A SUSTAINABLE DESIGN FOR WATER QUALITY MANAGEMENT ON TASIK GEMILANG, UTeM

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ABSTRACT: Eutrophication is the process by which the water is subjected to the overloading of nutrients that cause algae blooms, decreasing the productivity of the aquatic living things and malodor problems. With the aggravation of this condition, the dissolved oxygen level can be decreased. However, the application of a framework for water restoration is still inadequate. Therefore, this research proposed a Water Quality Management conceptual framework as a guideline. The design of an aerator with water filters aims at enhancing the level of DO. This aerator also applies IoT technology to regulate the water filter and give monitoring of the water quality. The result shows that the concentration of DO has increased to 28.94% when the aerator is in a polluted area. Meanwhile, the standard deviation and coefficient of variation for DO have obtained smaller values compared to the existing DO which indicates that improved DO contributes more consistent data range. Thus, implementing the conceptual framework of water quality management as a guideline for this study is acceptable since it shows that applying the aerator and IoT can improve and control water quality. The application of an aerator-IoT device not only has a positive impact on water quality but is also a good initiative for commercializing water restoration

purposes through sustainable design.

KEYWORDS: *Aerator; Eutrophication; Internet of Things; Water Quality Management*

1.0 INTRODUCTION

Water is a vital natural resource essential for human life and serves as a fundamental asset in development [1]. An excessive alga which is also referred to as algal blooms, can be problematic as it obstructs sunlight, hindering aquatic plants' photosynthesis and leading to a depletion of dissolved oxygen during their respiration process [2-3]. This phenomenon has come to be referred to as eutrophication which reduces the productivity of fish and hazardous algal blooms that create taste and odor problems [4]. When the amount of oxygen taken in from photosynthesis and the air is not enough to meet the needs, the quantity of dissolved oxygen (DO) drops, resulting in a deterioration of water quality [5].

Furthermore, the increased developments around the Internet of Things (IoT) have triggered an increase in the deployment of diverse sensors in water quality observation, examination, and mitigation of eutrophication [6]. The use of sensors is considered a promising alternative for water quality management [7]. Systematic monitoring addresses the issue of frequency by requiring comprehensive and detailed examination, sampling, and data gathering [8]. Other than monitoring the quality of water, restoration is also important to improve and control the quality of water. Improving the oxygen levels is essential for the treatment of contaminated water [9]. Aeration is one of the successful methods that can be utilized in water treatment due to its ability to enhance oxygen delivery [10-11].

The primary goal of this study is to improve the dissolved oxygen level in Tasik Gemilang, UTeM. Specifically, Tasik Gemilang, UTeM is polluted by leptospirosis which disrupts recreational and curriculum activities among staff and students. Upon observation, the water fountain located at the lake's center is insufficient to facilitate the passage of water to the drain. In addition, there is no indicator of a monitoring system provided to monitor the water quality parameters to ensure the safety of the lake. Ultimately, this study sought to improve the water quality management for Tasik Gemilang, UTeM.

However, the application of water quality management that involves IoT and an aerator based on a framework is still inadequate. The novelty of this study lies in proposing a framework approach for water quality management by Mahdzir et al. [12] as shown in Figure 1. This conceptual framework integrates a water quality model, IoT and an aerator to improve that water quality. This framework would offer a more robust and comprehensive solution that is currently lacking in maintaining the water quality of Tasik Gemilang, UTeM. This study contributes to the improvement of Tasik Gemilang, UTeM water quality by increasing the concentration of dissolved oxygen level and controlling the water quality by using monitoring systems.

