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Solar Cells Powered to Boat for Water Quality Monitoring of Nonghan River using Wireless Sensor

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Abstract

This research aims to study the most appropriate model design for a wireless water quality monitoring machine (a buoy-format), as well as a WLAN data transmission setup. The machine is to be capable of monitoring water quality in 4 parameters: Dissolved Oxygen (DO) level, temperature, turbidity, and pH level. Four locations were employed for the experiment: 1) The merging intersection pond of water in the front of The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus; an agricultural experimental site and recreational park, 2) a canal at Ban Nong Bua Yai municipality; a communal stream of water running through the community, 3) Sakon Nakhon City Wastewater Treatment Facility, and 4) Nam Phung Dam; right before the water merges into the Nong Han Lake, the water is a source for local agriculture, livestock, in-season rice planting, and fishery. This model design of the buoy allows for the maximum net weight of 52.65 kilograms and the capability of moving at a maximum speed of 40 km/h. The machine is controlled wirelessly via a smartphone using the Blynk application; an Internet-of-Things platform (IoT), the navigation and control of the buoy are powered by NodeMCU ESP8266 WiFi controller board. Data is stored in Firebase Cloud Firestore. Information is shown in real-time in the dashboard interface.

Keywords: solar cells power; water quality; wireless sensor

1. Introduction

Nong Han Lake, Sakon Nakhon is the largest lake in Northeastern Thailand, and the second largest in the country. The lake takes up 77,000 rai (~125.2 km^2) in area, with depths ranging from 2 to 10 meters, with average water storage of 200 million m^3. In 2009, The Pollution Control Department proceeded to monitor the water quality of the Nong Han Lake; the result was declining water quality caused by wastewater released from the community [1] of which broke down to 200 liter per person of daily waste. The point sources of these pollutions included the surrounding neighborhoods, car and motor service places, hotels, schools, restaurants, commercial budlings, laundromats, etc. In some neighborhoods, the sewage system was completely lacking, and in some parts, while had sewage system, lacked wastewater management; resulting in wastewater ultimately being released into the Nong Han Lake untreated. These neighborhoods included Nong Han Luang and Huai Mong [2] therefore, careful monitoring was of great importance to assess the current condition of the waters and the possibilities these variables could lead to in the future. Monitoring these waters will allow researchers to access data necessary to better manage the incoming wastewater, treat the current wastewater issues, and proactively prevent possible negative irreversible changes to the lake that may harm the people who live off its water.

