Real time fish pond monitoring and automation using Arduino

Real time fish pond monitoring and automation using Arduino

Z. Harun[1,*], E. Reda[1,2] and H. Hashim[3]

[1]Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, UKM Bangi, 43600, Selangor, Malaysia

[2]Department of Mechanical Engineering
Lotfy El-Sied st. off Gamal Abd El-Naser – Alexandria
Alexandria Governorate 11432, Egypt

[3]Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

*Correspondence: zambri@ukm.edu.my

Abstract. Investment and operating costs are the biggest obstacles in modernizing fish ponds in an otherwise very lucrative industry i.e. food production, in this region. Small-scale farmers running on small ponds could not afford to hire workers to man daily operations which usually consists of monitoring water levels, temperature and feeding fish. Bigger scale enterprises usually have some kinds of automation for water monitoring and replacement. These entities have to consider employing pH and dissolved oxygen (DO) sensors to ensure the health and growth of fish, sooner or later as their farms grow. This project identifies one of the sites, located in Malacca. In this project, water, temperature, pH and DO levels are measured and integrated with aerating and water supply pumps using Arduino. User could receive information at pre-determined intervals on preferred communication or display gadgets as long as they have internet. Since integrating devices are comparatively not expensive; it usually consists of Arduino board, internet and relay frames and display system, farmer could source these components easily. A sample of two days measurements of temperature, pH and DO levels show that this farm has a high-quality water. Oxygen levels increases in the day as sunshine supports photosynthesis in the pond. With this integration system, farmer need not hire worker at their site, consequently drive down operating costs and improve efficiency.

1. Introduction

1.1. World's aquaculture fish demand

Fisheries aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. According to The State of World Fisheries and Aquaculture 2016 [1], per capita fish supply reached a new record high of 20 kg in 2014, thanks to vigorous growth in aquaculture, which now provides half of all fish for human consumption, and to a slight improvement in the state of certain fish stocks due to improved fisheries management. In the last two decades, dramatic growth in aquaculture production has boosted average consumption of fish and fishery products at the global level. The shift towards relatively greater consumption of farmed species compared with wild fish reached a milestone in 2014, when the farmed sector's contribution to the supply of fish for human consumption surpassed that of wild-caught fish for the first time [1]. Total world fishery production (capture plus aquaculture) is projected to expand over the period, reaching 196 million tonnes in 2025. This represents an increase of 17% between the base period (average 2013–15) and 2025, but indicates a slower annual growth compared with the previous decade (1.5% versus 2.5%). Almost all of the increase in production will originate from developing countries. Their share in total output will increase from 83% in the base period to 85% in 2025. A more marked expansion is expected in Asia, with its share in total production rising from 70% to 73%. Surging demand for fish and fishery products will mainly be met by growth in supply from aquaculture production, which is expected to reach 102 million tonnes by 2025, 39% higher than the base period level.

1.2. Malaysia demand and production

Malaysia fisheries growths have increased steadily since three decades ago. In 1985 to 1997, Malaysia register growth of 4.5%. Most of the production was contributed by marine capture [2]. In 1997 the value added by the fisheries sector was estimated at about RM2 million representing about 1.5% of gross domestic product (GDP) or 11.1% of the agricultural GDP. Fisheries net export earnings were negative (-RM39.6 million) because Malaysia was a net importer of fish in terms of both quantity and value in 1997 [2]. Over the years, Malaysia rapid modernization on fisheries have improved fish products. Starting 2010, Malaysia has reached self sufficiency level (SSL) for most type of fish and therefore a net fish exporter since then on [3]. Figure 1 shows that Malaysia has achieved SSL level for 2010-2013(expected).

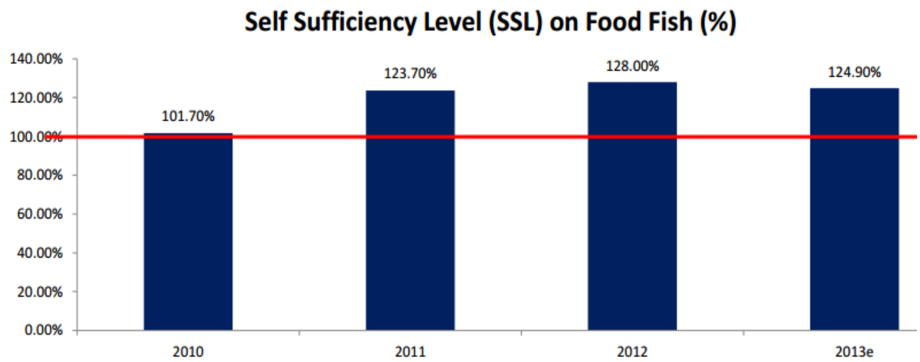


Figure 1: Malaysia's Self Sufficiency Level (SSL) on Fish Food (Source: Mazuki, H., 2015 [3].)

