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Water Monitoring System using Automatic Shut-Off Valves

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Abstract: Clean and safe water is supplied directly into the water storage tank of a house can provide comfort to the whole house. About 6 to 8 million people die each year due to water-related diseases. The existing water quality monitoring system with solenoid valves was only developed at the pre-water distribution stage and was designed only. Therefore, this study aims to design, develop and test the functionality of a water quality monitoring system with automatic shut-off valves and the notification message sender. This water quality monitoring system was developed using an engineering design process that consists of five phases: ask, imagine, plan, develop, and test. As a result of the product testing phase, this developed system has appropriately operated according to the program instructions in the NodeMCU ESP32 microcontroller. The water pH sensor and the total dissolved solids sensor can take readings of water quality values well and be displayed on the Blynk app display on smartphones. The water pH sensor can detect the pH value around 7.00 to 7.01 for a buffer solution with a pH value of 7.01. While for the lemon extract solution, the water pH sensor can detect a value of 1.86. For the total dissolved solids sensor, this sensor can detect the total dissolved solids around 0 to 494 for tap water while increasing up to a value of 4470 after salt is added. Solenoid valves that are assigned to block the passage of water can also operate properly according to set standards. The water filter used can only reduce the number of dissolved solids. Overall, the water quality monitoring system developed can help consumers always receive quality and safe water. Suggestions for improving the developed system are also submitted to ensure more effective functionality.

Keywords: Water Monitoring System, Automatic Shut-Off Valve, Engineering Design Process.

1. Introduction

Water is an essential resource not only to humans but also to every living thing on earth for survival. No life can survive without the presence of water. According to Perdana Samekto (2018), humans can

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survive without water for approximately four to seven days depending on the ambient temperature. Without water, humans can survive longer in low temperatures as water released is lower than in high temperatures (Azanella, 2018). Humans need clean and safe water. Among the uses of water are personal hygiene, agriculture, industry, and more. In addition to an adequate quantity of water, the water needed must be clean and safe to use. Without clean water, it will affect various activities and stunt potential areas.

In this fast-paced era, the ability to provide adequate clean and safe water has become a significant problem for some countries in the world. Pollution after pollution by irresponsible groups and the lack of law enforcement exacerbate this situation. Poor enforcement and light fines cause these perpetrators to have no fear of discharging toxic waste repeatedly into natural water sources such as the sea, rivers, and waterways. Penang Consumers Association (CAP) Rural Officer, Zulkifli Yusuf said that the most polluted river, Sungai Petani in Kedah, is due to garbage disposal, sewage water, and waste oil from residential and industrial areas (Mohd Noor, 2021). He also stated that because of this uncontrolled pollution, not only river life in Sungai Petani has become extinct, but the growth of mangrove trees found along the river is also affected. The release of toxic waste affects water quality and has a negative impact on the ecology of aquatic life (Mohd Noor, 2021). At the same time, it gives the effect of the shortage of marine products faced by fishermen due to the pollution of this toxic waste.

Apart from releasing toxic waste, water pollution in Malaysia is often caused by rapid logging activities. Recently, there has been increased international importance towards the concept of logging, which directly impacts access to clean drinking water (Mapulanga & Naito, 2019). This logging activity has resulted in the soil structure becoming loose due to a lack of grip from the tree roots (Mapulanga & Naito, 2019). When heavy rains occur, landslides nearby rivers can occur, causing the river to become shallow and murky. Logging also decreases the rate of water infiltration into the soil, which causes the water level in the ground to fall. This causes the cost of water treatment to be high (Mapulanga & Naito, 2019).

Access to clean and safe water is a fundamental right of every human, regardless of race, religion, wealth, or skin colour (Li & Wu, 2019). However, billions of people in developing countries still have struggled to get safe and sustainable water supplies over the past few decades. The responsibility of deep-water supplier services in ensuring effective, commensurate, and sustainable water distribution is becoming increasingly important (Jones et al., 2021). The water supplied to every residence must be in a safe condition to avoid any consequences that could affect consumers' health. Every year, about 6 to 8 million people die from water-related diseases (Rahmanian et al., 2015). This is because excess inorganic metallic substances in the water supply, such as lead (Pb), arsenic (As), and copper (Cu), can accumulate in human organs and affects the functionality of the nervous system. Several characteristics determine that the water condition is excellent and safe to use, i.e., taste, smell, colour, and concentration of organic and inorganic substances (Rahmanian et al., 2015). Based on the issues that arise, water quality needs to be monitored automatically so that it can be used by users safely.