According to Section 32 of the National Environmental Quality Act B.E. 1992, The National Environment Board acts as the main authority that governs the country's environment and keeps them in condition. For Water Quality Index (WQI), there are 5 parameters to be taken into consideration; 1) Dissolved Oxygen (DO) level, 2) Biochemical Oxygen Demand (BOD), 2) Total Coliform Bacteria (TCB), 4) Fecal Coliform Bacteria (FCB), 5) Ammonia-Nitrogen (NH3) level. A 2011 study experimented with wireless CO2 data collection using a WLAN-based technology with a wireless sensor network, as well as another CO2 sensor. 3 sites were experimented using the same setup: 1) Roof of Forest; 3 sensor nodes were deployed, 2 nodes set to monitor CO2, another as a repeater, 2) Roof of Information Institute; 3 sensor nodes were deployed, 1 node-set to monitor CO2, 1 node-set as a repeater, 1 node-set as the base station, and 3) The Purple Mountain, 1 sensor node was deployed; set to monitor CO2. [4] The advantage of this experimental design is enhanced accuracy in monitoring and collecting the data due to the sheer amount of sensor nodes and the multiple locations the systems were deployed; the roof of forest, the roof of Information Institute, and the Purple Mountain, all of them of various kinds of terrain, suitable for data comparison. The disadvantage of this experimental design is that it is a very demanding project. CO2 monitoring requires the user to have at least 1 computer and the JAVA program to process the data. The process is very expensive to set up and the data produced is not the most user-friendly. There were 3 sets of incoming data, but none was labeled as to the location a transmission came from, or from which sensor was picking up data. The monotonal graph also did not help. Another experiment was also performed. A similar WLAN module was employed to remotely monitor water quality in a fish farm. The main objective of this experiment was to predict the water quality in hopes of reducing possible future risks. The water was checked periodically every 30 minutes. The system is a combination of CDMA and VPN that split-operated into 2 parts: 1) Remote Monitoring Platform (RMP) and 2) Central Monitoring Platform (CMP). RMP is responsible for 4 parameters; 1) pH level, 2) DO, 3) Salinity, and 4) Temperature. All of the sensors transmitted analog 4-20mA outputs. The machine was also connected to external devices such as a pump and a valve as well, all of which can be operated via a microcontroller unit (MCU). The MCU allowed the pump and valve to pump up water samples to run tests; of which its data was collected and transmitted to a server via CDMA. That data was then forwarded to CMP for analysis. If the results were to come out below the set benchmark, the system would send a notification to an administrator so someone can be sent to rectify the issues [5]. Back data, as well as Error Reports were stored by dates in the in-house database that was made accessible for administrator(s). The administrator(s) would have the ability to download real-time data from the webpage. The advantage of this experimental design is that the machine itself is much more well-rounded, in comparison to ones from previous studies, in terms of remote controlling of the water pump and valve, a much more well-organized approach in data collection and storage (categorized by dates, months, and years), as well as more in-depth insights of the data. The disadvantages include inadequate displaying of certain details such as the infographics. The administrator couldn't make out the readings of the temperature from the pH level due to the colorways.

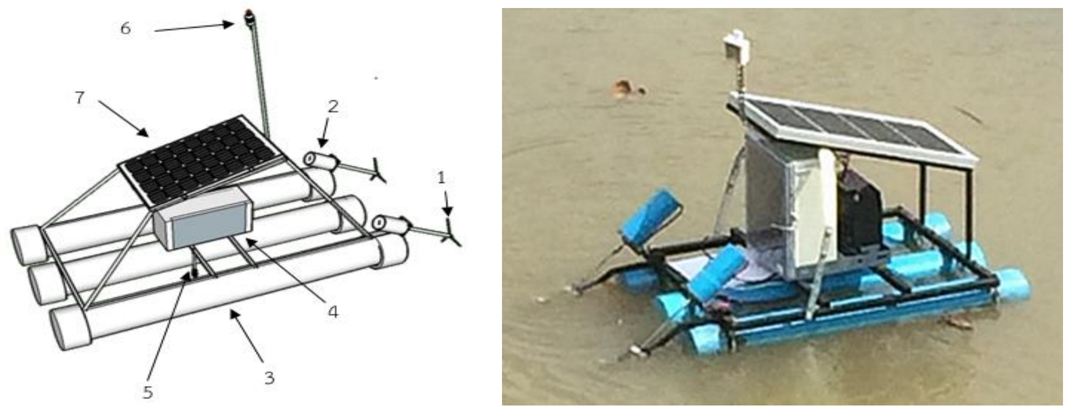
2. Materials and methods

This research experiment aims to develop a prototype for a wireless water quality monitoring buoy for the Nong Han Lake. The experiment includes: 1) experiment and study frameworks, 2) the buoy design, 3) the navigation system design for the buoy, 4) WLAN inputs and outputs, and 5) User Interface (UI) design.

1. Experiment and Study Frameworks

The goal is to produce a monitoring system for water quality of the Nong Han Lake and collect data necessary for analyses needed to keep the water in optimal conditions. The design of this buoy is to be installed above water surface, able to produce inputs and outputs wirelessly and is smartphone compatible. The buoy houses numerous sensors including turbidity sensors, temperature sensors, and pH level sensors. These sensors read the water components and wirelessly relay the data to the node station; once the node station receives the data, it then sends the data wirelessly (via GSM) to the platform (application) available on the smartphone for real-time display.