Moving further, the Malaysian government has realized the potential in aquaculture industry. Under the National Key Economic Areas (NKEA) for the 10th Malaysia ambitious, well-crafted development plan, the government has set up the Integrated Zone for Aquaculture (IZAQ) as one of the Entry Point Projects (EPP) to promote the industry, this is EPP6. The other two EPPs are the Integrated Cage Farming mainly for grouper, sea bass and tilapia and Seaweed Mini Estates. Figure 2 shows the projection under the IZAQ project. The 10 projects in IZAQ shall boost the growth to compound annual growth rate (CAGR) [3].

To ensure that projects rolled out are successful, the companies selected to trust into making the targets achieved, are companies with strong records and with established farming systems. For example, one of the anchor companies selected to achieve target 'an aquaculture park with large area dedicated to the organized production of high quality, fully certified shrimp for the premium market', is Hannan

Corp. Sdn Bhd. [4,5]. The big projects by Hannan Corp. involves farming areas more than 100 hectares, workers more than 400 and tasked to produce gross national income of RM500 million. The company has established its aquaculture expertise. This involves automation system, checking quality of water, pH, oxygen levels and etc. In this article, we propose a new approach to integrate devices usually used by aquaculture industries such pH, oxygen level and temperature sensors, pumps, aerators, lights and etc.

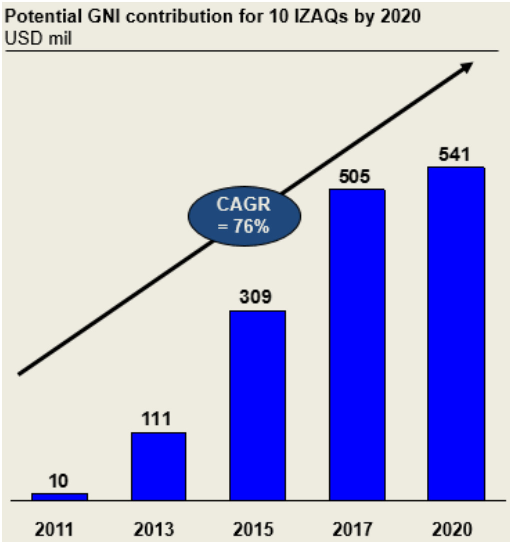


Figure 2: Malaysia's projection of the contribution of gross national income (GNI) for Integrated Zone for Aquaculture (IZAQ) is based on growth of 76%. (Source: Fisheries Department of Malaysia [3]).

2. Methodology

We have identified a site in Malacca as a typical aquaculture farm in Malaysia. The existing pond shown in Figure 3 has a length of 24 m, width of 13 m and depth of 1.2 m (typical water level). The pond produces tilapia and two of local Malaysian catfish favourites called *patin* and *keli*. The pond is located about 30 m from a creek, however the water level of pond is 8 m above the water level of creek on a typical day. There is also an abandoned well used to be a source of water supply using a suction pump.

Figure 3: Existing fish pond in Malacca, before real time fish monitoring and automation project started.

2.1. Instrumentations

Four sensors have been utilized in the proposed system; a temperature sensor to measure atmospheric temperature, a temperature sensor to measure water temperature, dissolved oxygen (DO) sensor and pH sensor. The specifications of these sensors are listed in Table 1.

Table 1: Specifications of the sensors implemented in the monitoring system.

	Model	Specifications
Temperature sensor	Digital Temperature Sensor (Dallas) – DS18B20	Range: -55 °C to +125 °C Accuracy: ±0.5 °C (-10 °C – +85°C)
pH sensor	Analog pH Meter Kit SKU: SEN0169	Measuring Range: 0-14 pH Measuring Temperature: 0-60 ℃ Accuracy: ± 0.1 pH (25 ℃) Response Time: ≤ 1min
DO sensor	Atlas Scientific	Range: 0-35 mg/L Max Temperature: 50 °C Max Pressure: 690 kPa Max Depth 60 M Response time = 0.3 mg/L per second

The temperature sensor used here comes with stainless-steel-covered tip, made by Digital Temperature Sensor (Dallas) – model DS18B20. It can measure extreme temperatures -55 °C to 125 °C with very good accuracy.