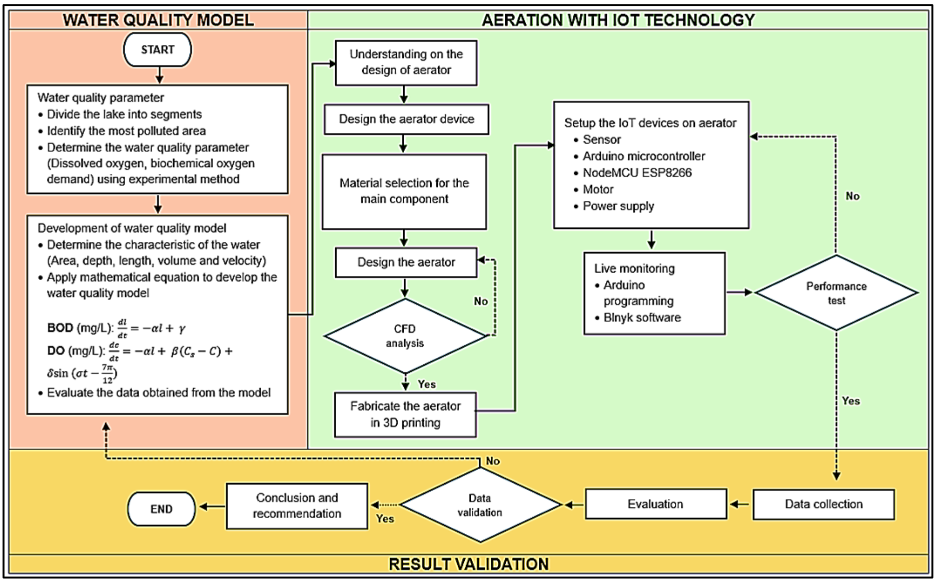


Figure 1: Water quality management framework [12]

2.0 METHODOLOGY

This section executes a new flow chart for the overall process, referring to the original conceptual framework. Based on the conceptual framework in Figure 1, this study will exclude the water quality model for the project since the scope is only designing aerators with the application of IoT technology. The flowchart in Figure 2 below will be used as guidelines for water quality management in Tasik Gemilang, UTeM. According to the flowchart, the first step that should be taken is to identify the segmentation of the lake. Since Tasik Gemilang has a huge area, segmentation is the best method to identify the water quality parameters thoroughly. By using segmentation, the most polluted area can be identified. The water quality parameter will be measured using sensors. When the condition of the lake is identified, an aerator with an IoT device will be applied to the lake.

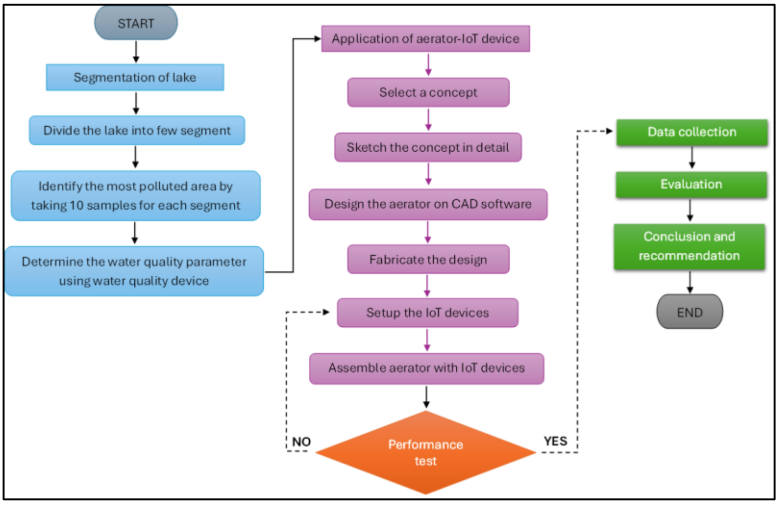


Figure 2: Flowchart of water quality management for Tasik Gemilang, UTeM

Tasik Gemilang, UTeM is divided into nine smaller segments for analysis, as illustrated in Figure 3. The analysis is conducted on a water sample from each segment both before and after the device is implemented. The segment that is heavily polluted will be chosen as the focus of this study. Testing of the water sample is required once samples have been collected at each lake segment. SolidWorks is the Computer-Aided Design (CAD) software utilized to create the 3D design model of the aerator device. The element drawing is subsequently transferred to the CAD software. Figure 4 shows the side view and isometric view of the aerator device that are designed on Solidwork software.