2. The Buoy Design



(a) (b)

Fig. 1 (a) Rendered image of the buoy design (b) The Buoy

Fig. 1 is the model used for this research, the parts include; 1) buoy propeller, 2) 12V direct current motor (rotation 800 rpm), 3) 3-inch PVC pipe as base, 4) housing box for navigation and system transmission modules, 5) pH level sensor probe, 6) light indicator, and 7) 20W solar panel for power source. Fig. 1(b) displays the buoy in practical setting.

2.1 Buoyant Force

As the buoy must stay afloat on the water surface, the researcher has to take into consideration the eventual buoyant force required to keep the buoy from sinking due to its weight. The weight of the buoy is broken down into 2 parts: 1) the high-density polyethylene (HDPE) PVP pip base that is in contact with the water, and 2) the other part that is not in contact with water. The calculation must provide enough to support overall weight and keep the whole thing from sinking with the PVC base barely immersed under the water surface [3]

$$F_B = \rho_{water} \times V_{dip} \times g \qquad (1)$$

$F_B = \rho_{water} \times V_{dip} \times g$ is the formula for finding buoyant force (F_b) that is exerted from; 1) fluid density (ρ_{water}) in gram per cubic meter (1g/cm^3), 2) Earth's gravitational force (9.8 m/s^2), and 3) fluid volume V_{dip} versus volume of displacing object (V_{air}), the latter of which is findable using

$$\sum M_B + (\rho_{pvc} \times V_{pvc(total)}) + (\rho_{air} \times V_{air}) = \rho_{water} \times V_{dip} \qquad (2)$$

Therefore the formula $\sum M_B + (\rho_{pvc} \times V_{pvc(total)}) + (\rho_{air} \times V_{air}) = \rho_{water} \times V_{dip}$ is used to find the overall weight of the buoy. There is 950 kg/m^3 for ρ_{pvc} , 1.2kg/m^3 for ρ_{air} , and if $V_{air} \approx V_{dip}$, the calculation would be:

$$V_{dip} = \frac{\sum M_B + (\rho_{PVC} \times V_{PVC(total)})}{(\rho_{water} - \rho_{air})} \qquad (3)$$

$$V_{PVC(total)} = V_{PVC1} + V_{PVC2} + V_{PVC3} ,$$

$$V_{PVC1} = V_{PVC3} = \pi(R^2 L - r^2 l) ,$$

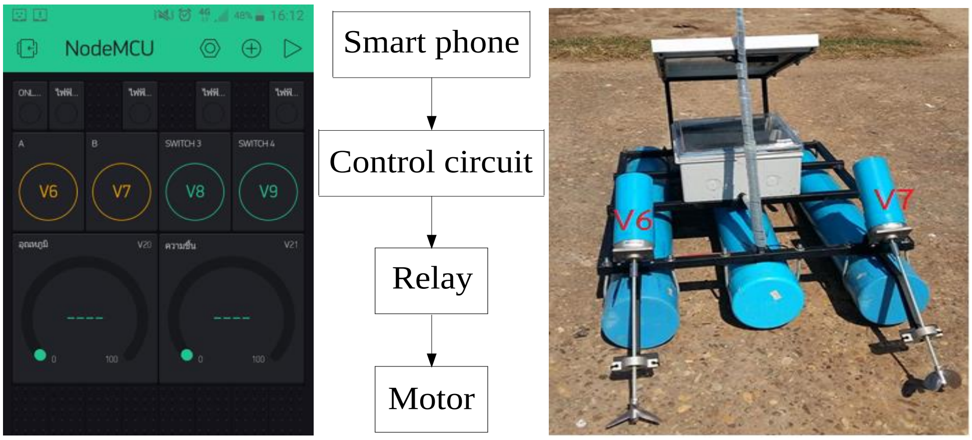
$$V_{PVC2} = \frac{\pi h}{4}(D_N^2 - D_n^2)$$

$$V_{PVC(total)} = 2\pi(R^2 L - r^2 l) + \frac{\pi h}{4}(D_N^2 - D_n^2) \qquad (4)$$