A pH meter is a scientific instrument that measures the hydrogen-ion concentration (or pH) in a solution, indicating its acidity or alkalinity. The term pH was originally derived from a French word, 'pouvoir hydrogéne', which means 'hydrogen power'. This parameter shows the quantity of hydrogen ions (H^+) in the water. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. At 25 °C, a pH of 7.0 is considered neutral, while values below 7.0 are considered acidic, and above 7.0 are alkaline. The pH sensor used here, analog pH Meter Kit SKU: SEN0169, has the capability to measure the entire range of acidity to alkalinity (0-14). It can work continuously in turbid, strongly acid and alkali solution for months.

The Atlas Scientific DO sensor used here is founded on dissolved oxygen expressed in mg/L (weight of oxygen over volume of water) or its equivalent, parts per million (ppm). It can measure a wide range of oxygen 0-35 mg/L. Generally, all countries have an average of DO levels ranging between 5.0 and 9.0 in freshwater, and 6.5 and 9.0 for marine, all of which are within the limits of optimum fish production [6].

Table 2: Acceptable conditions for fish production in selected countries (PHILMINAQ, 2008 [6], National Water Quality Standards for Malaysia [7])

Parameters	Malaysia	The Philippines	Australia	General desired condition for freshwater pond
Temperature (°C)	*Normal + 2 °C	-	-	Depending on fish
pH (index 0-14)	6.5 - 9.0	6.5 - 8.5	5.0 - 9.0	6.5 - 9.0 *5 – 9
DO (mg/L)	3.0 – 7.0 *3 - 5	5.0	> 6.0	**Minimum DO that supports a large population of various fishes is 4-5.
Alkaline (mg/L)		-	> 20	5-500
NO_2-N (mg/L)	0.40	-	0.10	*** < 1
Phosphorus (P) in different forms	0.10 - 0.20 (P)	0.05 - 0.10 (P) in lakes and reservoir	< 0.10 (PO4)	Excess concentrations especially in rivers and lakes can result to algal blooms. It limits nutrient needed for the growth of all plants-aquatic plants and algae alike.

* Based on National Water Quality Standards for Malaysia for Fishery III - Common economic value and tolerant species and livestock drinking [7].
** Based on Water Research Center [15]
*** Based AO recommendation [16].

Solar radiation is the source of heat for all water bodies. The amount and angle of incidence of sunlight decides the energy entering the water body. Distribution of heat within the water by conduction is negligible because of very low heat conductivity of water especially in the tropics. Much of heat mixing takes place by convection aided by wind action. Heat is lost due to evaporation and also by direct exchange to air and substratum (the soil underneath) [8]. In artificial ponds, where the depth is usually 1 – 2 meters, there is only a minor temperature difference between the surface and water bed. The surface water temperature could be much higher in the afternoons and it is likely that fish take shelter in the cooler and deeper portions of the pond for comfort and probably to survive. Notwithstanding, fish mortality due to temperature change is a rare phenomenon in the tropical plains. It quite often fish mortality observed is not due to temperature, but a combination of factors e.g. temperature, low oxygen, metabolite load and salinity [8]. The temperature in Malaysia has very little fluctuation over the year. For example, an on-site measurement for three weeks in a weather station shows that temperature fluctuates +/- 1.5 °C from its mean [9].