2. Methodology

The design development of water quality monitoring systems with automatic shut-off valves and notification message senders is based on the engineering design process (EDP) model. The EDP model was chosen as the design model of this project because the steps contained in the EDP are well suited for developing and solving technological problems. That is why engineers use the EDP model to solve technical issues is a problem-solving method of EDP (NAE & NRS, 2014, cited in Grubbs & Strimel, 2015). Besides, the EDP model can help students and professionals know the starting point to the end in developing a project through systematic procedures in EDP (Haik & Shahin, 2011).

According to May (2018), the National Aeronautics and Space Administration (NASA) has outlined six main phases in the EDP model: ask, imagine, plan, develop, and test. The six phases of EDP implemented in this project are described.

2.1 Ask Phase

The ask phase is when the researcher raises questions about the project to be developed. Through the questions posed, the researcher needs to identify the problems, the needs that must be met, and the constraints that must be considered (May 2018). In this phase, the researcher identified the problem by conducting an interview session with some random people from the community about the use of water in residential homes. Based on the information, the objective and scope of the project are set, which is to develop a water quality monitoring system with an automatic shut-off valve and a notification message sender.

2.2 Imagine Phase

The imagine phase is when ideas for problem-solving are triggered based on the results of questions and analyses that have been done in previous phases. In this phase, the researcher conducts brainstorming and research on the ideas that have been triggered and analyse the studies implemented previously (May 2018). The planning phase is a critical phase where problem-solving ideas are listed and taken to the next phase to select the best ideas. The brainstorming phase is an important phase where problem-solving ideas are recorded and taken to the next phase to select the best ideas. In this phase, the selection of ideas is made by the researcher by analysing each idea based on previous studies. In addition, the chosen idea considers the time and cost of project construction.

2.3 Plan Phase

The researcher will select the best ideas to meet the problem-solving criteria in the planning phase. Several solutions can be chosen to solve the problem of obtaining poor quality water into the water storage tank at home, namely:

- Installation of water quality sensors such as water pH and total dissolved solids at the water inlet into the tank to detect water quality.
- Solenoid valves prevent water flow after detecting water that does not meet the quality standards provided by the Ministry of Health (MOH).
- A notification message is given after the solenoid valve is activated.

All these ideas are combined as one project design. The design is divided into two parts: hardware design and software design.

2.4 Develop Phase

The water quality monitoring system with automatic shut-off valves and this notification message sender will work based on the water quality. There are two solenoid valves used in this product. The first solenoid valve will either open or close the passage for water through the valve directly to the water passage based on the detected water quality, while the second solenoid valve will either open or close the course for water to the water filter:

- If the water in the container with the water quality sensors gives a good reading, the first solenoid valve is opened while the second solenoid valve is closed.
- Suppose the water in the container with the water quality sensors gives a poor-quality reading. In that case, the first solenoid valve is closed, and the second solenoid valve leading to the water filter is opened.
- The end-user will receive a notification message regarding the closure of the solenoid valve along with the detected water quality readings.

The main hardware in developing water quality monitoring systems with automatic shut-off valves and notification message senders is the NodeMCU ESP32 electronic board. The ESP32 NodeMCU has 30 digital input and output pins along with 16 PWM output pins and a 32-bit Tensilica LX6 processor with a frequency of 240 MHz. Figure 1 shows a block diagram of the development of a water quality monitoring system with automatic shut-off valves and a notification message sender.

