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Article

Monitoring water quality and tracking pollution using water surface vehicle: The case of Ayer Keroh Lake, Malaysia

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Abstract: Physical sampling of water on site is necessary for various applications like drinking water quality checking in lakes and checking for contaminants in freshwater systems. The use of water surface vehicles is a promising technology for monitoring and sampling water bodies, and they offer several advantages over traditional monitoring methods. This project involved designing and integrating a drone controller, water collection sampling contraption unit, and a surveillance camera system into a water surface vehicle (WSV). The drone controller unit is used to operate the boat from the starting location until the location of interest and then back to the starting location. The drone controller has an autopilot system where the operator can set a course and be able to travel following the path set, whereas the WSV will fight the external forces to keep itself in the right position. The water collection sampling unit is mounted onto WSV so when it travels to the location, it can start collecting and holding water samples until it returns to the start location. The field of view (FOV) surveillance camera helps the operator to observe the surrounding location during the operation. Experiments were conducted to determine the operational capabilities of the robot boat at the Ayer Keroh Lake. The water collection sampling contraption unit collected samples from 44 targeted areas of the lake. The comprehensive examination of 14 different water quality parameters were tested from the collected water samples provides insights into the factors influencing the pollution and observation of water bodies. The successful design and development of a water surface surveillance and pollution tracking vehicle marks the key achievements of this study. The developed collection and surveillance unit holds the potential for further refinement and integration onto various other platforms. They are offering valuable assistance in water body management, coastal surveillance, and pollution tracking. This system opens up new possibilities for comprehensive water body assessments, contributing to the advancement of sustainable and efficient water testing. Through careful sampling efforts, a thorough overview of the substances presents in the water collected from Ayer Keroh Lake has been compiled. This in-depth analysis provides important insights into the lake's current condition, offering valuable information about its ecological health.

Keywords: water surface vehicle; robot boat; lake surveillance; water sampling; water resources management; pollution tracking; Malaysia; conservation

1. Introduction

River pollution is a significant environmental issue in Malaysia, affecting both the environment and the people who depend on these waterways for their daily needs. According to the Department of Environment (DoE), 195 rivers in Malaysia are slightly polluted, and 34 are polluted (Loh and Tan, 2021). A study conducted by the Malaysian Society of Marine Sciences in 2018 found that the Klang River, one of the most polluted rivers in Malaysia, had high levels of biochemical oxygen demand, and total suspended solids, indicating severe pollution. The main sources of river pollution in Malaysia include industrial and municipal wastewater discharge, agricultural runoff, and illegal dumping of waste as reported by Chan (2012) and Afroz et al. (2014).

Public educational and awareness campaigns, strict enforcement of environmental regulations, community monitoring, and incentives are effective conservation efforts to facilitate Malaysia's sustainable use and protection of rivers. The paper proposes that conservation is more effective, cheaper, and capable of minimizing river pollution in the long run compared to endless river clean-up programs (Lanree, 2004). The current initiatives of development, including the features of the natural environment and outcomes of past interventions, determine opportunities for future development and the need to restore and enhance water quality. Camara et al. (2019) defined water quality as a measure of water uses for various purposes, including drinking, recreational, industrial, agriculture, and habitation.

Furthermore, four military drones with a cost of RM2 million were purchased by the state government for aerial river surveillance purposes. Besides, the state government also studied the usage of River Watcher—an all-in-one automated water quality analyzer. River Watcher was able to measure 14 water quality parameters, for example, biological oxygen demand (BOD), Ammoniacal Nitrogen (AN) and Suspended Solids (SS), recording real-time data periodically (e.g., every five, 30 and 60 minutes), and activating an alarm when variation from quality parameters is detected (Loh and Tan, 2021). This project has successfully tackled pollution problems in South Korea recently a research team has embarked on pilot project test in Sungai Galing, Pahang which aims to provide an early detection system using an all-in-one automated water quality analyzer (New Straits Times, 2020). Despite its built-in features with advanced features of sensors and measurement tools, River Watch has its drawback of limitation in its mobility.

In conventional methods, water samples are collected periodically and analyzed in the laboratory to detect harmful changes in the waterbodies. However, these methods are costly and labor-intensive, and the measurements are not representative of the neighboring waterbodies (Moshi et al., 2022). The authors in paper (Gedda et al., 2021) present a brief introduction to the issue associated with municipal and industrial wastewater. Also, this chapter presents detailed information about the conventional wastewater treatment methods. Specifically, it discusses the steps involved in wastewater treatment in the primary, secondary, and tertiary treatment.

On the other hand, computer-based water sampling systems which are equipped with a robotic drone system with a water sampling system to traverse into the location of interest, once at a said location, the water sampling unit is deployed to collect a large sample of water for further testing as shown in **Figure 1**. However, this project lacks the ability to quickly identify the source of pollution in sections of rivers and estuaries. Early detection could be in the form of round-the-clock surveillance (Ahmed et al., 2022).

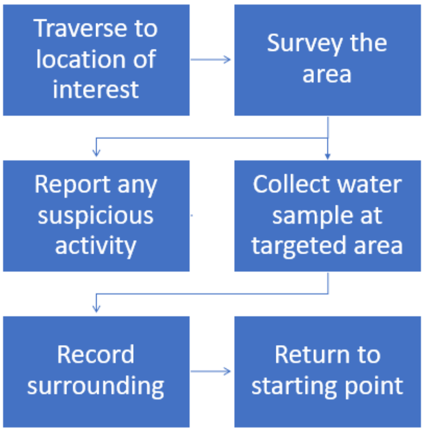


Figure 1. Block diagram of computer-based water sampling system.