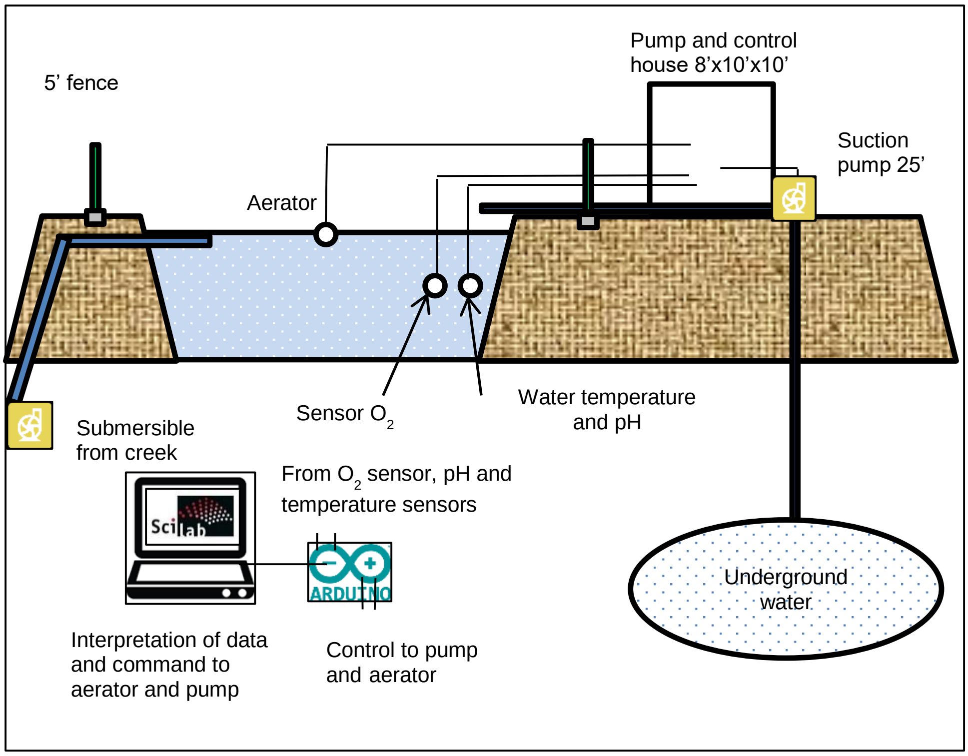


Figure 4: Schematic diagram of real time fish monitoring and automation project

The pH levels for natural waters range between 5.0 - 10.0 [6]. Based on the data shown in Table 2, the pH levels from three different countries i.e. Malaysia, The Philippines and Australia, fall within this range. The amount of oxygen consumption varies, depending on the size, feeding rate, activity level and species. Physical condition such as temperature, altitude, atmospheric pressures and salinity can also affect oxygen level. As temperature and pressure increase water holds less oxygen [6,12]. Therefore, for a typical fish pond system, a temperature sensor is necessary so that the reasons in the increase/decrease in chemical content could be traced, and might be attributed simply because of the rise in temperature rather than a direct leak (or other reasons) of these chemicals.

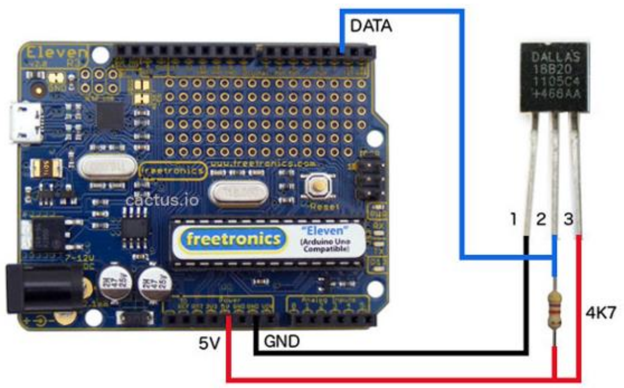
In aquaculture, alkalinity is the measure of the capacity of water to neutralize or buffer acids using carbonate, bicarbonate ions, and in rare cases, by hydroxide, thus protecting the organisms from major fluctuations in pH. Without a buffering system, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that may potentially decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbon dioxide will be consumed by the phytoplankton and, as a result, drive the pH levels above 10.0. As discussed, fish grow within a narrow range of pH values and either of the above extremes will be lethal to them [6].

Other parameters for a fish pond operation are biological parameters Ammonia-Nitrogen (NH_3-N), Nitrate-Nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N) and Phosphorous (P). There are also other parameters such as total solid (suspended or dissolved), heavy metals (mercury and lead) and pesticides. Monitoring the compliance and physical monitoring were identified as two critical factors that can ensure the success or failure of the monitoring system in place, however these are almost impossible for the at least for the Philippines [6].

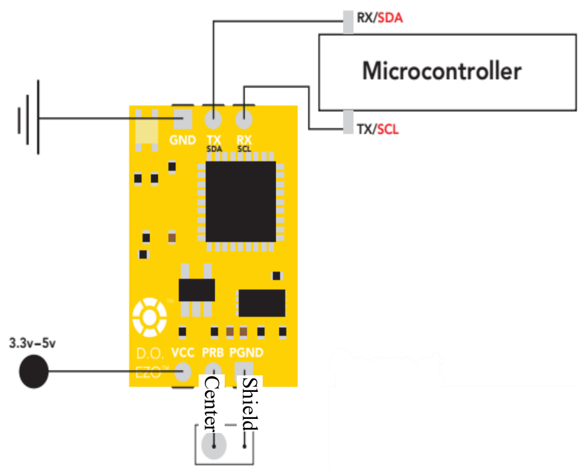
In our proposed system, we have combined the most important parameters which are the temperature, pH and DO levels. The system as shown in Figure 4 also contains an aerator, a submersible pump (to pump water from the creek) and a suction pump (to extract water from the well). The Arduino codes for the temperature, DO and pH sensors were downloaded from the manufacturers' websites [10-12], respectively. The DO sensor, pH sensor and one of the temperature sensors were packed together and dipped in the water 1.5 m away from one side of the pond. The second temperature sensor was left in the atmosphere, just outside of the water. The algorithm for the Arduino was first loaded from a laptop, after that the Arduino board takes the data from the sensors directly and the instructions to aerator and pumps.