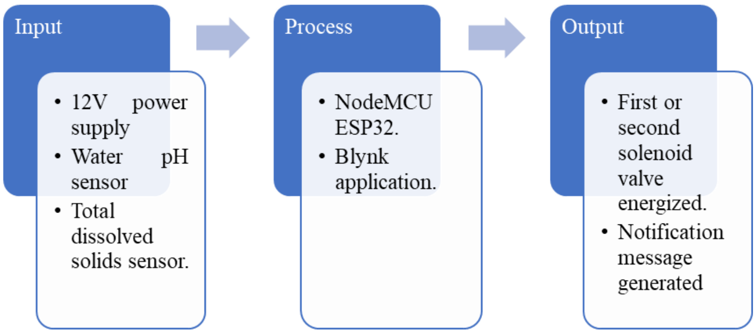


Figure 1: Block diagram of the system

Figure 2 shows the operating flow chart of a water quality monitoring system with automatic shut-off valves and a notification message sender.

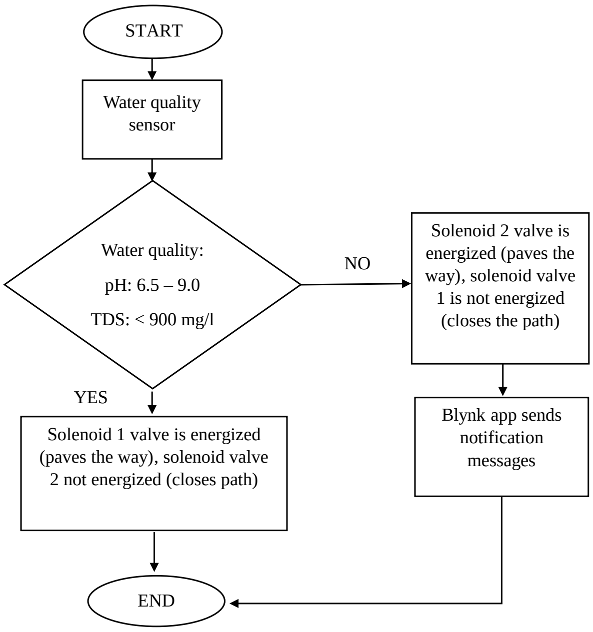


Figure 2: Flow chart of the system

2.5 Test Phase

Testing will be done on each part developed, from the circuit and programming to the project output. The NodeMCU ESP32 electronic board is emphasised acting as the operations centre to the water quality monitoring system with automatic shut-off valves, and notification message senders developed to ensure it can work practically and connect with Blynk applications.

2.5.1 Testing and Evaluation of Product

Circuit design analysis is an analysis to obtain the functionality of a circuit by conducting tests on the entire electronic circuit. From the analysis results, the potential and weaknesses of a circuit can be detected, and then revision and correction can be done. Several component connections have been made on a circuit in this developed product. Among the components used in this circuit are the ESP32 NodeMCU, water pH sensor, total dissolved solids sensor, turbidity sensor, 12V relay switch, 12V AC to DC converter plug, and solenoid valve. The ESP32 NodeMCU serves as the center of the circuit where this microcontroller processes the input from the sensor and, in turn, gives instructions to the solenoid valve which acts as the output of the circuit either to open or close the valve.

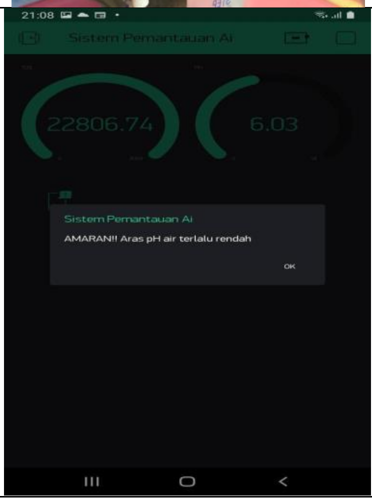
- Functionality Test on NodeMCU ESP32

The NodeMCU ESP32 microcontroller is used in this circuit as the main component that controls and processes the entire water quality monitoring system operation with automatic shut-off valves and this notification message sender. The test was performed on the NodeMCU ESP32 by measuring the voltage value on the 3V3 pin of the NodeMCU ESP32 and the negative leg of the NodeMCU ESP32. The voltage reading value from the tests carried out using a multimeter is 3.3 V.

- Functionality Test on Water pH Sensor

The water pH sensor measures the pH value of the water entering the home water system. Next, the data will be sent to the microcontroller and processed to perform operations on the output parts, solenoid valves 1 and 2. Table 1 shows the operation of the water pH detector and the notification from the Blynk application if the water pH value is less than 6.5 or above 9.0.