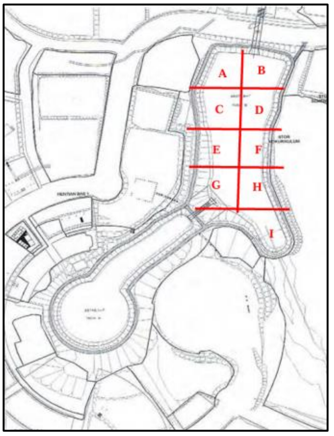


Figure 3: 9 segments of Tasik Gemilang, UTeM

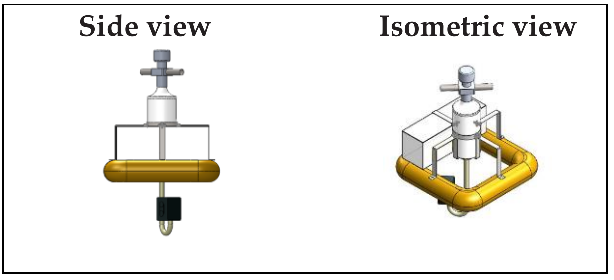


Figure 4: Side and Isometric views for aerator device

The objective of implementing IoT for this project is to decrease monitoring time and enhance efficiency by improving water quality at Tasik Gemilang, UTeM. DO and pH sensors are subsequently selected for this project. The water pump is selected for filtering the polluted water of the lake. Figure 5 is the schematic diagram for water quality management on Tasik Gemilang, UTeM, to show how the water quality management system works. Then, the data will be analyzed and collected wirelessly by Microsoft SQL Server and php file, which will be monitored by any devices. The implementation of this system enables efficient data collection for the water quality parameters.

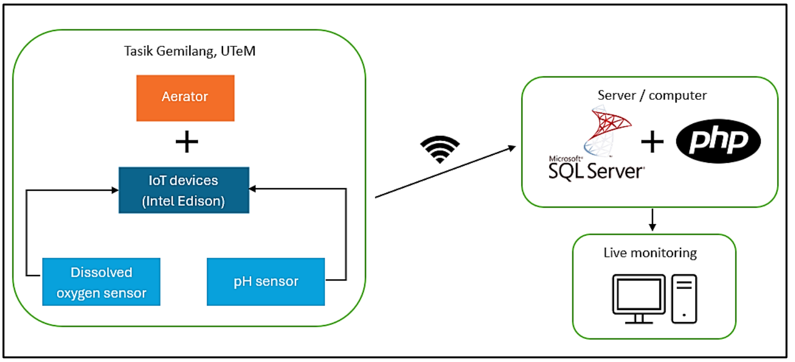


Figure 5: Schematic diagram for WQM on Tasik Gemilang, UTeM

On the other hand, Figure 6 is the complete circuit for the IoT device which generated using Cirkit software. To enable the pH sensor to transmit data to the database, the yellow wire is linked to the analog A0 pin. Subsequently, the red wire serves as the power input for the pH sensor, which is attached to the 5V pin on the Intel Edison Arduino Breakout Board microcontroller. Besides, the DO sensor features four connections: VCC, GND, TX, and RX. To enable the user to transmit the DO data and store it in the database, the TX (yellow) and RX (green) wires have been attached to the RX and TX pins on the Intel Edison Arduino Breakout Board. The input pin is connected to digital pin 7 on the development board to accept data from the board. The water pump is linked to the relay at the normally open (NO) terminal, ensuring it remains in standby mode until an activation signal is received.