2.2. Data acquisition

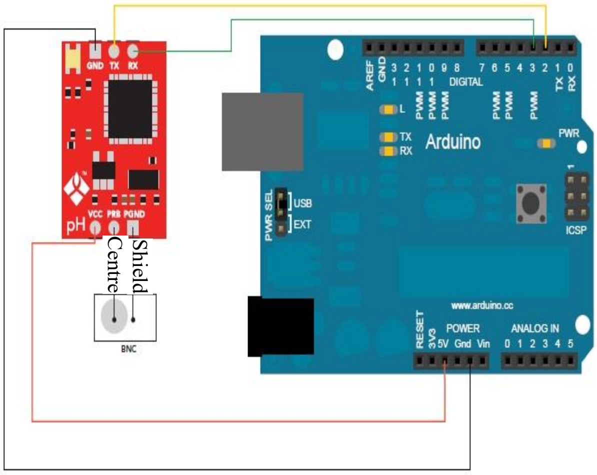
The readings of the sensors were collected via an Arduino® Mega 2560 microcontroller. The connections of the different sensors to the Arduino board are illustrated in Figure 5 (a-c). The data was then sent via the existing, domestic Wi-Fi network to an online Google® spreadsheet. To send data via Wi-Fi, an extra Arduino shield (Cytron ESP8266) was fitted to the main board. The data passes through an [Arduino – PushingBox – Google Form – Google spreadsheet] chain. The detailed steps of the web connection setup can be found on [12]. Data from all sensors were captured and uploaded online at a rate of one set per minute. The Google spreadsheet was shared between the research team and farm owner.



(a) Connections for temperature sensor



(b) Connections for DO sensor



(c) Connections for pH sensor.
Figure 5: Connections from the different sensors to the Arduino board.

Beside the Google spreadsheet, data were monitored in-situ via a 16×2 LCD. The connections of the LCD to the Arduino are illustrated in Figure 6. Again, the Arduino code of the Wi-Fi shield was obtained from the manufacturer's website [14], whereas the LCD code is built-in the Arduino compiler. A display like this is necessary because farmers usually depend on wall-mounted display rather than an online system.

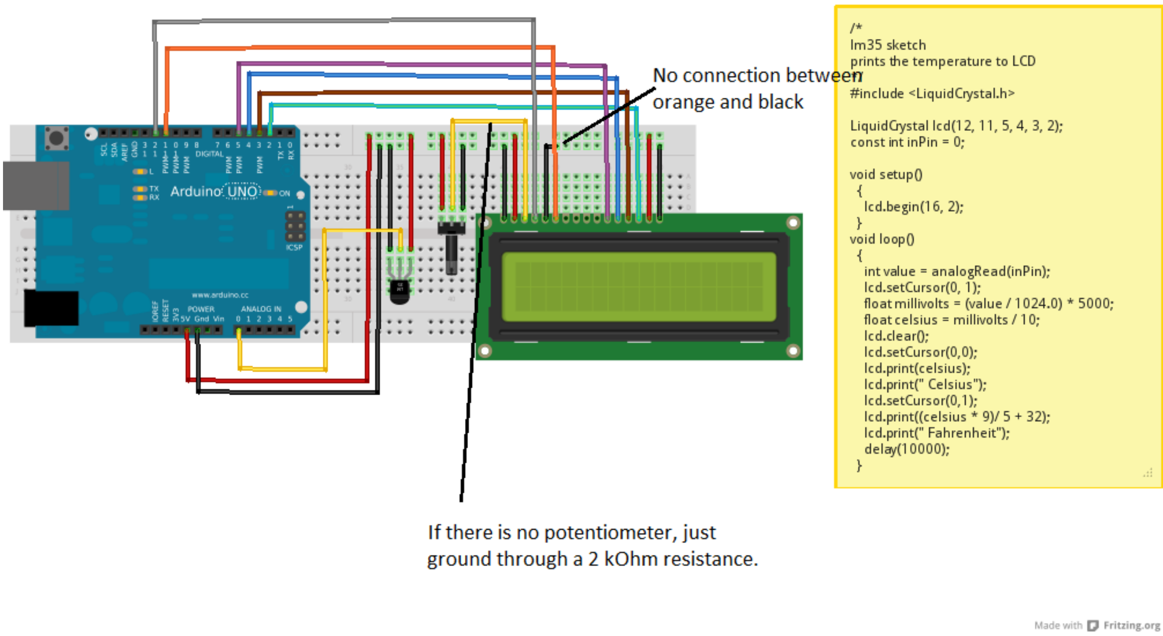


Figure 6: Connections of the LCD to the Arduino board.