In 2020, the Department of Environment collaborated with researchers Fatin Adila et al. (2020) from Universiti Teknologi Malaysia to test the use of UAVs for water quality monitoring in the Johor River. The UAVs were equipped with sensors to measure water quality parameters such as turbidity and chlorophyll-a. The data collected by the UAVs was compared to data collected from traditional water sampling methods, and the results showed that the UAVs were able to provide accurate and reliable data.

Similarly, Nazmi et al. (2022) proposed the use of Unmanned Aerial Vehicles (UAVs) also to identify the source of pollutants in the river which combined with proper image classification techniques. He used Parrot Bebop 2 quadcopter drone, and Quantum Geographic Information System (QGIS) software to identify targeted objects along the river. However, the use of drones might be severely affected by the temperature and strong wind. This is the weakness of drones as compared to boats. An autonomous boat is able to work in moderate weather conditions.

Mohamed Aslam and et al. (2022) proposed IoT based pollution monitoring RC Boat. There are few sensors including pH sensor, turbidity, temperature sensor and dissolved oxygen sensors to detect the conditions of the water. The data will be transferred to the IoT platform immediately. Similar research which applied IoT also can be found in articles (Annal et al., 2021; Baskaran et al., 2019; Nageswara et al., 2018; Vaishnavi et al., 2017; Varsha et al. 2019,) where the basic water quality parameters (pH, Temperature, TDS, Turbidity, Moisture sensor) are visible in real-time. The more detailed water quality test is still an issue due to the design mechanism, high costing of the advanced test kit.

The WSV conducts safe water sampling and river surveillance in specific areas of water using a remote-operated system that removes the human element from any danger. The operator will place the robot at a safe distance from the targeted area and guide the robot to the area of interest using a remote-controlled transmitter. Remote collecting has the advantage of making measurements on a large scale and over a long period of time, this allows the managers to observe the changes in water quality in coastal waters, estuaries, lakes, and reservoirs over time. Furthermore, the whole system is able to serve as a platform for further future iterations or new technology that can serve to help with search and rescue on streams and rivers.

The water quality in rivers, ponds, and lakes can be evaluated by monitoring water pH parameters, the measurement of the acidity, and how basic a solution is. Lead in water is caused by a chemical reaction occurring in plumbing materials that contain lead (Centers for Disease Control and Prevention, 2022). Iron in water is caused by the erosion of minerals from soil and rocks then dissolving into water (MN Dept. of Health, 2022), Chromium in water can be found in rocks, plants, animals and soil, in which two types of chromium, chromium 3 and chromium 6 exist (Bakar, 2020). Substances of Nitrate and Nitrites are found naturally, entering the environment through agricultural practices. Bromine is a naturally occurring element that is often found in seawater and freshwater (Ariza et al., 2021). Fluoride is a naturally occurring mineral found in groundwater and natural springs (Ebeid et al., 2018). Sulphate, similarly, found in mineral-rich groundwater, high levels of sulfate may cause laxative effects, resulting in diarrhea and dehydration.

Remote collecting has the advantage of making measurements on a large scale and over a long period of time. This allows the managers to observe the changes in water quality in coastal waters, estuaries, lakes, and reservoirs over time. Furthermore, the whole system is able to serve as a platform for future iterations or new technology that facilitates with search and rescue on streams and rivers.

Hence, the main objective of this paper is to focus its resources on environmental tasks, especially for water resource management in key areas that are reasonably hard to access. Water Surface Vehicle (WSV) is used to inspect the levels of substances and is made to have very minimal prepping time. Integration of the sampling system into the boat will allow the display of concentrations of substances from normal values to abnormal values. The design of the vehicle allows access to small and secluded places. This helps to identify more accurate pinpoint of suspected pollution areas. Lastly, evaluation and testing are performed in the water bodies of interest.

2. Research methodology

The initial task of the project is the development of a water sampling robot with a surveillance system. The need to combat the illegal dumping of toxic chemicals into the rivers forced many public facilities to close temporarily and caused the hospitalization of people living close to the area. The most severe and recent account was the pollution of Kim-Kim River in 2019.

In this project, the Ayer Keroh Lake (Coordinates: 2°16′27.6″ N 102°18′05.7″ E) located 11 kilometers from Melaka Heritage City has been chosen as the test-site. Being one of the largest lakes in Melaka, it is a natural lake offering a variety of activities such as sailing, canoeing, boat rides, and fishing. In addition to water sports, the lake features a jogging path, a playground, and several food stalls. Given the constant human activities in and around the lake, it is vital to preserve its natural conditions to ensure the stability of the ecosystem and safeguard marine life.

2.1. Water surface vehicle development

The water surface vehicle (WSV) is specifically designed for swift and efficient deployment, making it highly versatile in field operations. Its design allows for rapid setup and activation, enabling it to be deployed quickly and repeatedly in a single test area without significant downtime. **Figure 2** shows the overview of the design and development of the WSV. The platform is built of fiberglass material to withstand crashing into hard objects in the waterbody paired with a set of two jet propulsion propellers that would not get caught onto reeds and other water vegetation as shown in **Figure 2**. On top of the hull is a Field of View (FOV) camera that helps to survey the area and acts as the surveillance camera of the surveillance system. In the hull of the fiberglass boat is the water sampling system.