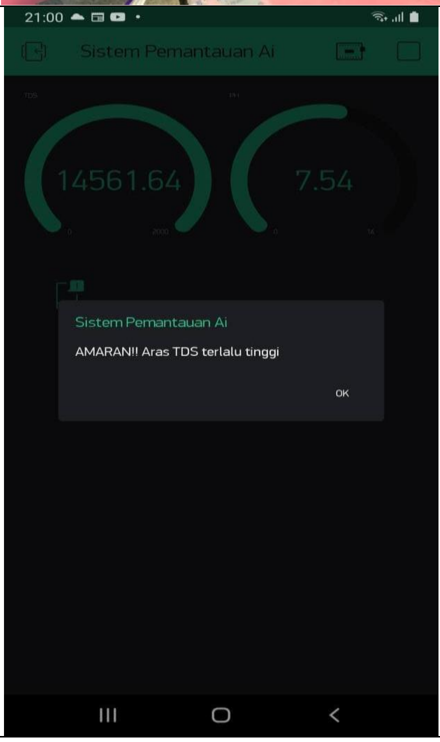
Table 1: Testing of water pH sensor operation and notification from Blynk application if water pH value is less than 6.5 or above 9.0

Operation	Description
	1. The water pH sensor is inserted into a container filled with water.
	1. Water pH value readings are shown on the Blynk application display. 2. A notification message is generated to warn of water quality not meeting the set standards.

- Functionality Test on Total Dissolved Solids Sensor.

The total dissolved solids sensor detects the total of solids dissolved in the water being tested. The data from the dissolved solids volume detector is then sent to the NodeMCU ESP32 microcontroller for processing. In turn, the microcontroller sends instructions to the output parts, namely solenoid valve one and solenoid valve 2, to act. Table 2 shows the total dissolved solids detector operation and the Blynk application notification if the total dissolved solids in water exceed 899 mg/liter.

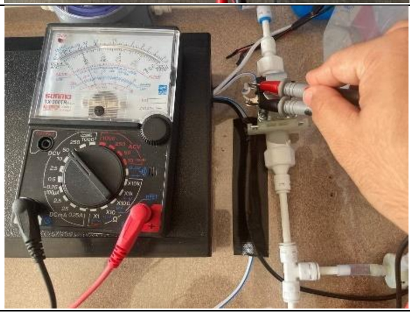
Table 2: Operational testing of the total dissolved solids sensor and notification from the Blynk application if the total dissolved solids in water exceed 899 mg/liter

Operation	Description
	1. The total dissolved solids sensor is placed in a container filled with water.
	2. A reading of the value of the total dissolved solids is shown on the Blynk application display. 3. A notification message is generated to warn of water quality not meeting the set standards.

- Functionality Test of 12V Solenoid Valve

A solenoid valve is used to allow or block the passage of water through it. Suppose the water quality data received by the NodeMCU ESP32 microcontroller indicates good water quality. In that case, the first solenoid valve will open and allow water to pass through it, while the second solenoid valve will close. If the water quality data received by the NodeMCU ESP32 microcontroller shows poor water quality, the first solenoid valve will be closed while the second solenoid valve will be opened for water to pass through it and directly to the water filter for the filtration process. Table 3 shows the operation of the first and second solenoid valves if the detected water quality is either good or bad. A multimeter is used to detect the presence of current and voltage at the solenoid valve.

Table 3: Operational test of the first and second solenoid valves

Operation	Description
	1. The multimeter reading indicates a value of 10V, indicating that there is a presence of direct current voltage that energises the first solenoid valve that leads to the main passage of water.
	2. The multimeter reading indicates a value of 10V, indicating that there is a presence of direct current voltage that energises the second solenoid valve that leads to the water filter.

- Functionality Analysis of Water Filter

The water filter filters the water that passes through the second solenoid valve. Throughout the testing on a water quality monitoring system with automatic shut-off valves and a notification message sender, the water filter can reduce the number of solids dissolved in the water. Table 4 shows the operation of the water filter used. The two main detectors re-evaluate the water coming out of the water filter.