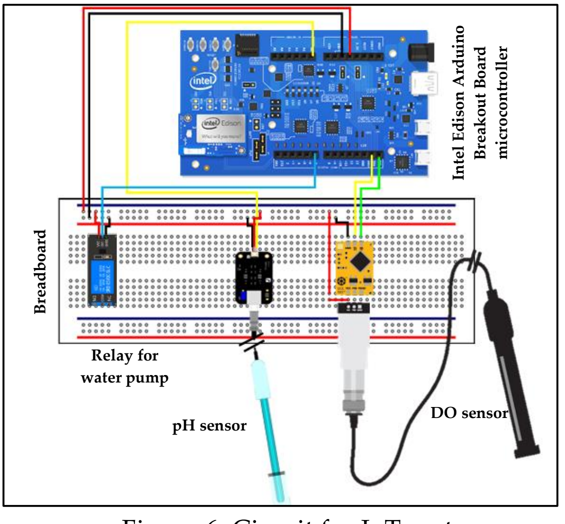


Figure 6: Circuit for IoT system

3.0 RESULTS AND DISCUSSION

The assessment of water quality in Tasik Gemilang, UTeM, involves measuring the dissolved oxygen level in the lake water. 10 data points are collected from each segment of the lake. The data collection interval is 1 minute, resulting in a total duration of 120 minutes for obtaining the DO readings from all points, inclusive of transportation between locations. Table 1 is the result of the DO level collected from Segment A to Segment I. Based on the data collected, it shows that Segment H has the highest value of DO concentration, which is 7.15mg/L, compared to other segments. This indicates the water quality in Segment H is better compared to other segments. Meanwhile, Segment A has the lowest concentration of DO which is 3.52mg/L compared to other segments. This shows that the quality of water in Segment A is the poorest compared to other segments.

Table 1: DO results from Tasik Gemilang, UTeM

Segment	Dissolved oxygen, mg/L										
	1	2	3	4	5	6	7	8	9	10	Average
A	3.3	2.2	4.0	4.7	3.7	3.0	3.7	4.5	3.5	2.6	3.52
B	6.6	6.6	6.1	6.3	6.1	6.5	6.1	4.3	5.8	5.7	6.01
C	6.1	6.2	5.9	6.0	5.8	6.0	5.8	6.0	6.0	6.2	6.00
D	6.4	6.2	6.2	6.3	5.7	5.5	6.0	5.4	6.3	5.6	5.96
E	6.4	6.7	6.4	6.2	6.4	6.2	6.5	6.2	6.1	6.2	6.33
F	6.2	6.0	6.0	5.7	6.2	6.0	6.0	5.8	6.3	6.4	6.06
G	5.9	5.8	6.0	5.9	5.1	5.0	4.9	5.6	5.0	5.5	5.47
H	7.3	7.1	7.0	7.3	7.1	7.3	7.2	7.0	7.0	7.2	7.15
I	6.7	6.7	6.0	5.9	6.1	5.8	6.0	5.8	5.8	6.1	6.09

The data is averaged and then plotted into a graph to facilitate analysis, as shown in Figure 7. The acceptable range of dissolved oxygen for recreational water with body contact is 5.0 mg/l to 7.0 mg/l as suggested by the Department of Environment, Malaysia. Consequently, the lines representing 5.0 mg/L and 7.0 mg/L are depicted on the graph to ascertain whether the point exceeds the limit. The graph indicates that segment A is below the lower limit of 5.0 mg/L, with an average value of 3.52 mg/L. This indicates that the segment is being polluted, as the DO reading is lower. Segment H marginally exceeds the threshold of 7.0 mg/L. Despite exceeding the recreational water quality range, it indicates that the water remains at a healthy level.