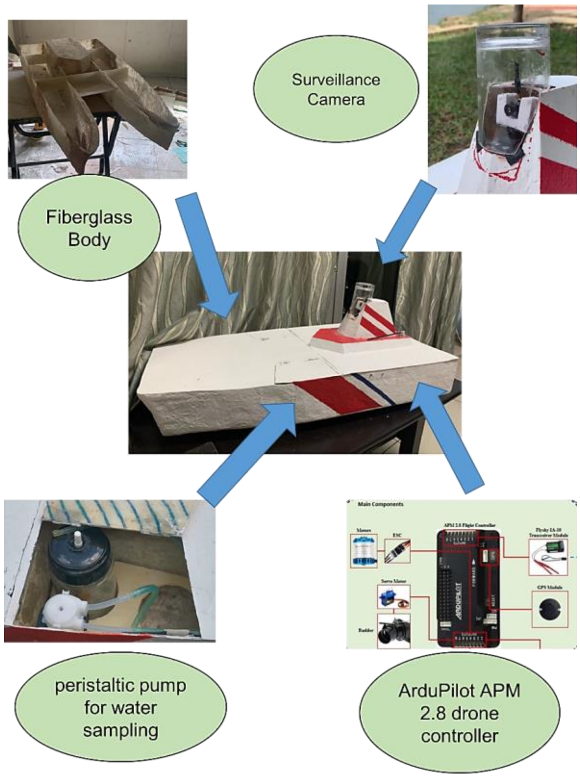


Figure 2. Development of water surface surveillance and pollution tracking vehicles.

Peristaltic rates a water sampling system that works on the use of a peristaltic pump driven by the control of radio frequency to control the on-and-off of the motor. The water is fed to the containment unit for further sampling. **Figure 3** shows the rendering and real unit of the water collection unit. The design of the mechanism uses individual pumps for every syringe sample, the sample of water will first get sucked up by the water pump, then the water will be fed into the syringe and stored there until it is purposefully removed to be tested for contaminants.

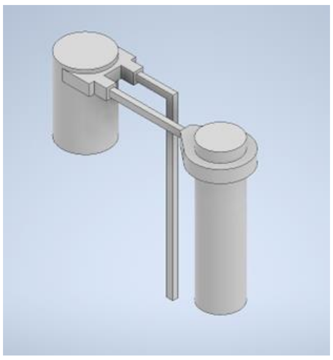


Figure 3. Rendering water collection.

The ArduPilot APM 2.8 drone controller brain is a highly advanced control system for the boat, and it enables the boat to be controlled remotely with great precision. The autopilot has various sensors, including a GPS module, a compass, and an accelerometer, which enable it to monitor the boat's position, speed, and orientation accurately. The autopilot can also communicate with the boat's propulsion system, enabling it to adjust the speed and direction of the boat according to the commands sent by the operator. The autopilot's software is highly configurable, and it can be tailored to suit the specific needs of the boat's operation. The autopilot can be programmed to follow pre-defined routes, perform specific tasks, and respond to different environmental conditions, making it an ideal control system for the boat. Additionally, the open-source nature of the ArduPilot APM 2.8 drone controller brain enables the boat's control system to be customized and extended easily, which is highly beneficial for research and development purposes.

2.2. Experimental setup

Ayer Keroh Lake is a scenic natural lake located just 11 kilometers from the bustling Melaka Heritage City, making it a convenient and peaceful escape for both locals and tourists. Surrounded by lush greenery, the lake serves as a popular recreational spot offering a variety of outdoor activities for all ages. Water sports enthusiasts can take part in exciting options such as sailing, canoeing, boat rides, and fishing, providing a perfect opportunity to enjoy the calm waters while surrounded by nature. One of the key highlights of Ayer Keroh Lake is its proximity to Zoo Melaka, a popular attraction in the region. Hence, it is crucial to protect its natural state due to the presence of ongoing human activities.

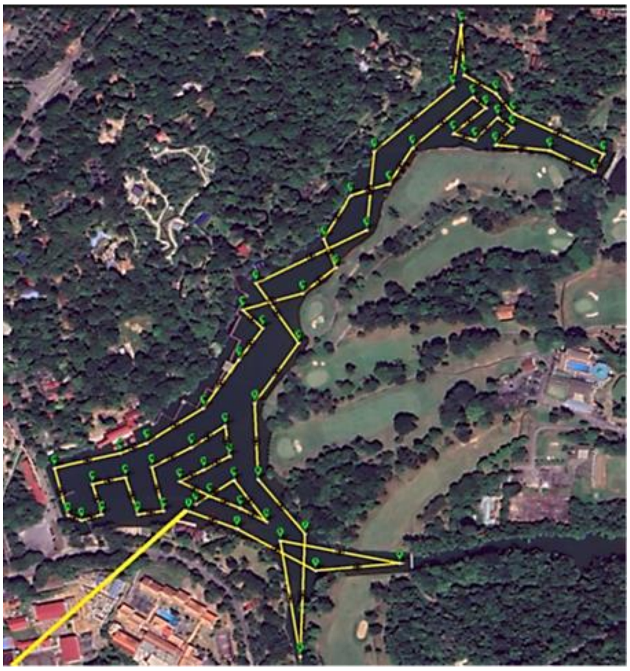


Figure 4. Planned path for the WSV.

Functionality test of the surveillance camera, water sampling, and water quality test was carried out in this location as shown in **Figure 4**. The lake has been carefully divided into 44 distinct sections, each chosen based on varying levels of human activity and interaction with the surrounding environment. These sections range from areas that experience high foot traffic, such as popular recreational spots and activity hubs, to more secluded zones that are rarely accessed by visitors. The purpose of this division is to better understand and manage the possible impact of human presence on the lake's ecosystem. The busier sections, which tend to be closer to facilities like jogging paths, playgrounds, and boating, require more focused monitoring and conservation efforts due to the higher risk of environmental stress. Conversely, the quieter, less-visited areas offer an opportunity to preserve and study more untouched aspects of the lake's natural habitat.

The data collection process was conducted over a one-week period during daylight hours, ensuring optimal visibility and accuracy in observations. To maintain consistency and reliability in the data, the tasks were carried out under stable and uniform weather conditions throughout the entire week. This approach helped minimize any potential environmental variables, such as changes in temperature, rain, wind, or precipitation, which could have influenced the results.

