Sustainable Surface Water Dissolved Oxygen Monitoring at Lake 7/1F, Shah Alam, Selangor

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ABSTRACT

Shah Alam is in Selangor, Malaysia and symbolized with several lakes that are popular among local communities and visitors for leisure and recreational activities. Among of these lakes, few lakes need management to look after its hygienic and well-being to serve its purpose as the recreational lake for the nearby community, such as Lake 7/1F, Shah Alam, Selangor. The secluded location of this water reservoir has made it unpopular, and improper management of it could invite an imbalance environment to its surrounding. Therefore, to initiate the effort, an Internet-of-Thing (IoT) water monitoring system is deployed at this lake to study the dissolved oxygen (DO) level in the water that could indicate the health status of this lake. The system consists of a DO sensor, embedded controller, self-charging power supply, wireless data transmission, and IoT dashboard for in-situ DO measurement. From the analysis, the lake has the normal cycle of DO production, but a

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dangerous condition is detected when the concentrated DO in the lake water is mostly below the saturation value.

Keywords: *Water Quality; Surface Water; Dissolved Oxygen; IoT System; Lake Water*

Introduction

Recreational lakes are becoming increasingly popular with local communities for leisure and social activities. Shah Alam is a city and the state capital of Selangor, Malaysia and was the first planned city in this country after the Independence Day in 1957. This well-designed plan has set up a few recreational areas in a walking distance from surrounding residential areas, such as catchment ponds and artificial lakes. Furthermore, the presence of well-developed parks with ponds and lakes has a positive impact on the perception of the historical, cultural, environmental, and recreational functions that can surely develop the domestic and international tourism [1]. On top of that, these lakes' aquatic systems can improve the urban microclimate problem by absorbing solid pollutants, increasing air humidity, and reducing the adverse thermal radiation during the hot season [2-3]. Besides, with these aesthetic and scenic values, they are enticing the attractive water resources, which are capitalized into property prices [4-5].

However, climate change and rapid developments around the lake have modified the ecological character of the lake. Climate change affects the levels of dissolved oxygen level and aquatic species in lake water. With the increase in surface water temperature, the concentration of dissolved oxygen in the water decreased [6]. The prolonged dry season also reduces the volume of lake water that affects the health of Urmia Lake, Iran. When the climate has changed the character of this lake water over the last few decades, its use for irrigation should be supplemented by other groundwater sources, further reducing the depletion of that lake [7]. There is also environmental concern regarding the relationship between nutrient runoff and biological growth, including harmful algal blooms and hypoxic conditions caused by the entry of untreated wastewater into the water, littering, and eutrophication [1,5]. If lake water cannot be self-purified, it loses its recreation and may be unfit to be used by the local communities.

The excessive presence of nitrate and phosphate in the water may invite unwanted weeds to cover the lake, which leads to the lake eutrophication. This condition can pose a threat to the public with dangerous diseases such as malaria, dengue and cholera, and other parasitic infections [1,8]. Figure 1 shows the Lake 7/1F condition with the growing weeds in the water.

Figure 1: The growing weeds on the banks of the Lake 7/1F, Shah Alam, Selangor.

The vast majority of studies included in the review suggest that the concentration of the dissolved oxygen in the lake water can determine the health of its ecosystem [6-10]. The dissolved oxygen concentration needs regular monitoring to observe any sudden and extreme changes in the data. Traditional in-situ measurements have too limited time and spatial resolution to make such a numerical model accurate. Efforts needed to use innovative tools to solve these limitations [11]. Consequently, a faster approach in monitoring the concentration of the dissolved oxygen level in the lake water is desired. Previous researchers in the literature have proposed a range of techniques. This approach incorporates two essential techniques, namely (1) in-situ measurement of the dissolved oxygen concentration, and (2) remote monitoring access. In-situ measurement is the critical element of continuously monitoring the water parameter in the lake. The sensor is attached to a self-power embedded system that contains a controller for a sustainable water monitoring system. A continuous dissolved oxygen monitoring data allow prediction on the health of the lake water and fish habitats by integrating it with the numerical analysis and prediction algorithm [6,10,11]. The changes in the dissolved oxygen concentration assessed through the computers and smartphones by using the intelligent sensor network implementation or the Internet-of-Thing (IoT) approach, which is one of the advantages of the automated monitoring system can provide to the local authorities and community. For this purpose, the system equipped with the wireless data transmission by using several IoT protocols such as Message Queue Telemetry Transport (MQTT), Hypertext Transfer Protocol (HTTP), and others [12-15] to display the monitored dissolved oxygen concentration level in the IoT dashboard. The use of IoT technology supported by the data retrieval method using sensors, embedded systems and remote communication technology can, therefore, help to simplify the assessment of lake water quality.

