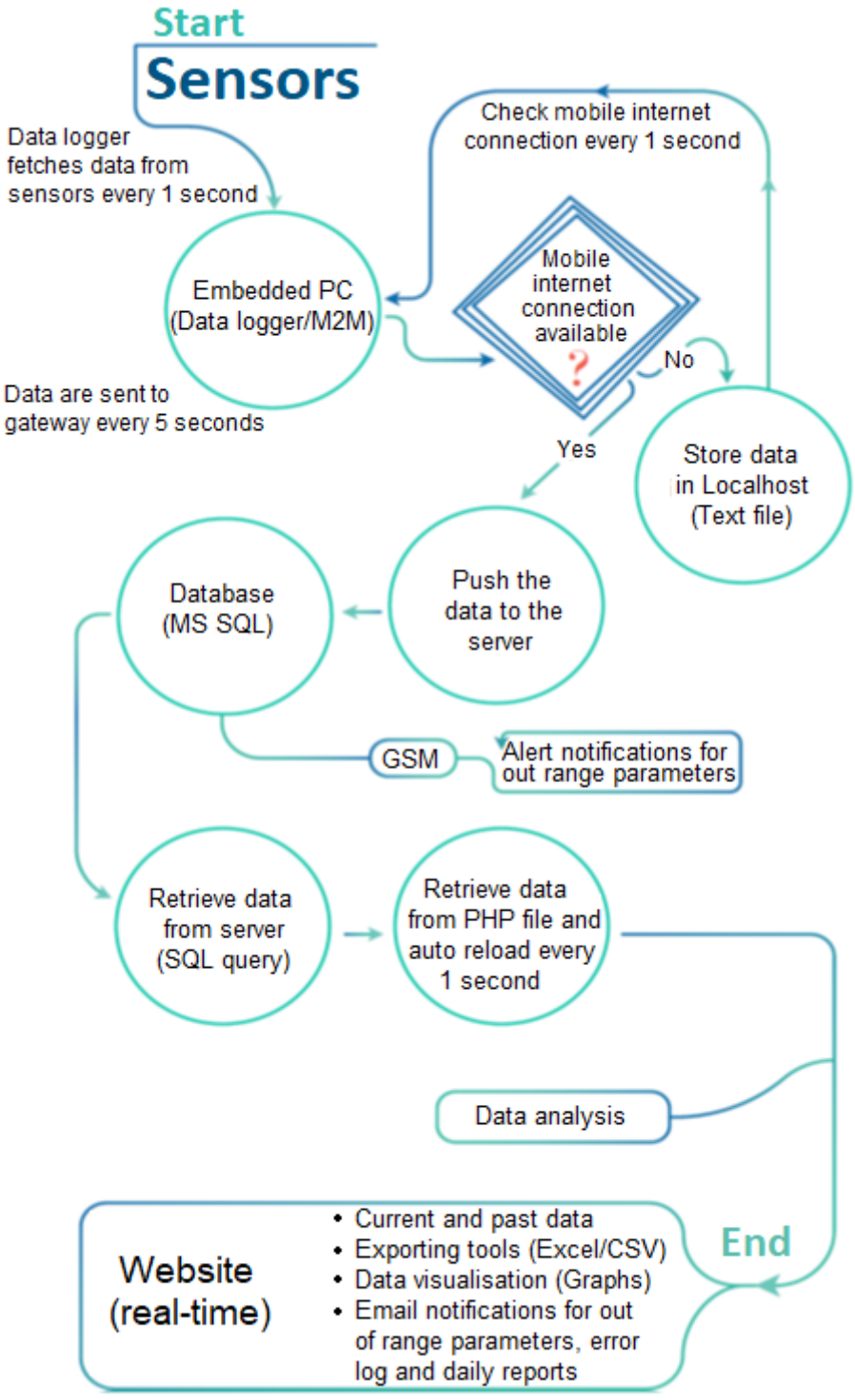


Figure 5. PANTAU flow chart

5.1.1 Hardware

There are few sensor or multi-probes used in PANTAU. Two multi-probes are used namely as Hydrolabs DS5 and Trios Opus.