By setting waypoints along the planned route, the boat's autopilot can use GPS coordinates to steer the boat from one point to the next, ensuring the boat follows the intended path. The autopilot can adjust the boat's direction and speed to stay on course and avoid any obstacles along the way. Moreover, waypoint-based navigation is also useful for mapping the waterways, as it enables the collection of data about the water bodies that can be used for future reference. By logging the position of the boat at each waypoint, a detailed map of the water body can be created, which can be used for navigation and scientific research. The results will be compiled and shown in a graph-like model. The graph shows the type of pollutants, and their concentrations categorized.

Various tests will be performed on the water body, including assessments for Total Alkalinity, Bromine, Copper, Chromium, Fluoride, Hardness, Iron, Lead, Mercury, Nitrite, Nitrate, pH, Residual Chlorine, and Sulfite. **Figure 5** provides a visual representation of the water test kits utilized for conducting these field tests. These kits typically contain various reagents, testing equipment, and instructions necessary for accurate and efficient assessment of water quality parameters. Utilizing these kits in field tests enables rapid evaluation of water quality on-site, facilitating timely decision-making and intervention measures to ensure the safety and suitability of water resources.

Figure 5. Water substance test kit.

Figure 6 provides an elaborate breakdown of the benchmark values associated with these substances, offering a comprehensive overview of their key attributes and characteristics. The data presented has been sourced from the National Water Quality Standards for Malaysia, as established by the Department of Environment under the

Ministry of Natural Resources and Environmental Sustainability. These standards serve as an essential guideline for maintaining and assessing water quality in Malaysia, ensuring that environmental health and safety regulations are met. The color red typically serves as an indicator of abnormality, signaling caution or potential issues, while green is commonly associated with normalcy or safety.

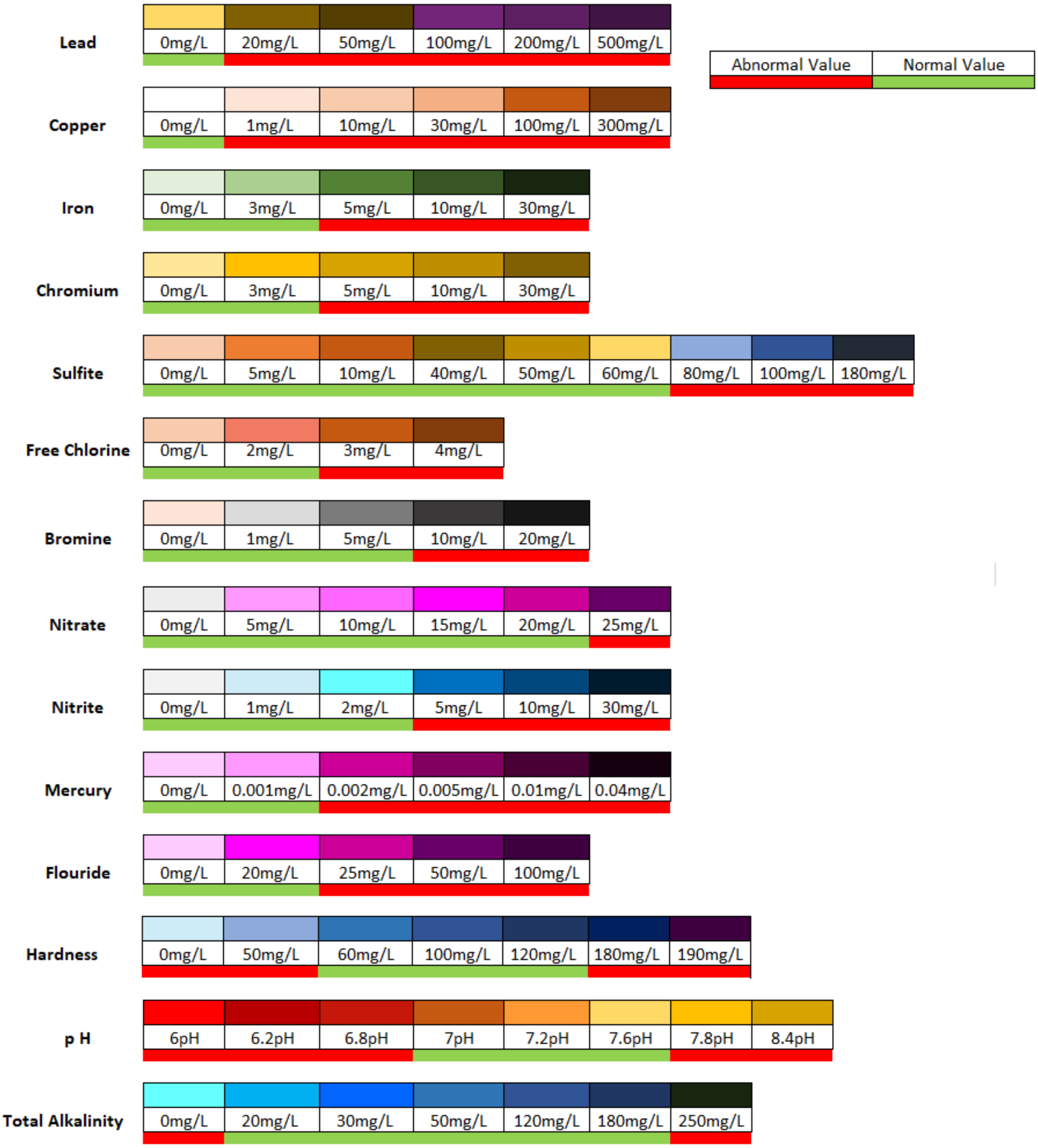


Figure 6. Benchmark values for substances.