If V_{PVC1}, V_{PVC2} and V_{PVC3} were to represent the value of density for the PVC pipe base for site 1, 2 and 3, and the values of parameters R , r , L , h D_N and D_n were to be as depicted in Figure 1, the result of buoyant force (F_B) for this buoy model equals to 516.45N (F_B = 516.45 N), therefore the maximum weight of the buoy is 52.65 kg

2.2 The Navigation System of the Buoy

As seen in Figure 2 below, the control of this buoy is powered by an application Blynk; of which runs on smartphones. The processing unit of the buoy requires a WIFI module (NodeMCU ESP8266 model was used) for Blynk to detect and operate the buoy. Once the Blynk application is launched, the User Interface (UI) will display a control panel as well as a navigation panel, from this interface the user has access in navigation of the buoy. The control is completely remote and wireless as it uses WiFi signal transmissions between the smartphone (built-in WiFi module) and the WiFi module in the buoy (NodeMCU ESP8266). The correspondence from the buoy end is handled by a chip that uses AT Command firmware, which then relays a response towards the motor. The motor responds to that information by activating the propellers. The user can control when to start and stop the motor.



(a) (b) (c)

Fig.2 Navigation System of the Buoy, (a) Blynk UI, (b) Blynk Control Sequences, (c) The Motor(s).

In Fig. 2 displays the prototype of the water quality monitor buoy deployed to monitor the water quality of the Nong Han Lake. The buoy dimension is 100 cm (H), 55 cm (W), and 85 cm (L), with 21 kg of overall weight. In the front has a red-light indicator, 12V direct current motors are located in the back side; both of which powers the propellers that navigate the movement of the buoy. In the middle locates a box that houses the rest of the electronics, which include: 2 set of circuits, 1) the navigation system, and 2) the monitoring unit that tests pH level, turbidity, temperature and DO (dissolved oxygen) level, as well as a powering unit of a 12V charger and battery that distributes electricity for all the electronics on the buoy.