5.1.1.1 Hydrolabs DS5

The Hydrolab DS5 as shown in Figure 6, is a thin and lightweight multi-probe sensor that reads the following water quality parameters:

a) temperature

b) pH;

c) conductivity;

d) DO;

e) TDS;

f) salinity (Sal);

g) ammonia;

h) ammonium; and

i) nitrate.

It supports serial communication protocols which is a common protocol for a data logger for communication.

Figure 6. Hydrolab DS5

5.1.1.2 Trios Opus

Trios Opus is the new generation of spectral sensors for online measurement of nitrogen and carbon compounds as in Figure 7. Through the analysis of a full spectrum, Trios Opus is able to deliver reliable readings for BOD, COD and TSS parameters.

Figure 7. Trios Opus

5.1.2 Data logger and gateway

PANTAU data logger is Advantech EKI 1524 BE as in Figure 8. It is 4-port serial device servers which can support up to 4 serial devices connected to it and 2 ethernet ports for TCP/IP communication. It is compact and small but very powerful. It can support communication with windows or Linux.

Figure 8. Advantech EKI 1524 BE

PANTAU uses a gateway as its central system and runs continuously in an outdoor environment. Therefore, controller might not be a suitable choice for harsh environment as compared to gateway.

Advantech ARK 1123H as in Figure 9 is an embedded computer. It is a window-based system operated by Intel Celeron Processor. The input voltage of this gateway is 12 Vdc and consist of 1 serial port, 3 Universal Serial Bus (USB) ports, 2 High-Definition Multimedia Interface (HDMI) connectors, 2 ethernet ports and a GSM module (mini Peripheral Component Interconnect express (PCIe) card with sim card holder).

Figure 9. Advantech ARK 1123H

The gateway can directly connect to:

a) sensors via serial port;

b) EKI 1524 BE via ethernet port for faster rate of data transfer;

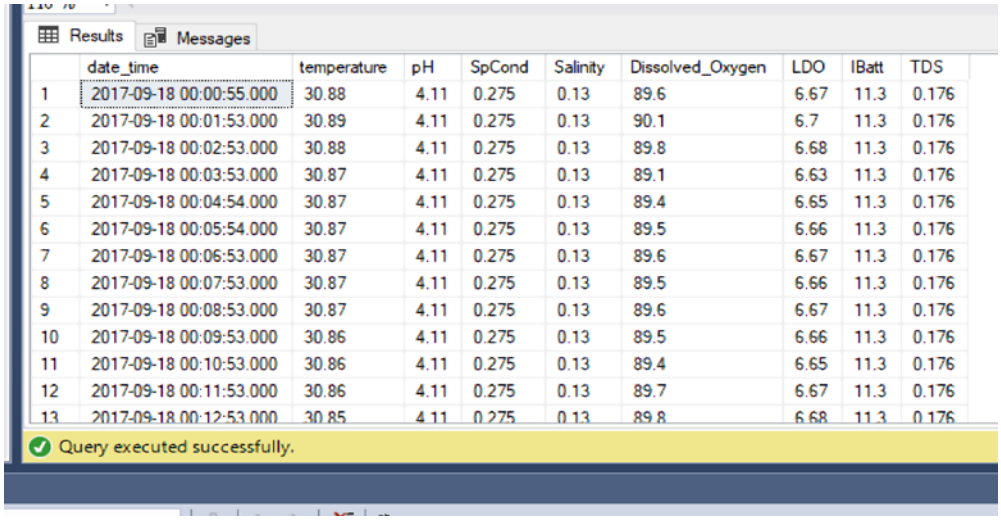
c) GSM module and sim card data for wireless internet connection; and

d) LAN cable via ethernet port for a local internet connection.

5.1.3 Software

PANTAU reads all the 12 parameters i.e. pH, DO, temperature, Sal, conductivity, TDS, ammonium, ammonia, nitrate, BOD, COD and TSS and compute the Water Quality Index (WQI) based on National Water Quality Standards for Malaysia as in Annex A.

Figures 10 and 11 show the screenshot of sensors reading data which can also be retrieved from the website.