3. Results and discussion

A total of 616 samples with 14 substances were tested in 44 sections of the said water body, as shown in **Figure 7**. The 14 types of samples that were tested are Total Alkaline, pH, Hardness, Lead, Copper, Iron, Mercury, Chromium, Bromine, Nitrate, Nitrite, Residual Chlorine, Fluoride and Sulphite. Each section will need to have a collection of 14 water samples. The results will be compiled and shown in a graph like model. The graph shows the type of pollutants and their concentrations categorised in comparison to the National Water Quality Standards benchmark values. These values outline permissible levels for various water quality indicators, such as pH, dissolved oxygen, biological oxygen demand, and concentrations of pollutants like heavy metals and chemicals. These benchmarks are crucial for both protecting aquatic ecosystems and ensuring the availability of safe water resources for human consumption, agricultural use, and industrial purposes across the country.

Figure 7. Rendering of the lake.

Figure 8 illustrates the outcomes of the comprehensive testing conducted on 14 distinct types of samples (horizontal axis) across the 44 designated locations (vertical axis). This presentation offers a detailed examination of the test results obtained from each sample type, providing valuable insights into their properties and performance within the specified sections.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Lead	Copper	Iron	Chromium/Cr	Sulfite	Free Chlorine	Bromine	Nitrate	Nitrite	Mercury	Floride	Hardness	p H	Total Alkalinity
1	0	0	0	1	5	0.5	0	10	2	0	0	0	6.1	20
2	5	0	0	1	5	0.5	0.5	10	3	0	20	0	6.1	23
3	10	0	3	2	10	0.5	1	10	3	0	10	50	6.1	30
4	10	0	3	1	80	0.5	0.5	5	1	0	20	60	6.1	30
5	20	0	5	2	100	3	3	5	3	0	0	60	6.1	30
6	15	0	3	2	60	2	3	5	2	0	0	60	6.4	40
7	10	0	3	2	60	1	2	5	1	0	0	60	6.2	40
8	10	0	2	2	60	0.5	1	10	1	0	0	50	6	40
9	0	0	2	2	80	0.3	1	10	2	0	20	50	6	35
10	0	0	5	1	90	0.5	1	10	2	0.001	20	50	5.8	30
11	0	0	5	1	100	0.5	1	20	1	0.001	22	100	7.2	40
12	0	0	5	1	100	0.5	1	25	5	0	25	100	6.8	40
13	10	0	5	1	90	0.5	1	22	5	0	22	200	6.8	20
14	10	0	5	1	100	0.5	1	15	3	0	25	230	6.8	20
15	10	0	10	2	180	0.5	1	10	1	0	50	100	6.2	20
16	20	0	10	2	180	3	1	10	1	0	25	100	6.2	0
17	20	0	5	1	100	1	1	0	1	0.002	20	50	6.2	0
18	0	0	5	1	80	0.5	5	0	5	0	0	0	6.2	0
19	0	0	5	1	80	0.5	1	0	1	0	0	0	6	0
20	0	0	5	1	40	0.5	1	0	1	0	0	50	6	0
21	0	0	0	1	10	1	1	0	1	0	0	50	6.2	40
22	0	0	0	1	10	2	1	5	5	0	0	50	6.2	30
23	0	0	0	1	10	0	1	0	3	0	0	50	6.2	20
24	0	0	0	1	10	0	1	0	1	0	0	50	6.2	0
25	0	0	0	1	10	0	0	0	3	0	0	50	6	20
26	0	0	0	1	10	0	0	0	3	0	0	50	6.2	20
27	5	0	0	1	10	0	1	0	3	0	0	50	6.2	40
28	20	1	0	2	60	0.5	1	0	1	0	0	0	6.2	240
29	20	0	0	2	40	0	0	0	3	0	0	50	6.2	40
30	20	0	3	1	80	0	0	10	5	0	0	25	6	20
31	10	0	0	2	50	0.2	0.2	15	3	0	20	25	6	20
32	10	0	3	2	40	0.3	0.2	0	1	0	25	25	6.2	0
33	0	0	5	1	10	0	0	0	1	0	25	0	6.2	0
34	0	0	3	1	40	0	0	0	3	0	0	0	6.2	0
35	0	0	0	1	80	0	0	0	3	0	0	0	6.2	0
36	0	0	3	1	80	1	1	0	5	0	0	0	6	0
37	20	0	3	1	40	0.5	1	0	5	0	0	0	6	20
38	0	0	2	2	40	0.5	1	10	5	0	25	50	7.2	20
39	0	0	2	2	80	0.5	1	0	5	0	25	50	6	20
40	0	0	3	2	40	0.5	1	0	3	0	0	50	6.2	20
41	0	0	3	1	10	0.5	1	1	1	0	0	0	6.2	20
42	0	0	2	1	10	0	1	1	1	0	0	50	6.2	0
43	20	0	5	2	50	0.5	1	0	1	0	0	50	6.8	20
44	0	0	5	1	60	0.5	1	5	5	0	0	50	6.2	20

Figure 8. Water test results conducted on 14 distinct types of samples at the 44 locations.

Figure 9a shows the concentration of lead found in the water body and most of the higher concentrations of lead are found on the edges of the water body. Lead is an important source of environmental contamination that comes from mining, smelting, manufacturing, recycling activities and is also used in a wide range of products. The highest concentration of lead was found at sections 5–6, 16–17, and 29–31of the lake. Human consumption or exposure to excessive lead might cause damage to the kidneys, brain, and reproductive organs.