Table 4: Water quality test after passing through the water filter used

Operation	Description
	1. Both water sensors are included in the filtered water container.
	2. The reading on the Blynk display the value of the total dissolved solids and pH of water. 3. The readings showed that the water filter could reduce the value of total dissolved solids but cannot increase the pH value of water.

3. Result and Discussion

The discussion is elaborated based on the three objectives of product development.

3.1 Designing Water Quality Monitoring System with Automatic Shut-Off Valves and Notification Message Sender

For the design steps of a water quality monitoring system with an automatic shut-off valve and notification message sender, a comprehensive study was conducted on seven water quality monitoring projects which are Khatri et al., (2019); Kavi Priya et al., (2017); Budiarti et al., (2019), Wiranto et al., (2015), Mukta et al., (2019) Krishna et al., (2020), and Kumar Jha et al., (2018). Once the study is implemented, several things can be improved and combined into one practical and suitable project to be installed at home. Therefore, improvements were made based on the existing products by developing a water quality monitoring system with automatic shut-off valves and a notification message sender.

At the beginning of the design process of a water quality monitoring system with an automatic shut-off valve and notification message sender, the researcher has identified some key components required, such as selecting a microcontroller, sensor, and even solenoid valve. These components are chosen to facilitate designing the necessary circuits and programs. The choice of components is also made carefully so that the product can operate as planned. The components selected were the NodeMCU ESP32 microcontroller, water pH sensor, turbidity sensor, electrical conductivity sensor, 12V solenoid valve, and relay switch. The very high cost of the electrical conductivity sensor caused the researcher to discuss replacing the electrical conductivity detector with a total dissolved solids sensor with the supervisor. The supervisor agreed with the researcher's proposal for a change of sensor type.

For the circuit design process, initially, the researcher has chosen Fritzing software but has changed to Proteus software as in Figure 3 due to the components that cannot be found in Fritzing library. Next, for the physical design of a water quality monitoring system with automatic shut-off valves and a notification message sender, the researchers used SketchUp software. This SketchUp software gives the researcher ease in the design process and can see the physical form of the water quality monitoring system project with automatic shut-off valves and this notification message sender. This software's advantages are that the design can be made in 3D.

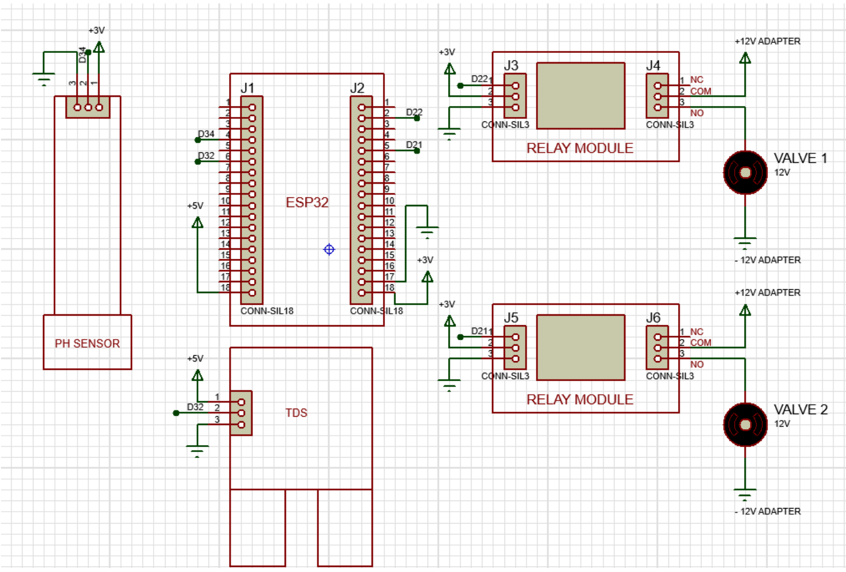


Figure 3: Schematic circuit drawing using Proteus software

Next, the coding for the Arduino software for the water quality monitoring system program with automatic shut-off valves and notification message sender was also identified for the suitability of each component used. Some code searches can be found through YouTube and Google.