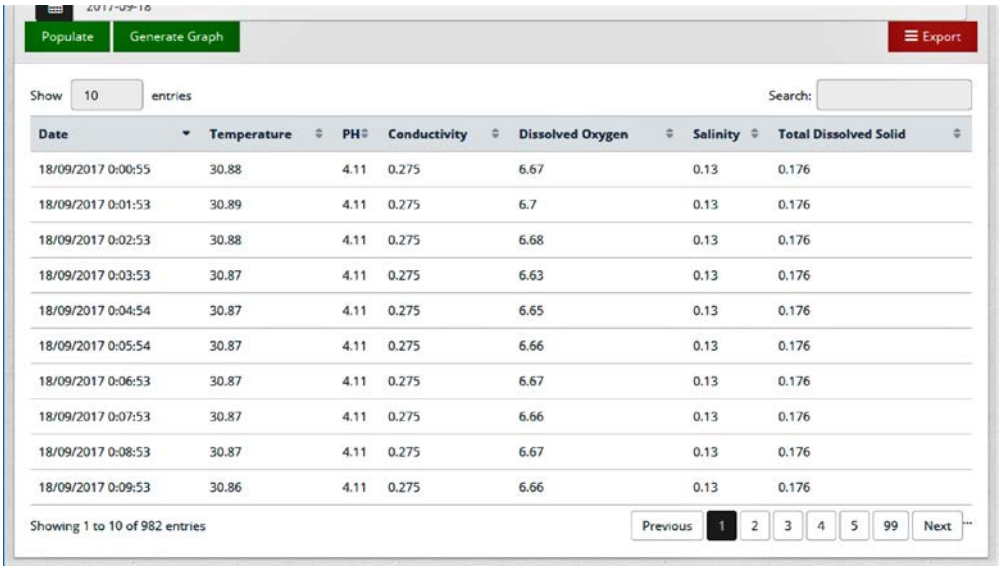


Results Messages

	date_time	temperature	pH	SpCond	Salinity	Dissolved_Oxygen	LDO	IBatt	TDS
1	2017-09-18 00:00:55.000	30.88	4.11	0.275	0.13	89.6	6.67	11.3	0.176
2	2017-09-18 00:01:53.000	30.89	4.11	0.275	0.13	90.1	6.7	11.3	0.176
3	2017-09-18 00:02:53.000	30.88	4.11	0.275	0.13	89.8	6.68	11.3	0.176
4	2017-09-18 00:03:53.000	30.87	4.11	0.275	0.13	89.1	6.63	11.3	0.176
5	2017-09-18 00:04:54.000	30.87	4.11	0.275	0.13	89.4	6.65	11.3	0.176
6	2017-09-18 00:05:54.000	30.87	4.11	0.275	0.13	89.5	6.66	11.3	0.176
7	2017-09-18 00:06:53.000	30.87	4.11	0.275	0.13	89.6	6.67	11.3	0.176
8	2017-09-18 00:07:53.000	30.87	4.11	0.275	0.13	89.5	6.66	11.3	0.176
9	2017-09-18 00:08:53.000	30.87	4.11	0.275	0.13	89.6	6.67	11.3	0.176
10	2017-09-18 00:09:53.000	30.86	4.11	0.275	0.13	89.5	6.66	11.3	0.176
11	2017-09-18 00:10:53.000	30.86	4.11	0.275	0.13	89.4	6.65	11.3	0.176
12	2017-09-18 00:11:53.000	30.86	4.11	0.275	0.13	89.7	6.67	11.3	0.176
13	2017-09-18 00:12:53.000	30.85	4.11	0.275	0.13	89.8	6.68	11.3	0.176

Query executed successfully.