The concentration of copper in the water is very low and only a small portion of the water body has a slight spike in copper concentration located in the most left sections of 28–29 as illustrated in **Figure 9b**. Speculations on why that specific section of the water body has slightly higher levels of copper concentration could be due to runoff from a food court located in the specific area. Other than that, there are no signs of any pollution that can be found in the water body.

Many rock formations contain iron, and it will be dissolved by rainfalls to water bodies, however, iron is not directly hazardous to human health. Speculations of why the concentrations of iron in the water are high at sections 10–18 may be because they are close to iron-rich rocks or soils. The detailed scattered concentration map is found in **Figure 9c**.

Figure 9d depicts the concentration of Chromium found in the lake. Many chromium compounds are relatively water-insoluble except Chromium Oxide and Chromium Hydroxide. A concentration amount of 3 mg/L was found in sections 5–9 and 38–40.

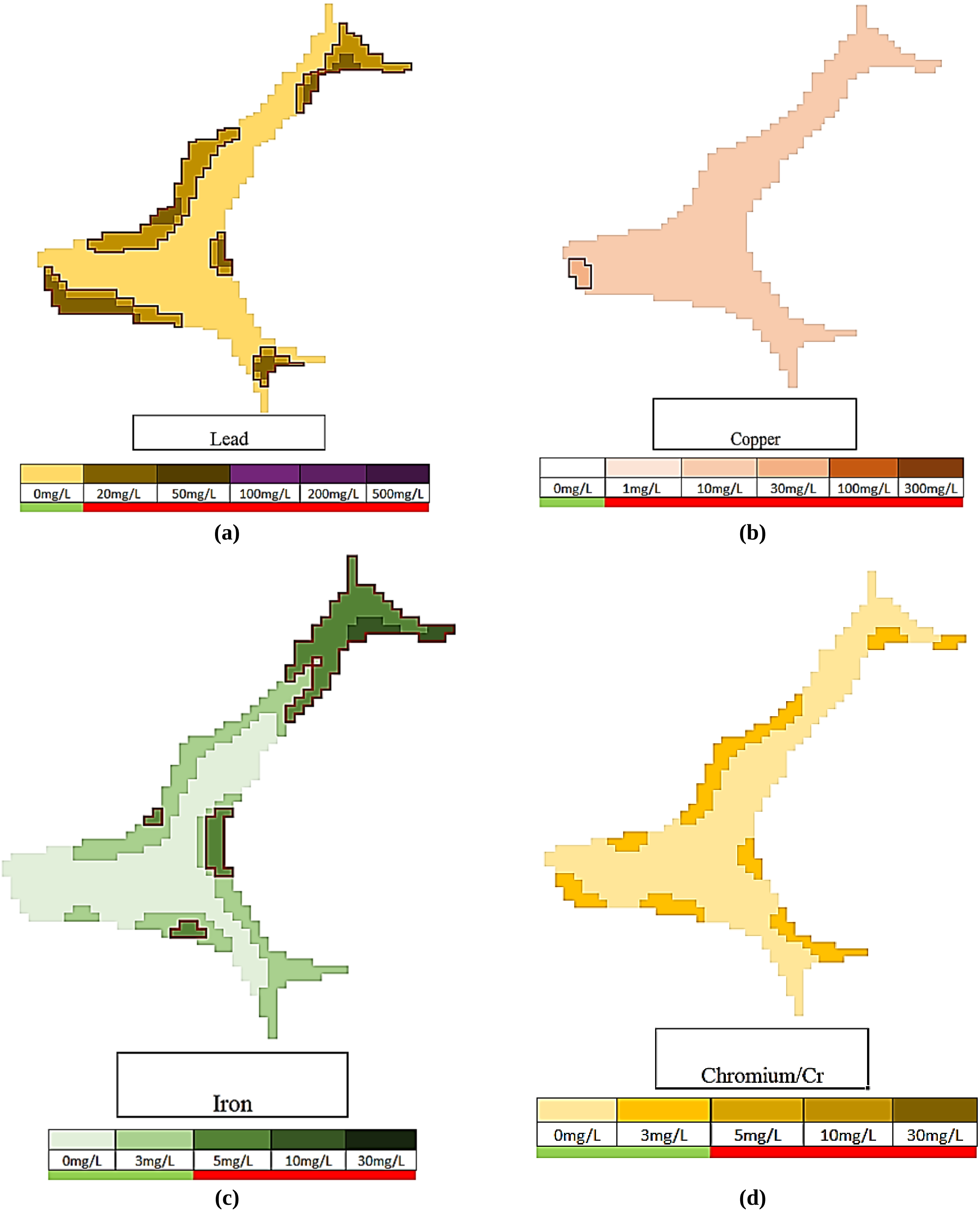
Sulfite can trigger asthma and symptoms of an anaphylactic reaction. **Figure 9e** above shows the concentration of Sulfite found in the lake which has more than 100 mg/L scattered around sections 10–18, 33–35 and 40–42. The sections of the water body that have higher concentrations seem to come from sections with increased human activities and water treatment. Free Chlorine found in the water body usually is nontoxic to humans. The concentration of Chlorine shown in **Figure 9f** is relatively low.