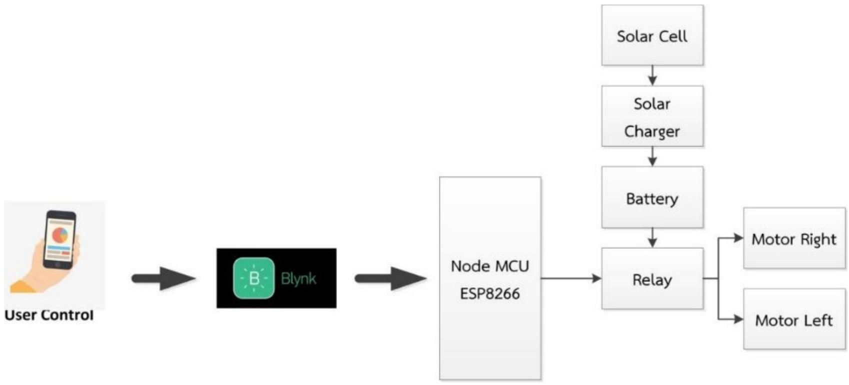


Fig.3 The Outline of the Buoy Control System

2.3 The Control System Flow

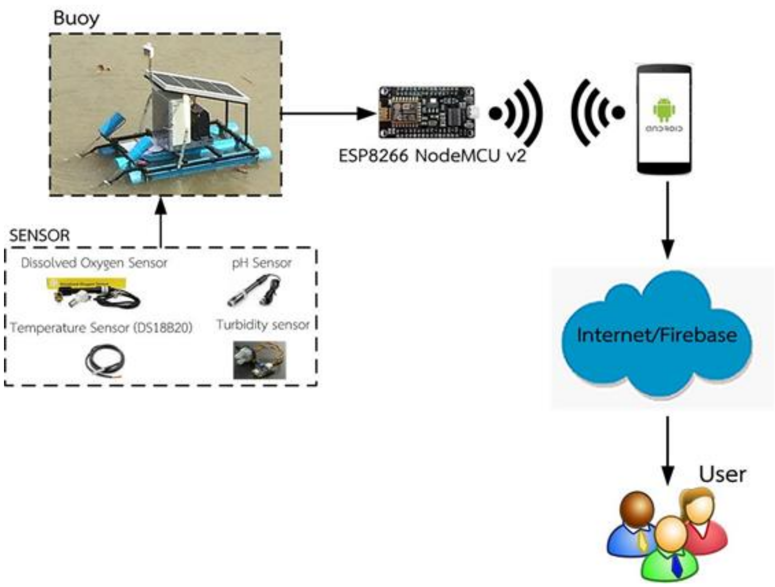


Fig.4 The Flowchart of the Nong Han Lake Water Quality Monitor Buoy Control System

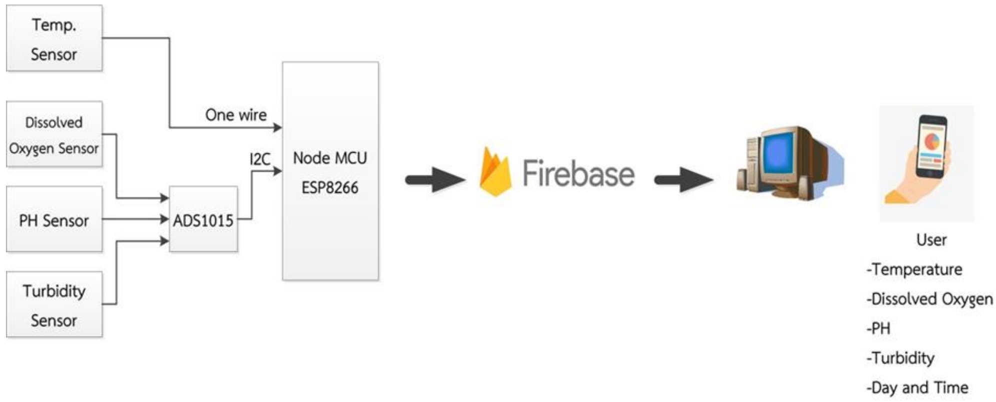


Fig. 5 The Transmissions and Data Storage and Display Layout

Fig. 4 and Fig. 5 show how the system runs in order to collect data of 4 parameters 1) pH level, 2) turbidity, 3) temperature, and 4) DO level. The system then relays the data as inputs to the Node MCU ESP8266 WiFi microcontroller module so the Blynk application can detect that data (powered by Arduino IDE), the Node MCU microcontroller then stores this data in Firebase Cloud Firestore; of which operates as the main NoSQL document database. The database archives data in the formats of map <key, value>, and the values can be set to text, number, Boolean, lists or maps. The user has access to real-time display of the collected data on the application dashboard, which is powered by efinMobile application. The frequency of updates is based on the preassigned algorithm.

3. Results and Discussion

This research and its experiment aimed to study and invent a prototype of a wireless, autonomous, and cloud-based water quality monitoring machine. The machine is to be in a buoy format and tests the water quality in 4 sites; which were 1) the merging intersection where the Nong Han waters come in The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus (the front of the site); of which is mainly used for agricultural purposes, 2) at a canal where foreign water flows in and enters the Nong Han Lake at Ban Nong Bua Yai municipality; a communal water source, 3) a wastewater treatment facility that treats the water before letting it flow into the Nong Han Lake at Sakon Nakhon City Wastewater Treatment Facility, and 4) Nam Phung dam; right before the water merges into the Nong Han Lake, the water is a source for local agriculture, livestock, in-season rice planting, and fishery.