Figure 10. Screenshot of sensors reading in database (back end)



Populate Generate Graph Export

Show 10 entries Search:

Date	Temperature	PH	Conductivity	Dissolved Oxygen	Salinity	Total Dissolved Solid
18/09/2017 0:00:55	30.88	4.11	0.275	6.67	0.13	0.176
18/09/2017 0:01:53	30.89	4.11	0.275	6.7	0.13	0.176
18/09/2017 0:02:53	30.88	4.11	0.275	6.68	0.13	0.176
18/09/2017 0:03:53	30.87	4.11	0.275	6.63	0.13	0.176
18/09/2017 0:04:54	30.87	4.11	0.275	6.65	0.13	0.176
18/09/2017 0:05:54	30.87	4.11	0.275	6.66	0.13	0.176
18/09/2017 0:06:53	30.87	4.11	0.275	6.67	0.13	0.176
18/09/2017 0:07:53	30.87	4.11	0.275	6.66	0.13	0.176
18/09/2017 0:08:53	30.87	4.11	0.275	6.67	0.13	0.176
18/09/2017 0:09:53	30.86	4.11	0.275	6.66	0.13	0.176

Showing 1 to 10 of 982 entries Previous 1 2 3 4 5 99 Next

Figure 11. Screenshot of sensors reading/historical data retrieved from website

All the readings parameters as shown in Figure 12 can be monitored real-time on a personal computer or mobile phone on the website. The website is designed to provide a user-friendly interface for the user and available to highlight the data collected from sensors. The development process involved Hypertext Markup Language version 5 (HTML5) to explore tools for more immersive and form fitting interfaces, PHP for backend processes, JavaScript and Ajax for data acquisition from database.