Research Methodology

This project developed a Buoy water monitoring to gather a broad data set of the water parameter. This system involves the design and development of the floating Water Quality Monitoring Platform, Sustainable Power Supply System, Sensor Network, IoT Mobile Dashboard & Cloud Data Storage System. This system installed at Lake 7/1F, Shah Alam, Selangor, as shown in Figure 2.

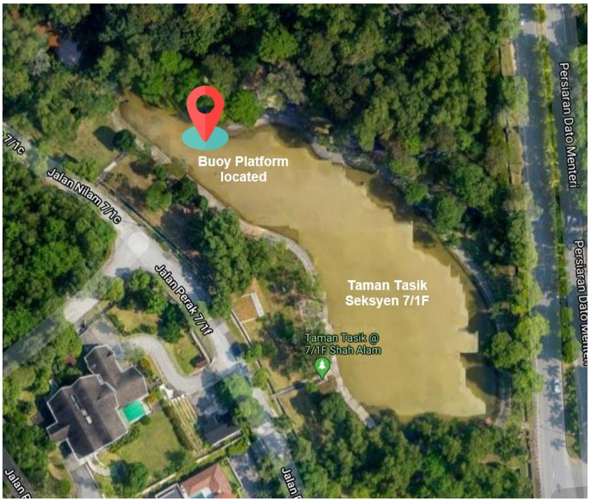

Figure 2: The research location at Lake 7/1F Shah Alam, Selangor.

Development of IoT-based water Qquality monitoring system

Five components involve in this development, namely, are the floating platform (buoy), sustainable power supply management unit, embedded controller unit, sensor network system, IoT dashboard, and physical data storage for the backup system during failure. Each component includes the mechanical and electrical/ electronic components, has been weatherproofed to be placed in the lake water. The overall architecture diagram of the system is shown in Figure 3 and Figure 4, respectively.

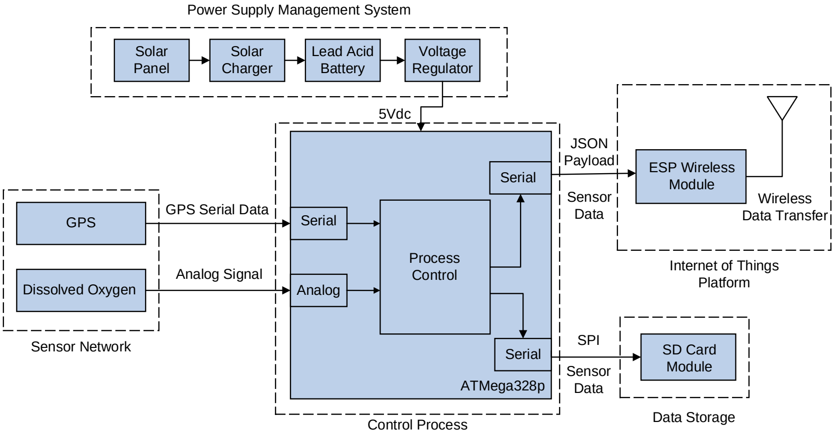

Figure 3: Block diagram of the floating water quality monitoring system.