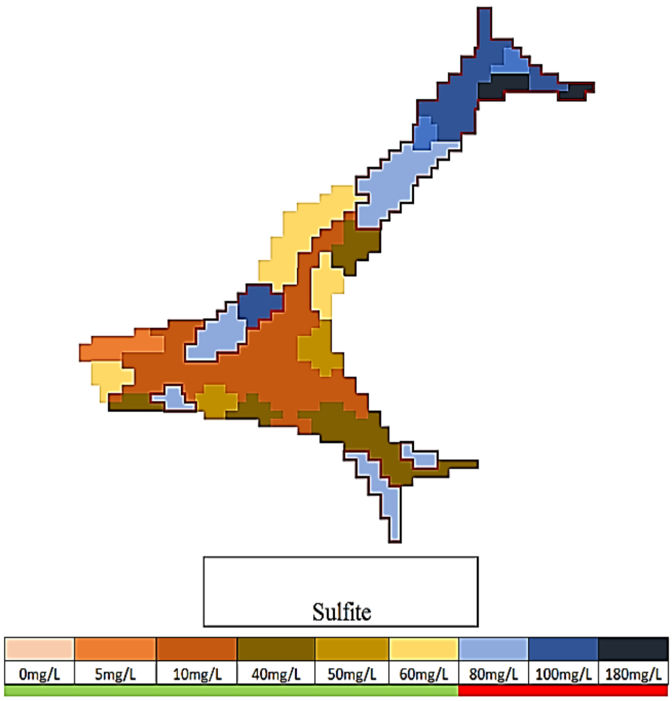
Bromine is a volatile liquid that gives off suffocating vapors, is corrosive to the skin, and may cause severe gastroenteritis if ingested. Inhalation of bromine vapors or direct contact of bromine liquid or vapor with the skin and mucous membranes will produce direct tissue injury. The water testing results show that more than 10 mg/L Bromine at sections 5–7, 17–18 as illustrated in **Figure 9g**. This conjectured from products containing bromine which is used in agriculture and sanitation or alternative to chlorine for water treatment. Fortunately, the Bromine found in the water body is not at a level of concern as it is not that high to the extent of causing any serious effects if ingested, but precautions to not allow the concentration to increase further should be taken.

Figure 9h depicts the concentration of Nitrate found in the lake. The highest concentration of Nitrate levels is in the 12–13 sections. Speculations are caused by wastewater or urban drainage as the section of the water body is located close to a resort where people live. Nitrates are essential plant nutrients, but in excess amounts, they can cause significant water quality problems.

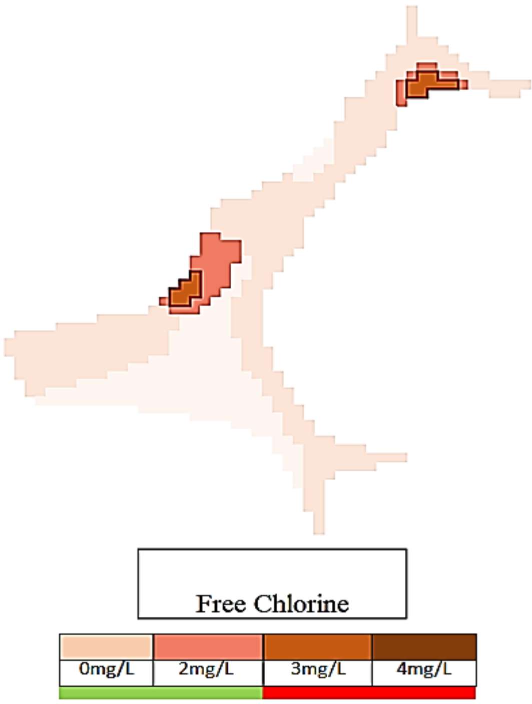
Nitrates and nitrites are nitrogen and oxygen compounds that are found in nature as part of the nitrogen cycle. However, in the feed or the gastrointestinal tract, they are transformed into nitrites, which are poisonous. The toxicity of nitrite is 6–10 times that of nitrates. The existence of Nitrite could be traced significantly at sections 12–13,17–18,35–39, 43–44 as shown in **Figure 9i**. This finding is suspected caused by groundwater contamination from animal waste run-off from Zoo Melaka which is located next to the lake, excessive use of fertilizers, or seepage of human sewage from private septic systems. Besides, microorganisms in the soil, water, and sewage change the nitrate to nitrite. The local authority is required to take some precautions and steps to control the situation.

As reported by World Health Organization (WHO), mercury may have toxic effects on the nervous, digestive, and immune systems, and on the lungs, kidneys, skin, and eyes. There are many ways that mercury can get into your drinking water: rain and snow can carry mercury from the air into surface water supplies such as lakes, rivers, and reservoirs. Mercury can seep into underground water supplies from industrial and hazardous waste sites. A light concentration of mercury was found in the water sample collected from sections 17–18 as illustrated in **Figure 9j**.