3.2 Installing the Hardware and Software of the Water Quality Monitoring System with Automatic Shut-Off Valves and Notification Message Sender

Once the project design process of the water quality monitoring system with automatic shut-off valves and notification message sender is implemented, it is followed by the system hardware and software installation process. At the beginning of the process, the water pH sensor and the turbidity sensor are installed separately and tested to ensure that the detector is in good condition and that the program code entered is also appropriate. After that, the detector is installed by selecting the right pin. The program code is combined, and the sensor is tested first to ensure that the program code that has been connected is accurate and that the water value reading can be detected. Then the installation of the relay switch is made on the pins that have been planned in the schematic circuit. The 12V solenoid valve is connected to a female power plug jack adapter on COM and neutral on NO. This female power plug jack adapter will be connected to the 12V AC-DC adapter as a voltage supply to the 12V solenoid valve. The program code for opening the solenoid valve is included in the previously created program.

For hardware connections to the Blynk app, smartphones that use the Android-type user interface are used. To connect the sensor readings with the Blynk application, a code must first be generated from the Blynk application and inserted into the program code created. Next, the connection of the microcontroller with broadband internet is also essential and needs to be made by adding code to the program. The NodeMCU ESP32 microcontroller is connected to a 2.4 GHz wavy internet connection. On the Blynk display, the researcher used a gauge-type show for each sensor type. Each gauge display is set with an appropriate range according to the type of sensor. All circuits are kept in a box for tidying purposes and protect several components such as a microcontroller, relay switch, and module of each detector for water quality monitoring system with automatic shut-off valves and notification message sender. The entire installation is based on 3D drawings created on the SketchUp software. There is a constraint for the turbidity detector for a comprehensive installation where it is not built as a waterproof component. This presents difficulties to the researcher. Researchers have already used hot glue to make the turbidity detector waterproof, but it cannot last long. Thus, the turbidity detector was dropped from being one of the water quality detectors. The water pH sensor and total dissolved solids volume sensor are used in this water quality monitoring system with automatic shut-off valves and a notification message sender.

3.3 Testing the Functionality of Water Quality Monitoring System with Automatic Shut-Off Valves and Notification Message Sender

After each component is installed, testing is carried out in a test run (test run) on the entire water quality monitoring system project with automatic shut-off valves and a notification message sender. This test run uses water mixed with salt water to test the water pH sensor and the total dissolved solids sensor. Water is drained into a container where there is a water quality sensor. After that, the Blynk app started. The Blynk display can display water quality value readings well. A notification message can be generated correctly if the water quality is not in good condition as specified in the program code. The pH value of good water has been set around 6.5 to 9.0, while the value of total dissolved solids has not exceeded 900g/L. Suppose the assessed water does not meet the specified criteria. In that case, the solenoid valve on the water filter passage will be energised and open the water passage while the solenoid valve on the main passage is not energised. The increased water level on the water filter indicates that the solenoid valve is functioning properly and coincides with the predetermined program. In addition to looking at the water level on the water filter, a multimeter is used to measure the input voltage to an energised solenoid valve.

After several test runs, the water quality monitoring system with automatic shut-off valves and notification message sender can operate adequately and coincide with the project operation flow chart and code that has been programmed. Next, the water from the water filter filtration was tested with the water pH sensor, and the total dissolved solids sensor found that the water filter used could not work correctly. Water filters can only reduce the number of dissolved solids but cannot raise the pH of the water.

4 Conclusion

The water quality monitoring system with automatic shut-off valves and notification message sender can work well and meet the set objectives. The water pH sensor and the total dissolved solids sensor work well and give readings. The use of the latest features NodeMCU ESP32 microcontroller is very suitable for low and medium-cost projects and has excellent ability to connect to broadband internet. The Blynk app display also functions well and displays precise readings and a notification system that can work well when assessing low water quality. The functionality of both solenoid valves is also suitable for blocking water flow. For water filters, other selections can be made for better quality water filters and increase the water's pH value. This water quality monitoring system with automatic shut-off valves and notification messages can assure users of their daily water consumption at home.