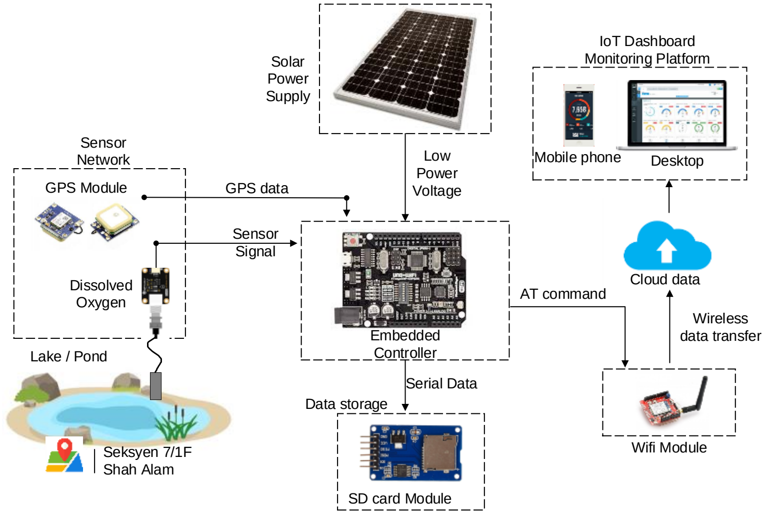

Figure 4: The architecture of the Floating Water Quality Monitoring using IoT System.

The Design of the Floating Platform for Water Monitoring System

The system used a buoy to float the water monitoring system platform on the lake while measuring the DO parameter. The size of the buoy used is approximately 750 mm outer diameter and 450 mm inner diameter with a load capacity of 14.5 kg above water, which is suitable to be used as the total weight of the water monitoring system is 4 kg as depicted in Figure 5(a). The required floating platform must then be larger than the hardware mounted on the platform. The buoy platform frame made of aluminium steel to prevent rust from occurring due to the oxidation process. An opening is made in the middle of the buoy platform to allow trouble-free water flow and exchange, and therefore, avoid the stagnant water which can interrupt the precise measurement. The buoy platform was anchored via the nylon cable on the lake to prevent it from drifting into the middle of the lake, as shown in Figure 5(b). The electrical/electronic components and sensor network are installed at this frame using the grey polycarbonate boxes fitted with a standard IP67 waterproof compliance [16]. The external dimensions of the IP67 boxes were about 300 mm (H) x 200 mm (L) x 80 mm (W) and were equipped with the stainless-steel screws to avoid corrosion. A solar panel is placed on top of the aluminium frame, as shown in Figure 5(a).

(a) (b)

Figure 5: (a) Buoy monitoring system platform, (b) The floating buoy platform in the Lake 7/1F, Shah Alam, Selangor.

Sustainable solar power supply system

The buoy platform is fitted with 1000 mm x 670 mm solar panels which mounted horizontally on the buoy platform [16]. The installed system hardware powered by a solar power supply system with 30W small solar panel, 12V solar charger, 12V 7AH lead-acid rechargeable battery and a low voltage converter [17-19]. The voltage regulator is used to supply different voltage to different components, which is 5Vdc to the embedded controller and 9Vdc to the sensor network. The solar panel is mounted facing higher solar exposure to get the optimum solar energy to charge the rechargeable battery. As an estimate, the power storage could provide enough for the entire system to operate with optimum voltage and current for 24 hours operation.

Embedded control unit

Embedded controller AtMega328p used as the central controller for this project to process all the sensor data parameters [19-20]. Appropriately, C program with Arduino IDE software used to read the analog sensor value data via the ADC at setup time intervals to digitize the required parameter value to the exact unit value. The controller also integrated with the offline data storage SD card module to gather all sensor data parameters via the Serial I2C data transfer. It is also integrated with the ESP wireless module for transmitting all the necessary parameter data to the cloud storage to the IoT dashboard platform for Big Data Analysis and data visualization [19-20]. All water parameters instantaneously and wirelessly updated in a requisite setup period, which can be monitored at anytime and anywhere by the authorized person [19].

Water sensors

The water parameter sensor network comprises two sensors, namely the DO sensor and Global Positioning System (GPS) as shown in Figure 6. The former is a sensor used to measure the chemical parameter, which is the dissolved oxygen in the water. The latter used to read the location of the water monitoring system at the lake [16, 21]. An Industrial DO sensor module used to obtain precise oxygen level information from the water [17, 22]. The DO sensor is immersed approximately 30 cm from the surface of the water, beneath the buoy platform [23]. The selected location of the sensors in the buoy is to keep them protected from shock and other problems. The integrated real-time clock (RTC) in the SD card module used to record data using pre-loaded sampling time.