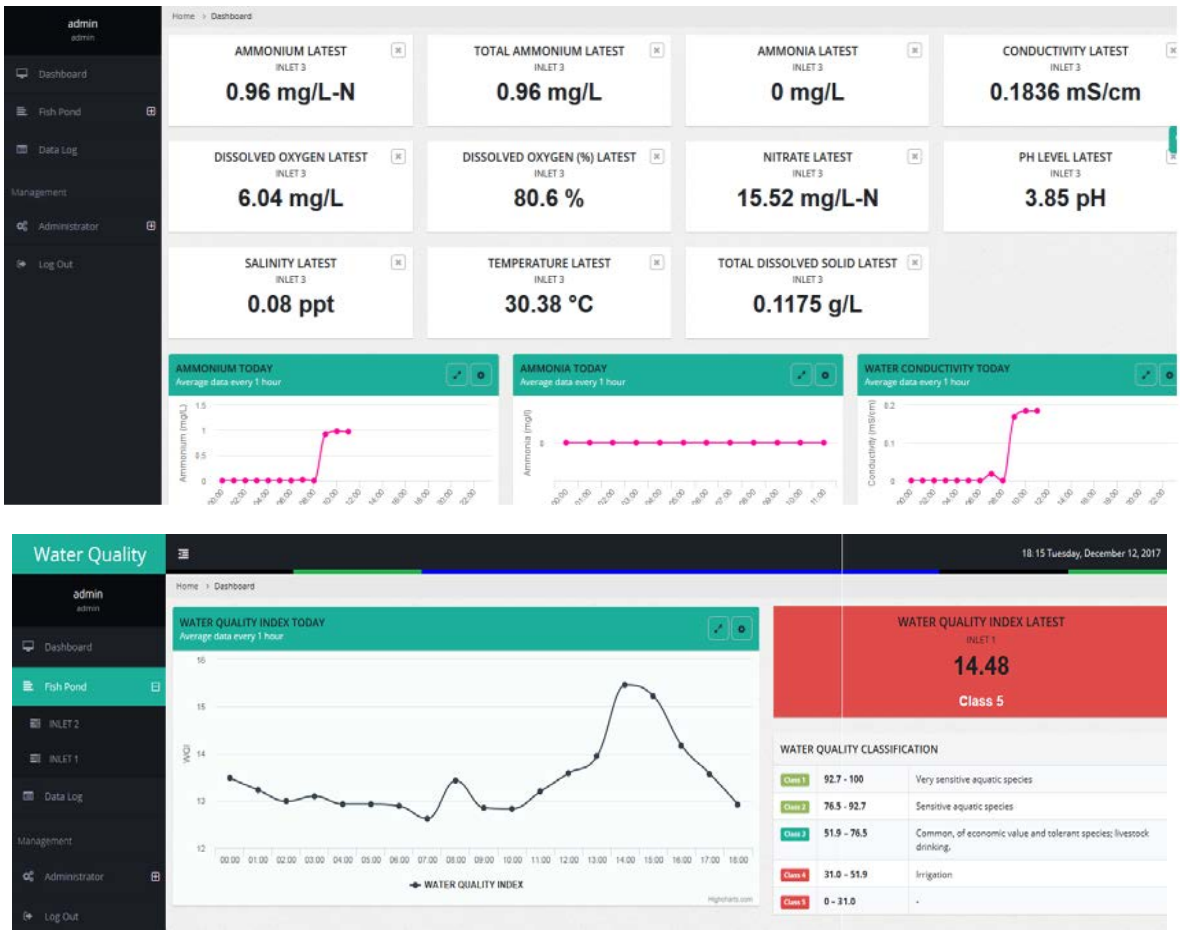


Figure 12. Screenshot of website/dashboard

Water quality parameter readings that fall outside the defined threshold as in Table 1 due to changes in pond conditions are notified to users via email and SMS. The screenshot of the email and SMS alert/notification are shown in Figure 13.

Table 1. Parameter range for lower and higher threshold

Parameter	Lower threshold	Higher threshold
Temperature	27 °C	31.4 °C
pH	6.5	9
Conductivity	0.3 mS/cm	1.2 mS/cm
DO	4.5 mg/L	No limit
TDS	0.5 mg/L	1 mg/L
BOD	3	6
COD	25	50
TSS	50	150
Ammonia	No Limit	9
Ammonium	No Limit	9
Nitrate	0.5	3

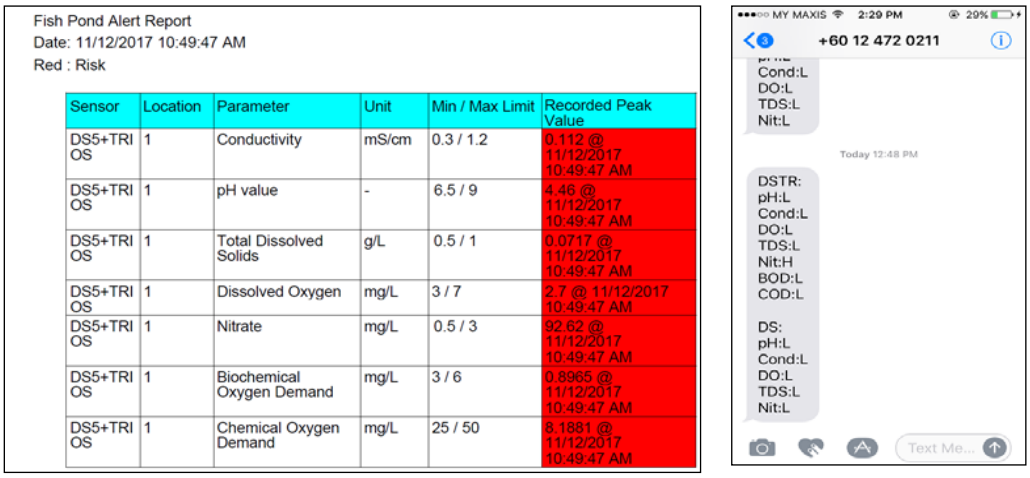
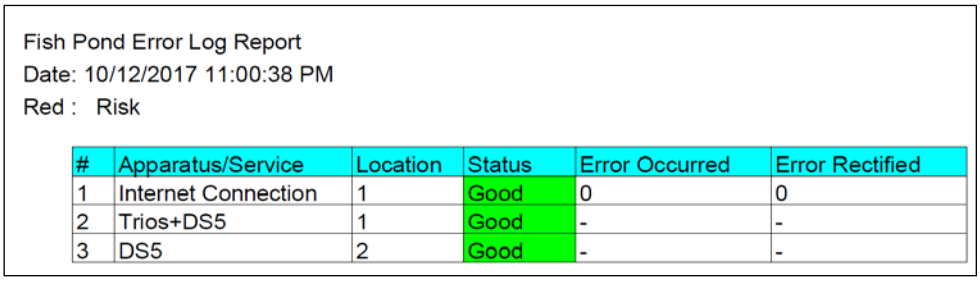


Figure 13. Screenshot of email and SMS alert/notification

PANTAU also provides the error log report to notify the user status of sensors, data loggers, PC, power supplies and internet connectivity which include time of failures and recovery. The screenshot of the error log report is shown in Figure 14.