1. The Prototype Monitor Buoy and Data Transmissions

This prototype is a design developed further from a previous model (K Chaarmart, 2017). This model adds more sensors as well as upgrading from a ZigBee microcontroller to the Node MCU ESP8266 WiFi module. This new model now has new maximum weight at 52.65 kg (the buoy of this research weighs only at 21 kg) and can travel up to 40 kph in stagnant water. The control and navigation are accessible via a smartphone using Blynk application. Transmissions are handled by the Node MCU ESP8266 WiFi microcontroller module as it is capable of IEEE 802.11b/g/n. The module facilitates in data transfers from the buoy to the Blynk application using the internet that it connects to via SmartConfig. SmartCofig allows the Nod MCU ESP8266 microcontroller to act as the access point; meaning the user to not having to provide SSID (username of WiFi) and the WiFi password up on installation. This allows for better troubleshooting, mode-switching and updates compared to the previous model that required username and password every time. The administrator can also toggle between different modes wirelessly from the smartphone, as well as system reboot as the buoy now does not require a hard-reset button after switching to a new mode. Remote navigation distance is now up to 80-meter range (without obstructions); however, in the range of 70-80 meters, inconsistency emerged. In the 90-meter range and over, disconnects emerged due to range limits.

Fig. 6 Wireless Monitor Buoy Prototype

Table 1 Navigation Test Results (Wireless/Remote Control)

Directions	Distance (m)	Movement	Relay Time (sec)
	10	Forward	
	20	Forward	
	30	Forward	
Forward	40	Forward	
Left Turn	50	Forward	
Right Turn	60	Forward	10-20
	70	Inconsistent control	20-25
	80	Inconsistent control	20-30
	90	Disconnected	
	100	Disconnected	

2. Nong Han Lake Water Quality Test Results

2.1 The merging intersection where the Nong Han waters come in a pond in the front of The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus

Fig. 7 Site 1. The merging intersection where the Nong Han waters come in The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus. Source of water for agricultural purposes.

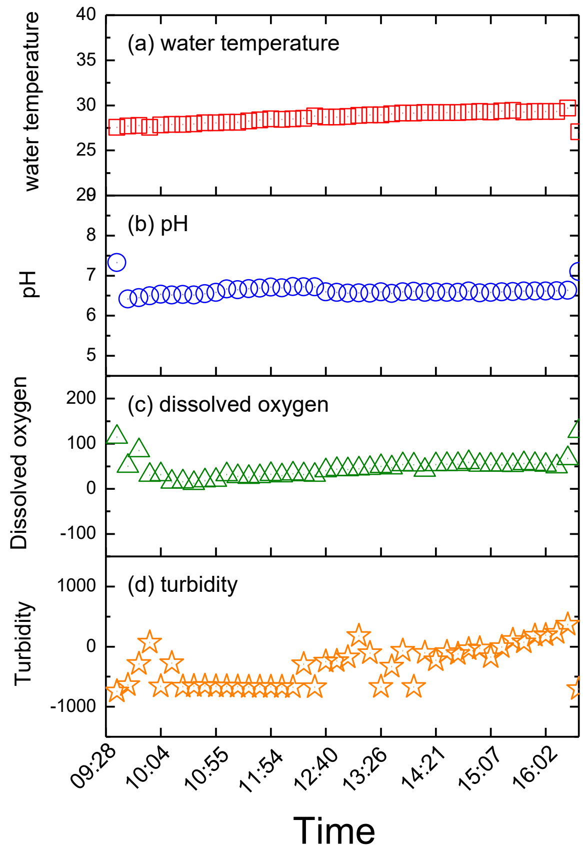


Fig. 8 Data collected from Site 1: The intersection pond in front of the Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus.

Date: August 5, 2019.

From the data of temperature, pH level, DO level, and turbidity of Site 1 The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus, collected on August 5, 2019, from 09.28 AM – 04.35 PM. Table 4.2 showed that the intersection where the Nong Han water comes in, there was a slow increase in temperature from 09.28 AM to 04.20 PM. After that, the temperature dropped to the average range of 27.56 Celsius to 29.68 Celsius. The pH level averaged at 6.62; considered slightly below average (average pH level is 6.8-7.3), meaning the water was leaning towards being too acidic (corrosive water). DO level was high and increased over time. Turbidity is very high. Theses finding were then illustrated in a graph format and then stored to be retrieved later when necessary.