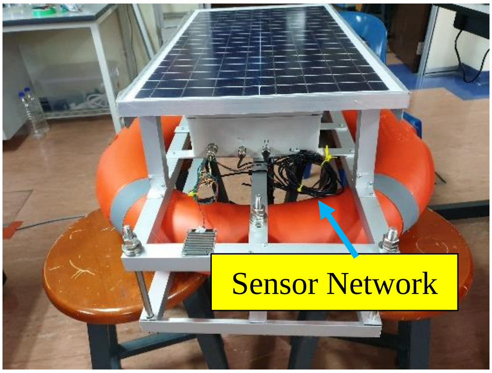

Figure 6: The sensors network.

Data storage

With the emerging of the IoT advancement nowadays, device-to-device and device-to-cloud are the two types of communication that regularly applied in this intelligent system [24]. The latter approach is the most adopted in the developed IoT-based systems for data storing and online monitoring [25]. Besides, this technology also provides a complete solution for system notification to the authorized person when unnecessary water condition occurs during the monitoring process. There are two types of data storage used to store the data obtained from the sensor network, namely the offline and online storage systems. An SD card used to store the data offline using the CSV file format through the serial 12C data transmission protocol. While on the other hand, an online data storage which using cloud storage through the MQTT protocol. These data transmitted to the IoT dashboard for real-time water monitoring system application using JSON payload data. Figure 7 shows the block diagram of the data visualization process through IoT dashboard.

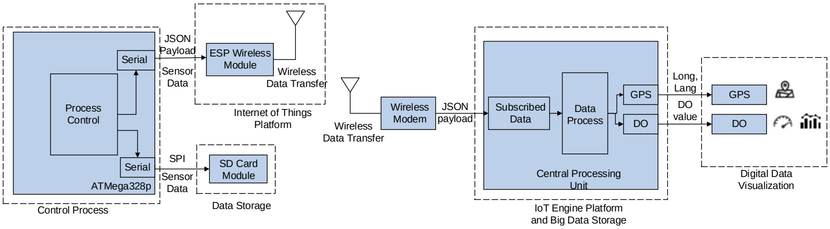

Figure 7: The IoT dashboard for data visualization.

Result and Discussion

In this section, the concentration of DO in Lake 7/1F, Shah Alam, is analyzed and summarized in Figure 8 and Figure 9. The data is sampled from 18 February 2020 to 3 March 2020 to monitor the DO concentration level pattern in this lake. Figure 8 shows the output trend obtained from the DO sensor for 24 hours. The concentration of the DO varies in the lake during the day, and night time is analyzed. The DO concentration level inclines after sunrise and approaching the noon. The minimum oxygen concentrations in the water occurred during sunrise (2.8 mg/L–3.0 mg/L) after a full respiration process by the aquatic life at night [26]. The Sediment denitrification in the sallowed vegetated lake water can also reduce the dissolved oxygen concentration, which can be the first sign of nitrogen pollution in the lake ecosystem [27]. The highest DO value of 7.11 mg/L obtained during the afternoon, around 4.40 PM. During the night, the DO level declines to 2.68 mg/L. When the DO level in the surface water is less than 5 mg/L, it indicates a distressed environment to the aquatic lives such as fish [28]. It also indicates the appearance of sediment oxygen demand (SOD) caused by the algae in the water as well [29]. This value indicates an alarming sign as growth of aquaculture will be slow due to low exposure of dissolved oxygen.

The broad range of DO value is indirectly proposing the lake has excessive algae and phytoplankton which high oxygen consumption by the photosynthetic organisms in the lake. However, more studies are needed to confirm this condition. Correlation between different parameters needs to be determined and measured for further studies. The temperature of the lake water also plays a prominent role in dissolved oxygen levels. During this monitoring period, the range of the water temperature at Lake 7/1F Shah Alam is from 29 ºC to 33 ºC, which is considered high [12]. The rain also contributes to the DO concentration level in the lake water. Figure 9 shows the scenario explained. A plausible and useful theory behind the situation is that the cloudy day affects the rate of photosynthesis by aquatic life. During the dry season, the DO concentration is higher compared to the wet season [30]. During rainy days, the highest DO concentration level at this lake ranges from 6.63 mg/L to 7.75 mg/L. Table 1 summarizes the percentage of the DO level distribution during the monitoring period. From this table, 62.4% of the DO concentration levels are below 5 mg/L, which is not a good sign for a healthy lake ecosystem. Only 2% obtain more than 8 mg/L during the peak of hot weather.