3. Results and Conclusions

The researcher team met the farmer a few times to design an appropriate system and based on the conditions and requirement. A proper pump house was built where most of the devices are stored. An underground crossing from the pond to the creek was also built. This underground crossing is important because it houses a few pipes for water supply from the creek, excess water discharge back to the creek and electrical supply to the submersible pump. The pump house and the manhole serving the underground pipe is shown in Figure 7.

(a) Pump house

(b) Manhole serving underground pipes

Figure 7: Physical installation of the fish automation and monitoring

Figure 8 shows actual acrylic container which houses the Arduino board, Wi-Fi shield, relay, sensor boards and the display. To the left, there is a fan, to ensure the temperature does not go out of control within the container. The first and second readings (top line) are atmospheric and water temperature i.e. T_a = 27.7 ºC and T_w=29.7 ºC. This picture was taken at about 6pm, where the ambient temperature has dropped but the water temperature is still high. The bottom line shows DO and pH level at 9.52PPM and 6.03.

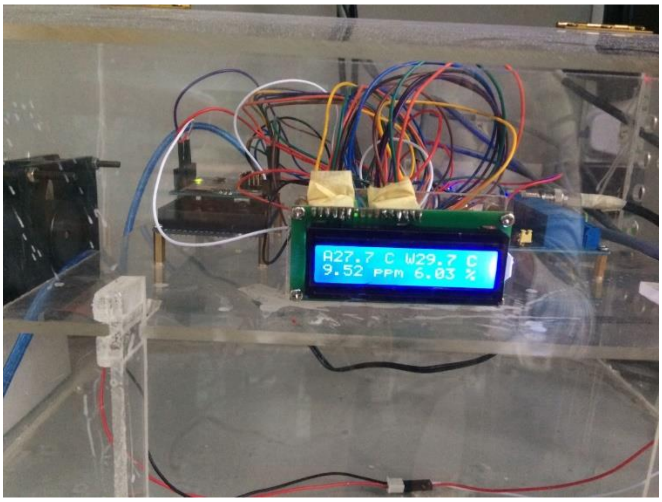


Figure 8: Actual installation and sample reading on display

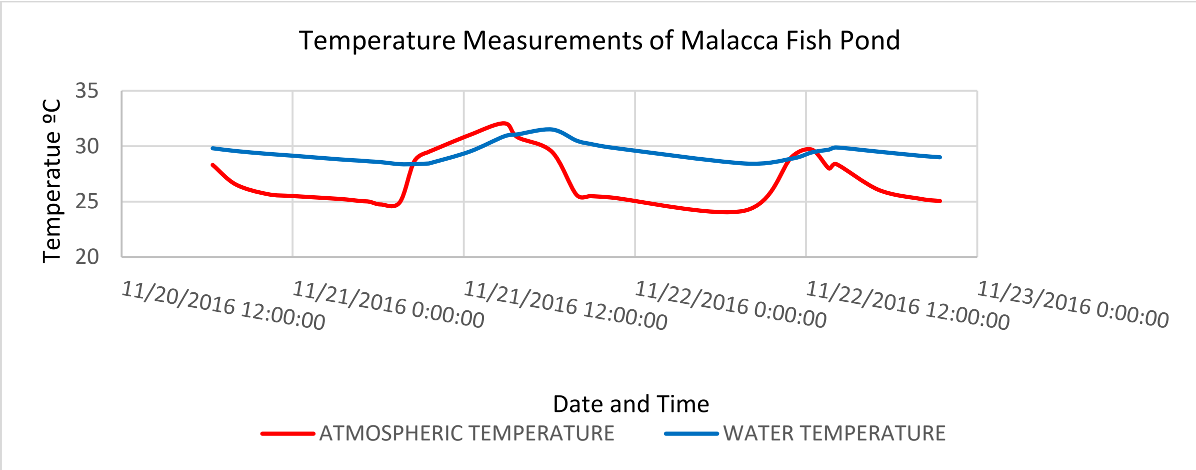


Figure 9: Temperature Measurements of Malacca Fish Pond

Figure 9 shows the water temperature and ambient temperature. This data was collected in November 2016, where the North East Monsoon is about to start. The water temperature is high with a mean of approximately 30 ºC. The ambient temperature fluctuated bigger with a maximum +/- 3 ºC from its mean, slightly bigger but similar to [8]. It seems that the pond temperature responded to ambient temperature a slow pace with a small lag.