2.2 An intersecting canal at Ban Nong Bua Yai municipality, Sakon Nakhon

This site is a natural canal channeling a flow from Huai Sai lake and cuts through Sakonnakhon Technical College. The canal also stretches past Sakonnakhon Rajabhat University, Na Weng Market; passing by the local agricultural sites and another shopping mall (Robinson), amounting waste along the way before eventually merges into the Nong Han Lake. See the coordinate and picture in Fig. 9 below.

Fig. 9 Site 2. A communal canal (Khlong Ka-pod) at Nong Bua Yai neighborhood, Mueang Sakon Nakhon.

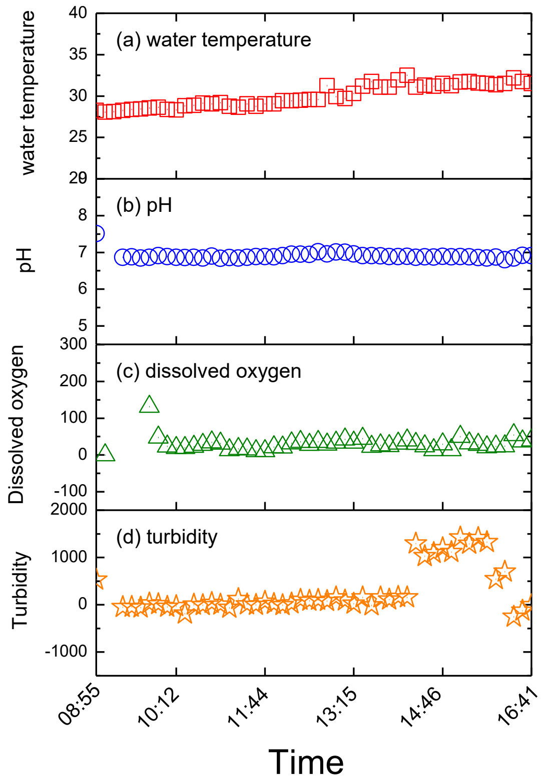


Fig. 10 Data collected at Site 2 on August 6, 2019.

On August 6, 2019, data collection began at 08.55 AM and concluded at 04.41 PM. Table 4.3 shows that there was a slight increase in temperature from 08.55 AM to 04.08 PM, and after that the temperature started to drop. Water temperature ranged from 28.25 Celsius to 32.18 Celsius, with peak at 32.18 Celsius at 04.18 PM. The water pH level averaged at 6.9; which is considered to be relatively balanced (6.8-7.3). The DO level was very high and consistent throughout the day. The turbidity was also high but lower than Site 1.

2.3 Sakon Nakhon City Wastewater Treatment Facility is a facility that treats the incoming waters before letting them merge into the Nong Han Lake at Srinagarindra Park.

Fig. 11 Data Collection at Site 3 on August 7, 2019. Sakon Nakhon City Wastewater Treatment Facility.

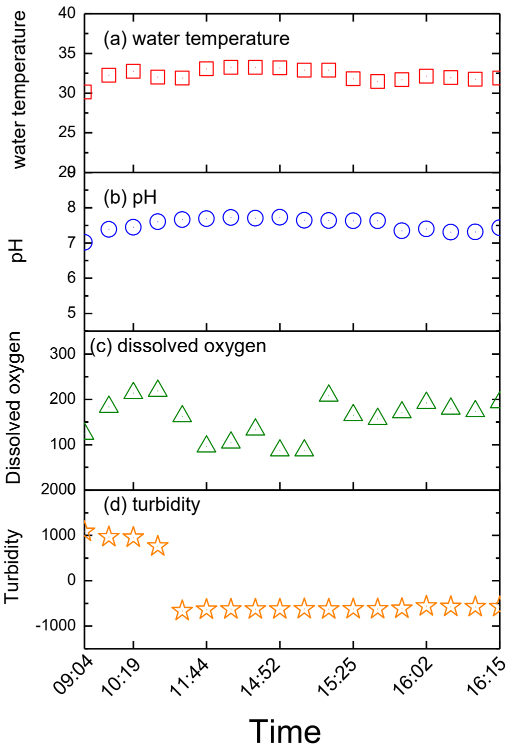


Fig. 12 Data collected from Site 3 on August 7, 2019. Sakon Nakhon City Wastewater Treatment Facility.