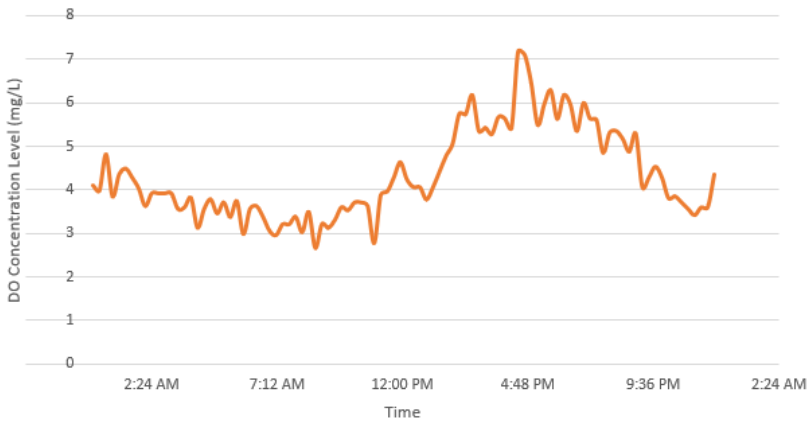

Figure 8: 24 hours DO concentration level measurement in the Lake 7/1F, Shah Alam, Selangor.

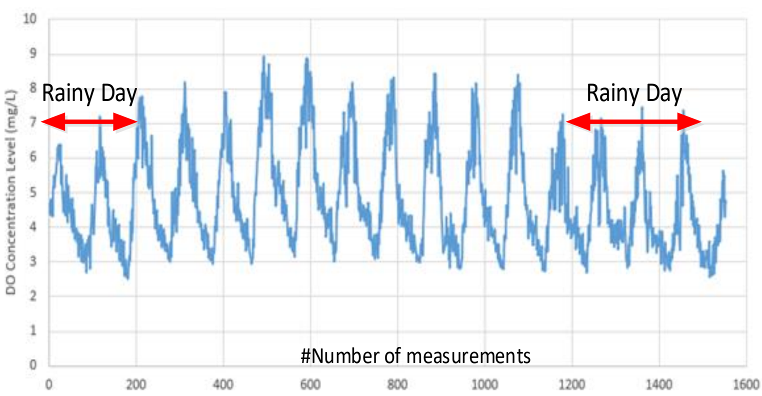

Figure 9: The pattern of DO concentration level at Lake 7/1F, Shah Alam, Selangor for 16 days of observations.

Table 1: DO Concentration Level Results at Lake 7/1F, Shah Alam, Selangor

	$x < 5$mg/L (%)	5 mg/L $\leq x <$ 8 mg/L (%)	$x \geq$ 8 mg/L (%)
DO Concentration Level	62.4	35.6	2

This study was limited to the pattern monitoring of DO concentration level at Lake 7/1F for a short period before the COVID-19 pandemic and Movement Control Order by the Government of Malaysia. More studies are needed to address issues that are related to the obtained DO concentration level results. This study can be extended by observing other water parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Turbidity, pH, Electrical Conductivity, Total Dissolved Solids, and others to confirm the quality and well-being of this recreational lake in more details.

Conclusion

In this paper, the design and development of the real-time monitoring system for DO concentration level at Lake 7/1F, Shah Alam, Selangor is presented. The deployed system consists of DO sensor, an embedded system with the Arduino board implementation, together with the ESP wireless module and SD card for physical back up data storage. The output of this experimentation leads to the conclusion that the pattern of the DO concentration level at this lake shows the vital sign of the photosynthesis appears in the lake water ecosystem. This shows a good indication of a healthy lake cycle, but the consumption of the oxygen in the water during night time is alarming as the DO level drops below the permitted value. This issue should be anticipated and addressed in future research work.

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