Fish Pond Error Log Report
Date: 10/12/2017 11:00:38 PM
Red : Risk

#	Apparatus/Service	Location	Status	Error Occurred	Error Rectified
1	Internet Connection	1	Good	0	0
2	Trios+DS5	1	Good	-	-
3	DS5	2	Good	-	-

Figure 14. Screenshot of error log report

PANTAU has an efficient data recovery function. At times, fixed line internet and 3G/4G GSM network experience service degradation which results in temporary loss of connectivity. This occurs as the telco provider upgrades its network or due to other unforeseen circumstances. However, PANTAU is able to verify connectivity with the internet via 3G/4G cellular network and server connection before data is sent. If there is no network connectivity, the data is saved in a logger system and to be sent on the next scheduled transmission.

PANTAU performs a gateway daily restart as the gateway is running continuously. A daily restart is required for the gateway as resting purpose. This is crucial as components inside the gateway basically are mechanical items such as fans, hard drives, Central Processing Unit (CPU), chipset and etc. Although the gateway able to run all day long over weeks or months, but it is a good option to have a daily rest time (15 minutes) for the gateway to turn off and release the physical duress on all the operating components, so that this could minimise the possibility that the gateway gets overheated (if cooling system fails) and damage other components.

6. Result analysis

The growth analysis is carried out for 41 497 observations in Pond 1, 39 962 in Pond 2, 52 760 in Pond 3 and 42 074 in Pond 4 where the data of 12 parameters are monitored from 30th June 2017 to 17th October 2017 and are divided into sequential monthly data. The study revealed that some of the water quality parameters in the BAS system are interdependent and also have strong interrelationships in four tested pond locations (1, 2, 3 and 4). The BOD and TSS are revealed to be similar influential water parameters in all ponds.

The findings also show that conductivity, pH and TDS are the common predictors in ponds 1, 2 and 4. Though the four models give the accurate and reliable results which indicating the versatility of the developed models, it is worth to note that ponds 1 and 2 resembled the important water quality parameters for fish culturist except the presence of temperature in pond 2. In facts, pond 1 has the lowest mean - squared error (MSE) and the highest adjusted R^2. The suggested predictive equation for WQI is:

WQI = 12.86 - 126.9*SpCond - 1.048*pH + 83.60*TDS - 99.44*Sal + 0.09141*Nitrate - 1.665*BOD + 1.541*√COD + 5.125*√TSS

NOTE. SpCond is Specific Conductance.

The equation is then used to calculate new WQI values by substituting values from each recorded parameter. The classification of fish pond water will be conducted once the value of WQI is confirmed.

7. Conclusion

PANTAU is effectively used in evaluating water quality in concern with BAS. It provides detection of any signs of deterioration in water quality to minimise the mortality rate of ketutu fries and shorten the harvesting period.

The sources of monitored data would be a valuable scientific resource because of potentially extending the scope, scale and replicability of data gathering for assessment purposes, as well as of developing new models and methodologies. The result of the study of interrelationships among water quality parameters in BAS for ketutu farming can be utilised by other aquaculture researchers and replicate to other types of fish species.

PANTAU architecture and its features are also suitable for any other sensor's related application which requires real-time monitoring where the data can be measured and monitored real-time from anywhere via PC, laptop, mobile phone or tablet.

The potential applications for this solution are as follows:

a) fish farming/aquaculture monitoring (other fish species and prawn farming);

b) waste water treatment monitoring;

c) river/lake water pollution monitoring;

d) rainfall/landslide monitoring;

e) solar panel performance monitoring;

f) continuous gas emission monitoring; and

g) PANTAU to bridge existing none web-based/manual monitoring system.