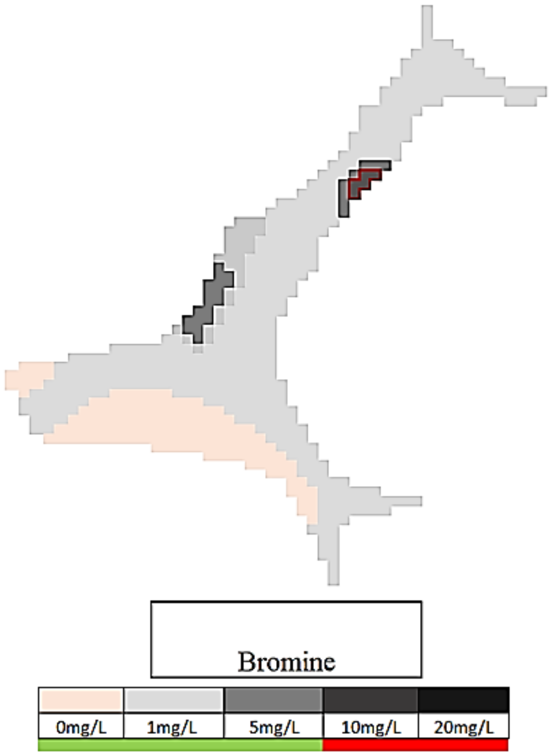



Sulfite
0mg/L
5mg/L
10mg/L
40mg/L
50mg/L
60mg/L
80mg/L
100mg/L
180mg/L

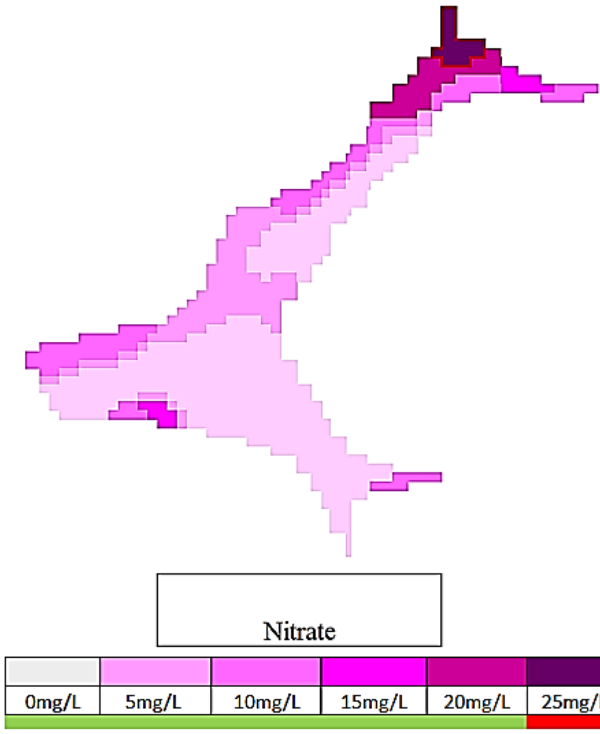
(e)


Free Chlorine
0mg/L
2mg/L
3mg/L
4mg/L

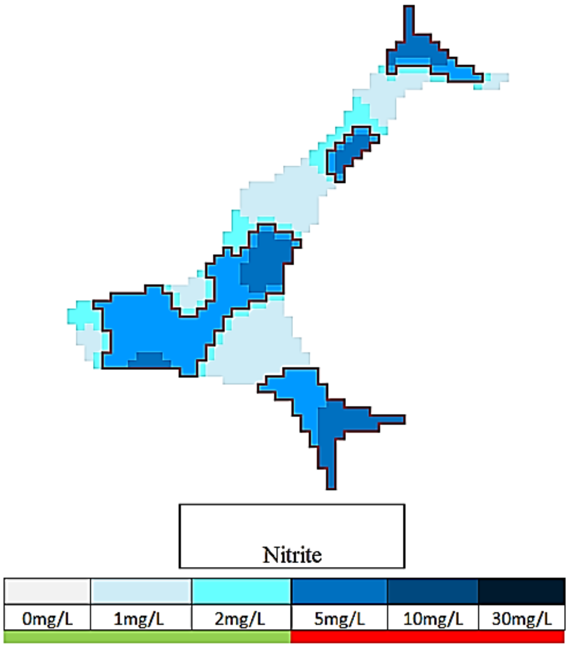
(f)


Bromine
0mg/L
1mg/L
5mg/L
10mg/L
20mg/L

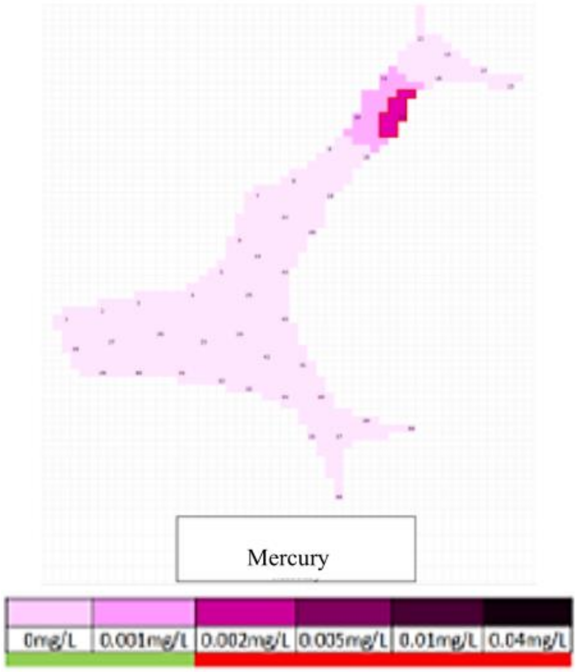
(g)


Nitrate
0mg/L
5mg/L
10mg/L
15mg/L
20mg/L
25mg/L

(h)



(i)



(j)

Figure 9. Concentration of the substances found in the water body. **(a)** Lead; **(b)** Copper; **(c)** Iron; **(d)** Chromium; **(e)** Sulfite; **(f)** Free Chlorine; **(g)** Bromine; **(h)** Nitrate; **(i)** Nitrite; **(j)** Mercury.

4. Conclusion

The advancement of the Water Surface Vehicle (WSV) marks a significant leap forward in the realm of river surveillance and water sampling, particularly for large water bodies aimed at water quality assessment. Demonstrating remarkable efficacy, the proposed WSV model consistently delivers reliable performance across various tests conducted at different times of the day. Through meticulous sampling efforts, a comprehensive overview of the substances presents in the sample water collected from Ayer Keroh Lake has been compiled. This detailed analysis sheds light on the current condition of the water body, offering valuable insights into its ecological health. Impressively, Ayer Keroh Lake remains as a beacon of a robust marine ecosystem, reflecting a state of overall environmental well-being in its vicinity. Looking ahead, there exists ample room for further enhancement of the system’s capabilities, particularly in the realm of on-site water testing. By leveraging real-time data transmission, authorities can swiftly receive and act upon test results, facilitating prompt decision-making and ensuring timely interventions when necessary. This potential for seamless integration into operational protocols underscores the pivotal role of WSV technology in advancing environmental monitoring and management efforts.

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