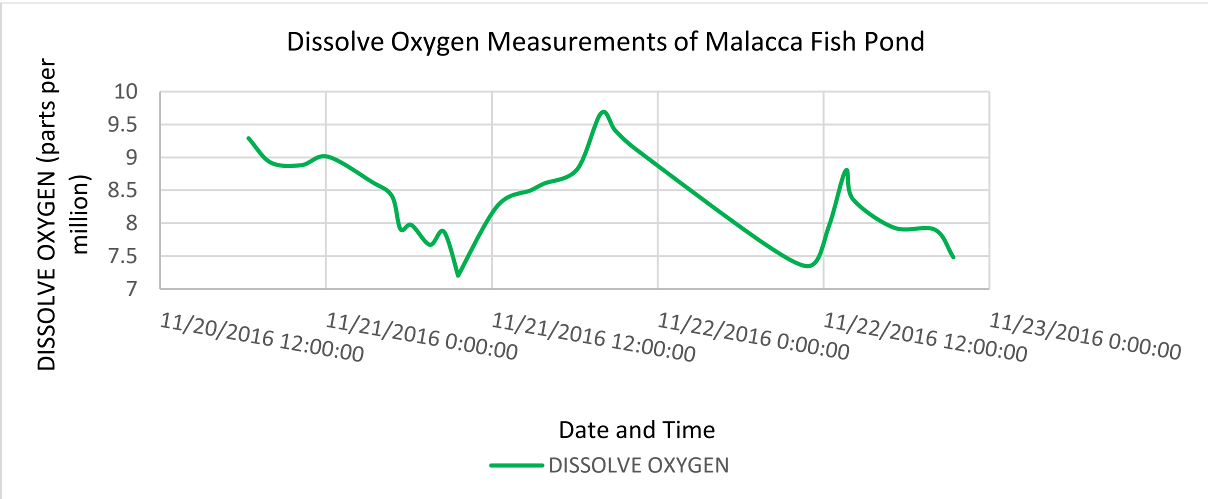


Figure 10: Dissolve Oxygen (DO) Measurements of Malacca Fish Pond

Figure 10 shows the DO levels for the two-day measurements. The fluctuation is relatively high 7-9.5 mg/L or PPM. The DO levels follow the sun cycle, confirming previous study [6] where pond produces oxygen via photosynthesis by phytoplankton, when there is direct sunlight.