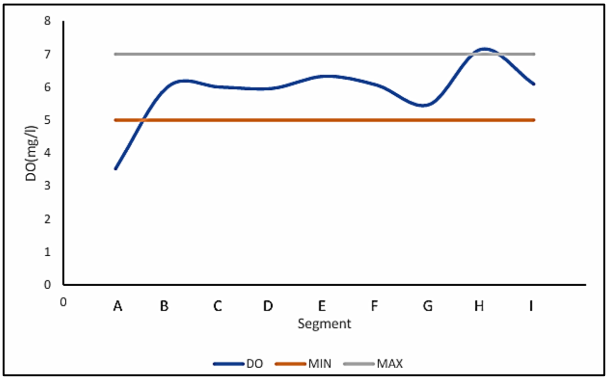
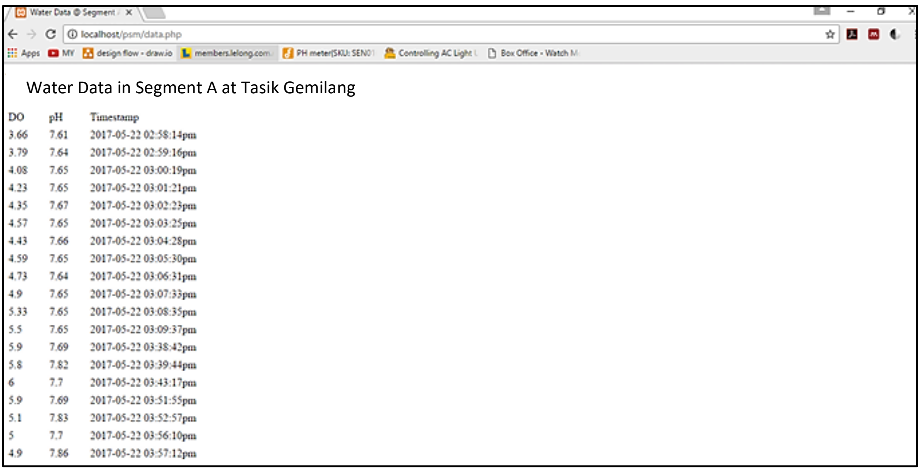


Figure 7: Graph analysis based on DO data

Table 1 and Figure 7 show that the concentration of dissolved oxygen in Tasik Gemilang, UTeM has readings within the threshold line among each segment except Segment A. This may happen due to the movement of water outflow to the drain nearby which is slower compared to Segment B which is located near the drain. Hence, the algae and bacteria are most likely accumulated in that area. In addition, from Segment B to Segment I, Segment G has the lowest value of DO concentration. From on-site observation, it is because the water starts to inflow from that area. However, since the water is consistently moving, the DO concentration is still between the threshold which is not less than 5.0mg/L. Since the data collection has shown that Segment A has the lowest concentration of dissolved oxygen, it is significant to implement the aerator-IoT device in that area, as shown in Figure 8. The purpose of this device is to filter the water and contribute real-time data for users.


Figure 8: Aerator-IoT device placed on Segment A

The implementation of IoT efficiently acquires the data of DO at Tasik UTeM to be monitored. This study involves connecting the IoT gadget to a personal Wi-Fi hotspot for connectivity. To link the IoT development board to the local server, both the server and the IoT development board must establish a shared connection. Figure 9 shows the data visualization of DO and pH readings when the server is connected. The data's accuracy is guaranteed by setting the sample of DO reading capture duration at 1 minute per reading.


Water Data in Segment A at Tasik Gemilang

DO	pH	Timestamp
3.66	7.61	2017-05-22 02:58:14pm
3.79	7.64	2017-05-22 02:59:16pm
4.08	7.65	2017-05-22 03:00:19pm
4.23	7.65	2017-05-22 03:01:21pm
4.35	7.67	2017-05-22 03:02:23pm
4.57	7.65	2017-05-22 03:03:25pm
4.43	7.66	2017-05-22 03:04:28pm
4.59	7.65	2017-05-22 03:05:30pm
4.73	7.64	2017-05-22 03:06:31pm
4.9	7.65	2017-05-22 03:07:33pm
5.33	7.65	2017-05-22 03:08:35pm
5.5	7.65	2017-05-22 03:09:37pm
5.9	7.69	2017-05-22 03:38:42pm
5.8	7.82	2017-05-22 03:39:44pm
6	7.7	2017-05-22 03:43:17pm
5.9	7.69	2017-05-22 03:51:55pm
5.1	7.83	2017-05-22 03:52:57pm
5	7.7	2017-05-22 03:56:10pm
4.9	7.86	2017-05-22 03:57:12pm

Figure 9: Data visualization of DO and pH on Segment A

On the other hand, Table 3 shows the comparison of DO concentration before and after improvement, percentage of improvement, average, standard deviation and coefficient variation. The average mean for both existing and improved DO will be calculated using the Equation (1):

$$Average, \mu = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (1)$$

where n is the number of values and x_i is the data set values. The percentage improvement of DO concentration will be calculated using the Equation (2):

$$Percentage, \% = \frac{|Initial\ value - Second\ value|}{\frac{(Initial\ value + Second\ value)}{2}} x\ 100 \quad (2)$$

and standard deviation will be calculated using Equation (3):

$$Standard\ deviation, \sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu)^2} \quad (3)$$