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References

Azanella, L. A. (2018). *Berapa Lama Manusia Bisa Bertahan Tanpa Makan dan Minum? Halaman all - Kompas.com*. Kompas.Com. https://sains.kompas.com/read/2018/10/18/145322323/berapa-lama-manusia-bisa-bertahan-tanpa-makan-dan-minum?page=all

Budiarti, R. P. N., Tjahjono, A., Hariadi, M., & Purnomo, M. H. (2019). Development of IoT for Automated Water Quality Monitoring System. *Proceedings - 2019 International Conference on Computer Science, Information Technology, and Electrical Engineering, ICOMITEE 2019*, 211–216. https://doi.org/10.1109/ICOMITEE.2019.8920900

Grubbs, M., & Strimel, G. (2015). Engineering Design: The Great Integrator. *Journal of STEM Teacher Education*, *50*(1). https://doi.org/10.30707/jste50.1grubbs

Haik, Y., & Shahin, T. M. M. (2011). *Engineering Design Process Second Edition* (Second). Cengage Learning.

Ibrahim, M. Y. (2020, June). "Hitam macam air longkang", penduduk kesal tahap kualiti air Kelantan. *MalayMail*, 4–7. https://www.projekmm.com/news/berita/2020/06/12/hitam-macam-air-longkang-penduduk-kesal-tahap-kualiti-air-kelantan/1874746

Jones, L. J. N., Kong, D., Tan, B. T., & Rassiah, P. (2021). Non-revenue water in Malaysia: Influence of water distribution pipe types. *Sustainability (Switzerland)*, *13*(4), 1–16. https://doi.org/10.3390/su13042310

Kavi Priya, S., Shenbagalakshmi, G., & Revathi, T. (2017). Design smart sensors for real-time drinking water quality monitoring and contamination detection in water distributed mains. *International Journal of Engineering & Technology*, *7*(1.1), 47. https://doi.org/10.14419/ijet.v7i1.1.8921

Khatri, P., Gupta, K. K., & Gupta, R. K. (2019). Smart Water Quality Monitoring System for Distribution Networks. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3352296

Krishna, S., Sarath, T. V., Kumaraswamy, M. S., & Nair, V. (2020). IoT-based water parameter monitoring System. *Proceedings of the 5th International Conference on Communication and Electronics Systems, ICCES 2020, ICC's*, 1299–1303. https://doi.org/10.1109/ICCES48766.2020.09138001

Kumar Jha, M., Kumari Sah, R., Rashmitha, M. S., Sinha, R., Sujatha, B., & Suma, K. V.

(2018). Smart Water Monitoring System for Real-Time Water Quality and Usage Monitoring. *Proceedings of the International Conference on Inventive Research in Computing Applications, ICIRCA 2018*, *Icirca*, 617–621. https://doi.org/10.1109/ICIRCA.2018.8597179

Li, P., & Wu, J. (2019). Drinking Water Quality and Public Health. *Exposure and Health, 11*(2), 73–79. https://doi.org/10.1007/s12403-019-00299-8

Mapulanga, A. M., & Naito, H. (2019). Effect of deforestation on access to clean drinking water. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(17), 8249–8254. https://doi.org/10.1073/pnas.1814970116

May, S. (2018). *Engineering Design Process*. NASA. http://www.nasa.gov/audience/foreducators/best/edp.html

Mohd Noor, Z. (2021, May). *Pencemaran Sungai Petani semakin serius*. 1–7. https://www.utusan.com.my/alam/2021/05/pencemaran-sungai-petani-semakin-serius/

Mukta, M., Islam, S., Das Barman, S., Reza, A. W., & Hossain Khan, M. S. (2019). IoT-based Smart Water Quality Monitoring System. *2019 IEEE 4th International Conference on Computer and Communication Systems*, 669–673.

Rahmanian, N., Ali, S. H. B., Homayoonfard, M., Ali, N. J., Rehan, M., Sadef, Y., & Nizami, A. S. (2015). Analysis of physiochemical parameters to evaluate the drinking water quality in the state of Perak, Malaysia. *Journal of Chemistry*, *2015*. https://doi.org/10.1155/2015/716125

Wiranto, G., Maulana, Y. Y., Hermida, I. D. P., Syamsu, I., & Mahmudin, D. (2015). We have integrated online water quality monitoring. *2015 International Conference on Smart Sensors and Application, ICSSA 2015*, *September*, 111–115. https://doi.org/10.1109/ICSSA.2015.7322521