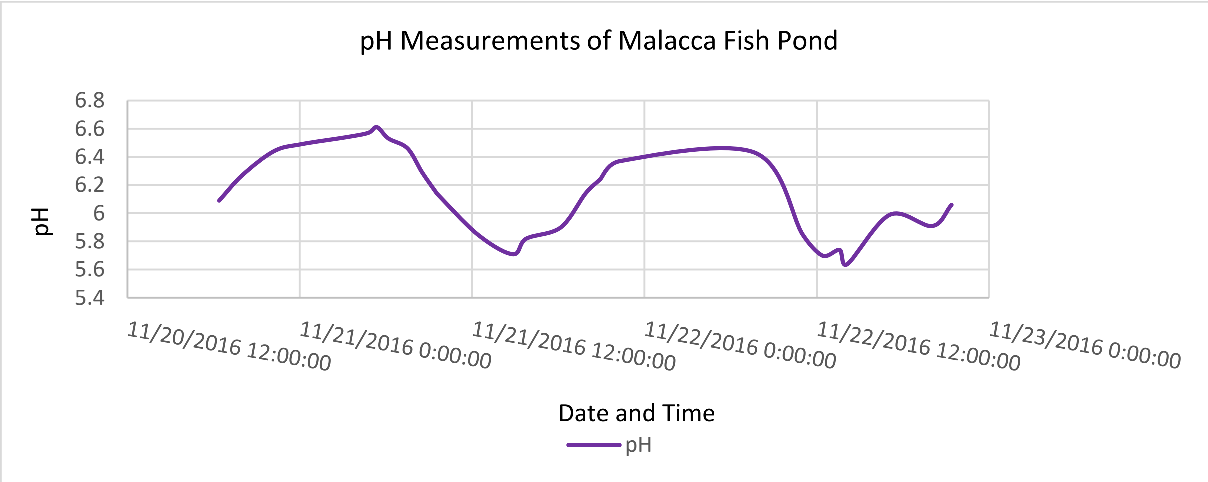


Figure 11: pH Measurements of Malacca Fish Pond

Figure 11 shows the pH measurement for the 2 days. It follows the daily cycle, the photosynthesis process by phytoplankton consume carbon dioxide (CO_2), driving down the pH level at noon. Figure 9-11 show that these important parameters are well within the good conditions for aquaculture shown in Table 3. The material costs for the Arduino boards, circuits, Wi-fi, relay are within RM1000, most of the costs went to construction of infrastructure and pumps. With the very minimum costs like this, farmers are able to monitor and automate their pond more efficiently.

This project has become a reference for ongoing capstone/design projects and final year projects (FYP) for the authors. The industry-extensive involvements especially both at the design/requirement and installation stages provide students a lot of experience dealing with industrial requirements. The involvements of researchers in the industry such as this will help the long-term aim of the country towards modernization [17].

Acknowledgements

The researchers would like to express gratitude for the Public-Private Research Network (PPRN) grant 100/IRMI/GOV/ 16/6/2, owner Mr. Omar Md. Diah and the Ministry of Education for providing the Exploratory Research grant ERGS/1/2013/TK01/UKM/03/2.

References

[1] The State of World Fisheries and Aquaculture (2016). Food and Agriculture Organization of the United Nations.
[2] Ahmad, A. T., Salim, K., Ean, C. P., Isa, M. M., & Fong, L. C. (2003). An overview of the socio-economic status of fisheries in Malaysia. Fisheries Research Institute, 11960.
[3] Mazuki, H. (2015). Industry and Market Status of Tilapia in Malaysia, 4th International Trade and Technical Conference And Exposition on Tilapia (Tilapia 2015).
[4] Yusof M., Presentation, Program National Key Economic Areas (NKEA) on Agriculture, Fisheries Department of Malaysia, Downloaded on 15 Feb. 2017. http://etp.pemandu.gov.my/upload/NKEA_Agriculture.pdf
[5] ETP Annual Report (2014) on Agriculture, The Ministry of Agriculture and Agro-Based Industry, Downloaded on 21 Feb. 2017. http://etp.pemandu.gov.my/annualreport2014/upload/13_NKEA11_ENG_Agriculture.pdf
[6] PHILMINAQ (Mitigating impact from aquaculture in the Phillippines), 2008. Water Quality Criteria and Standards for Freshwater and Marine Aquaculture, Marine Science Institute, Univ. of the Philippines, downloaded on 21 Feb. 2017,

http://aquaculture.asia/files/PMNQ%20WQ%20standard%202.pdf
[7] National Water Quality Standards For Malaysia (2008), downloaded on 21 Feb. 2017, http://www.wepa-db.net/policies/law/malaysia/eq_surface.htm
[8] Kutty, M. N. (1987). Site selection for aquaculture: physical features of water, Nigerian Institute for Oceanography and Marine Research, Food and Agriclture Organization of The United Nations. Downloaded on 21 Feb. 2017, http://www.fao.org/documents/en/detail/69895/
[9] Harun Z., Reda, E. and Zulkifli, R. (2017). Buoyancy effect on atmospheric surface layer: measurements from the East Coast of Malaysia, IOP Conference Series.
[10] https://www.milesburton.com/Dallas_Temperature_Control_Library
[11] https://www.dfrobot.com/wiki/index.php/Analog_pH_Meter_Pro_SKU:SEN0169
[12] http://www.atlas-scientific.com/product_pages/circuits/ezo_do.html
[13] http://www.instructables.com/id/Post-to-Google-Docs-with-Arduino/
[14] http://cytron.com.my/p-shield-esp-wifi
[15] Water Research Center website, downloaded 21 Feb. 2017, http://www.water-research.net/index.php/dissovled-oxygen-in-water
[16] Somerville, C., Cohen, M., Pantanella, E., Stankus, A. & Lovatelli, A. (2014). Small-scale aquaponic food production. Integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Paper No. 589. Rome, FAO.
[17] Harun, Z., Khamis, N. K., Isa, M. D., Mohamed, Z. and Hashim, H. (2013). The roles of professional engineers at the institutions of higher learning in nation-building, International Education Studies, vol. 6(6), 137.