Annex A

(informative)

National Water Quality Standards

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
BOD	mg/l	1.0	3.0	3.0	6.0	12.0	>12.0
COD	mg/l	10.0	25.0	25.0	50.0	100.0	>100.0
DO	mg/l	7.0	5.0-7.0	5.0-7.0	3.0-5.0	<3.0	<1.0
pH	-	6.5-8.5	6.0-9.0	6.0-9.0	5.0-9.0	5.0-9.0	-
Colour	TCU	15.0	150.0	150.0	-	-	-
Electrical Conductivity*	umhos/ cm	1,000.0	1,000.0	-	-	6,000.0	-
Floatables	-	n	n	n	-	-	-
Odour	-	n	n	n	-	-	-
Salinity	%	0.5	1.0	-	-	2.0	-
Taste	-	n	n	n	-	-	-
Total Dissolved Solid	mg/l	500.0	1,000.0	-	-	4,000.0	-
Total Suspended Solid	mg/l	25.0	50.0	50.0	150.0	300.0	300.0
Temperature	°C	-	Normal +2°C	-	Normal +2°C	-	-
Turbidity	NTU	5.0	50.0	50.0	-	-	-
Faecal Coliform **	counts/ 100 mL	10.0	100.0	400.0	5,000.0 (20,000.0)[a]	5,000.0 (20,000.0)[a]	-
Total Coliform	counts/ 100 mL	100.0	5,000.0	5,000.0	50,000.0	50,000.0	>50,000.0
Iron	mg/l	Natural levels or absent	1.0	1.0	1.0	1.0 (Leaf) 5.0 (Others)	Levels above IV
Manganese	mg/l		0.1	0.1	0.1	0.2	
Nitrate	mg/l		7.0	7.0	-	5.0	
Phosphorous	mg/l		0.2	0.2	0.1	-	
Oil & Grease	mg/l		0.04; N	0.04; N	N	-	

Notes:
n : No visible floatable materials or debris or No objectionable odour, or No objectionable taste.
* : Related parameters, only one recommended for use.
** : Geometric mean.
a : maximum not to be exceeded.
N : Free from visible sheen, discolouration and deposits.

Class	Uses
Class I:	Conservation of natural environment. Water Supply 1 – practically no treatment necessary. Fishery 1 – very sensitive aquatic species.
Class IIA:	Water Supply II – conventional treatment required. Fishery II – sensitive aquatic species.
Class IIB:	Recreational use with body contact.
Class III:	Water Supply III – extensive treatment required. Fishery III – common, of economic value and tolerant species; livestock drinking.
Class IV:	Irrigation
Class V:	None of the above

References

[1] National Green Technology Policy, July 2009

[2] *Design of Remote Monitoring System for Aquaculture Cages Based on 3G Networks and ARM-Android Embedded System,* Yanle Wang, Changsong Qi, Hongjun Pan (2012), 79- 83.

[3] *Effect of Aeration on Selected Water Quality Parameter in Freshwater Fish Culture,* International Journal of Biological and Chemical Science, AO Akinwole, AB Dauda, TA Oredein (2014), 2858-2865.

[4] *Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality, Polish Journal of Environmental Studies,* Naubi, Zardari, Shirazi, Lavania & Ibrahim (2016), 231-239, Vol 25

[5] *Online Water Monitoring System Based on Zigbee and GPRS*, Xin Wang, Longquan Ma, Huizhong Yang (2011), 2680-2684.

[6] *Water Quality Monitoring and Control for Aquaculture Based on Wireless Sensor Networks,* Journal of Networks, Daudi S.Simbeye & Shi Feng Yang (2014), 840-848, Vol 9 No 4

Publication of:

Malaysian Technical Standards Forum Bhd (MTSFB)

Malaysian Communications and Multimedia Commission (MCMC)
Off Persiaran Multimedia, Jalan Impact, Cyber 6
63000 Cyberjaya, Selangor Darul Ehsan
Tel: (+603) 8320 0300
Fax: (+603) 8322 0115
Website: www.mtsfb.org.my

In collaboration with

Malaysian Communications and Multimedia Commission (MCMC)

MCMC Tower 1
Jalan Impact, Cyber 6, 63000 Cyberjaya
Selangor Darul Ehsan
Tel: (+603) 8688 8000
Fax: (+603) 8688 1000
Website: www.mcmc.gov.my