On August 7, 2019. Data collection started from 09.04 AM to 04.57 PM. As shown in Table 4.4, the water temperature was relatively high and remained constant throughout the collection period. The temperature range was 30.12 Celsius to 33.25 Celsius. The pH level was relatively consistent throughout the collection period and was leaning towards the more basic side (7.51). The DO level was very high, as well as the turbidity of water.

2.4 Nam Phung Dam at Ban Don Yang, Lao Po Daeng sub-district, Mueang Sakon Nakhon. The waters here were mostly for agriculture and fishery. It also served as a habitat for the fishes for mating, nesting as well as laying eggs, especially for the spawning season.

Fig. 13 Data collection at Site 4 on August 8, 2019. Nam Phung Dam at Ban Don Yang, Lao Po Daeng, Mueang Sakon Nakhon.

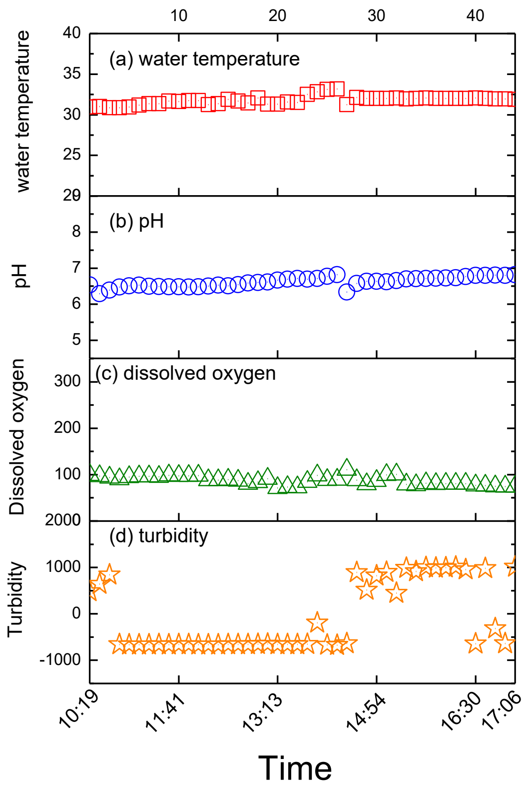


Fig.14 Data collected at Site 4 on August 8, 2019. Nam Phung Dam, Ban Don Yang, Lao Po Daeng, Mueang Sakon Nakhon.

4. Conclusion

The research is consisted of a design of a prototype model of a wireless water quality monitoring machine. The final design ended up with a buoy format that houses sensors that can collect water samples, analyze the water composition, and then the information would then be stored in a cloud-based storage space. The water samples were tested for 4 parameters: 1) temperature, 2) pH level, 3) Dissolved Oxygen (DO) level, and 4) turbidity.

The pre-experimental test runs revealed some limitations of this monitor buoy design. The buoy can be operated remotely at maximum distance of 80 meters while maintaining accurate and consistent performance in navigation. The battery and the solar panel were sufficient source of electricity for full-day operation.

The monitoring buoys were deployed at 4 data collection sites: 1) The Front of The Lotus Park at Kasetsart University Chalermphrakiat Sakon Nakhon Province Campus; an agricultural experimental cite and recreational park, 2) a canal at Ban Nong Bua Yai municipality; a communal stream of water running through the community, 3) Sakon Nakhon City Wastewater Treatment Facility, and 4) Nam Phung Dam; right before the water merges into the Nong Han Lake, the water is a source for local agriculture, livestock, in-season rice planting, and fishery. The data collected via the sensors used for the monitor buoy came out to be reliable. These findings, along with the use of call-back database are deemed significant in water quality prediction, which can be vital in aquatic biome preservation, as well as to study about possible environmental impacts.

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