Standard deviation determines the dispersion between values of the sets. The larger the range of values, the bigger the standard deviation. In addition, the coefficient of variation also be calculated using Equation (4) to determine the ratio between standard deviation and mean. The high value of standard deviation will provide a high value of coefficient variation.

$$CV = \frac{Standard\ deviation, \sigma}{Mean, \mu} \tag{4}$$

Table 2: Data for existing DO and improved DO on Segment A

No	Existing DO concentration (mg/L)	Improved DO concentration (mg/L)	Improvement (%)
1	3.33	3.66	9.91
2	2.2	3.79	72.27
3	4.0	4.08	2
4	4.7	4.23	-10
5	3.7	4.35	17.57
6	3.0	4.57	52.33
7	3.7	4.43	19.73
8	4.5	4.59	2
9	3.5	4.73	35.14
10	2.6	4.90	88.46
Average	3.52	4.33	28.94
STD	0.74	0.37	
CV	0.22	0.09	

Based on Table 2, the concentration of DO on the first and second measurements is 3.66mg/L and 3.79mg/L respectively, which is lower than other measurements. This is because the filtration is at the initial phase. However, after filtration by the water pump is activated for a few moments, the concentration of dissolved oxygen has increased gradually. In this study, the average concentration that has improved is 4.33 mg/L compared to 3.52mg/L. Compared to the improvement of DO concentration obtained by Zhang et al. [13] which is 25.16%, this study has achieved a higher DO concentration which is 28.94%. Based on the results, it is proven that aerators can improve the DO concentration, similar to the findings by Zulkarnain et al. [14] and Cahyadi and Zulkarnain [15]. Additionally, the value standard deviation and the coefficient of variation of the existing DO concentration are larger than improved DO concentration respectively.

This indicates that the application of aerator-IoT provides a consistent DO reading. This result is supported by Huan et al. [16] who found that IoT monitoring for aerator provides low relative error, so it will provide strong data support for water quality management. Hence, real-time data can be monitored remotely without concern to ensure the water quality is well maintained [17-18]. The results from this study also align with the previous findings by Mawardi et al. [19], reinforcing the conclusion that implementing an aerator with IoT will provide efficient results that would advance the aquaculture industry.

4.0 CONCLUSION

Water quality management is important to improve and control the water quality so that further pollution can be prevented. This study has applied a water quality management framework that integrates an aerator and IoT to improve the water quality of Tasik Gemilang, UTeM. The aerator-IoT device is designed with a water filter pump to filter the water and sensors to read the water quality parameters. Based on the data, it shows that the application of the aerator-IoT device has improved the concentration of DO with an average of 28.94% compared to before aerating. The result from this study also proved that aerator-IoT would provide a consistent and stable reading of DO concentration compared to before, based on the smaller value of standard deviation and coefficient of variation. Hence, the objective of this study is to improve the water quality of Tasik Gemilang, UTeM has achieved. In addition, the quality can be controlled remotely by the IoT monitoring, so early action can be taken. Meanwhile, for future work, the aerator-IoT device can be placed in large areas instead of a specific area to provide an impactful water quality management. In addition, more data related to other water quality parameters should be anticipated in future research to have a better understanding of water quality. Hence, this study has the potential to be sustainable practice in water quality management by improving the water quality of polluted aquaculture.

This study can be commercialized for universities to achieve the concept of a University in the Garden.

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AUTHOR CONTRIBUTIONS

M.M. Mahdzir: Conceptualization, Methodology, Writing- Original Draft Preparation; S.H. Yahaya: Validation, Supervision, Writing-Reviewing; M.H.F. Md Fauadi: Writing-Reviewing; T.Y. Tneh: Data Collection, Result and Validation.

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the manuscript, agree with its submission and declare no conflict of interest on the manuscript.

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