© Universiti Tun Hussein Onn Malaysia Publisher's Office

JAESRR

http://publisher.uthm.edu.my/ojs/index.php/jaesrr

e-ISSN : 2821-2819

Journal of Advancement in Environmental Solution and Resource Recovery

Monitoring Water Level and Water Quality in Rainwater Harvesting Tank using Internet of Things (IoT) Device

Looi Zhe Hui[1], Siti Zanariah Rahmat[1*]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jaesrr.2022.02.02.008
Received 14 September 2022; Accepted 22 November 2022; Available online 28 December 2022

Abstract: Rainwater harvesting (RWH) system has great potential to mitigate the risk of water shortage issue throughout the world. However, continuous monitoring needs to be done to achieve the optimum performance in terms of water quantity and quality of the system. To address these issues, Internet-of-Things (IoT) technology is deployed to efficiently monitor water levels and water quality in the water tank. Furthermore, in Malaysia, research on the online monitoring especially using IoT is still very limited and needs to be explored. The objectives of this present study were twofold: first, to monitor the water level, pH and turbidity values of water in the RWH storage tank built using IoT devices, and second, to estimate the suitable volume of RWH storage tank on the rooftop of Kumpulan Perubatan Johor (KPJ) Batu Pahat Specialist Hospital. The combination of ultrasonic sensors, pH sensors, turbidity sensors and rain gauge with the Arduino were utilized for the water monitoring system installed at the storage tank. The output of the data, including water level, pH value, turbidity and rainfall depth were monitored through the online portal of MyAgriTECH Monitoring System within six months from November 2020 to April 2021. The time interval for the measurement of the parameters was every 10 minutes, from the beginning until the end. The water level obtained ranged from 132.15 cm to 184.11 cm. The pH value recorded ranged from 5.45 to 12.38, whereas the lowest turbidity and highest turbidity was 9.25 NTU and 67.11 NTU, respectively. For the estimation of optimum size for rainwater harvesting storage tank, the results obtained was 5 m^3. The use of IoT device in monitoring water level and water quality in RWH tank can be implemented due to RWH system is indeed one of the alternatives to solve the problem of water supply.

Keywords: Internet of Things, rainwater harvesting storage tank, water level, pH, turbidity

1. Introduction

Water quality is one of the essential elements in maintaining the human body's health, as water plays a vital role in humans' daily needs. As the human population grows throughout the year, the water consumed by the residents in Malaysia per day increases drastically. Compared to Malaysia's domestic metered water usage per day in 2012, the water usage has increased from 5.87 billion litres per day to around 6.82 billion litres per day in 2019 [1]. The differences are up to 1 billion litres per day. Apart from domestic usage, the water is consumed in non-domestic industry like Kumpulan Perubatan Johor (KPJ) Batu Pahat Specialist Hospital. According to KPJ's annual sustainability report in 2019, the annual water consumption for all the KPJ branches in Malaysia is up to 1,305,374 m^3 which is equivalent to 1,305,374,000 liters [2].

Due to the high-water demand, one of the water conservation approaches is the rainwater harvesting (RWH) system. RWH is a technique for collecting and storing rainwater for usage daily. RWH devices come in a variety of configurations. For instance, a simple system consisting of a rainwater collection tank and a more complicated structure

*Corresponding author: nazahiya@uthm.edu.my

consisting of pumps, tanks, and a purifying system. In Malaysia, despite the country's abundant water resources, the problem of water scarcity persists in several locations, including Kuala Lumpur, Petaling, Klang, Shah Alam, Kuala Selangor, Hulu Selangor, Gombak, and Kuala Langat [3]. In this case, Malaysia is also one of the countries with high yearly rainfall and consumes a lot of water for numerous purposes [4]. Therefore, the government has a high potential for adequately utilizing RWH system. The RWH system can be improved with the combination of IoT system to monitor the water level and rainfall data regularly to prevent unexpected circumstances like flooding.

Over 98 percent of Malaysia's water supply comes from surface water sources such as rivers and dams, while groundwater supplies are less than 2% only [5]. As a result, river water quality becomes a consideration in determining whether clean water resources are distributed to each location in need of water supply. Malaysia has seen tremendous development and urbanization [6], which has had a deleterious influence on the country's river basins to some extent [7]. Recently, severe river water contamination has resulted in water supply problems in several locations, most notably the Klang Valley. This issue should be tackled since it has detrimental effects on health [8], economic development in numerous sectors [9], and socioeconomic development [10]. In short, the primary source of raw water in the country, the river, has been facing the problem of water pollution due to waste being poured illegally into the river. Thus, monitoring of water quality from time to time becomes significant as when an abnormal situation occurs, immediate action can be taken to prevent contaminated water from being used.

This study aims to monitor water level and water quality in RWH storage tank at KPJ Batu Pahat Specialist Hospital using the IoT device. The study's objectives were to develop an IoT device to monitor the water level, pH value and turbidity in the installed RWH storage tank. The second objective was to estimate the suitable volume of the RWH storage tank installed.

2. Illustrations

IoT applications can permeate several spheres of daily life for people and even societies. The IoT is being deployed in various fields, including the environment, transportation, agriculture, industry, construction, and lifestyle. Monitoring and control are two applications that can add value to the user. It is a system that collects data on equipment performance, energy consumption, and environmental conditions. It enables managers and automated controllers to monitor it continuously and in real-time, anytime and everywhere. This advanced monitoring system will perform tasks such as revealing operating patterns, identifying areas for potential improvement, and forecasting future results, all of which will help optimize operations, save costs, and enhance productivity [11]. Figure 1 shows the IoT applications in various industries.

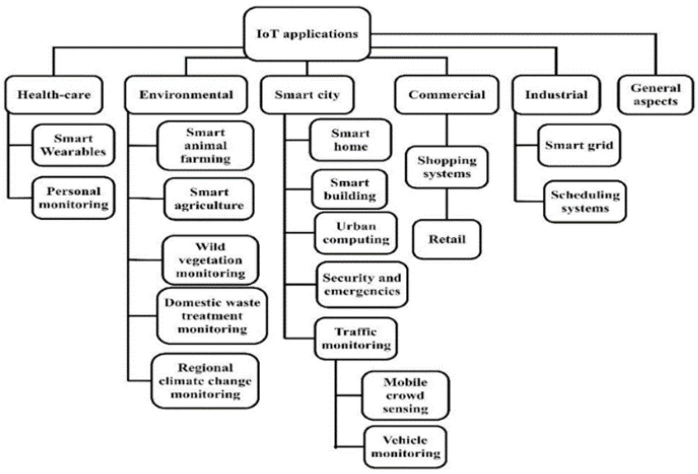


Fig. 1 - The taxonomy of IoT applications [12]

The IoT may be characterized as a network that connects everything to the Internet using specific protocols and information sensing equipment to perform smart recognitions, locating, tracking, monitoring, and administration. It can be monitored and managed inside the current Internet infrastructure since it consists of large web items integrated with wireless technologies [13].

2.1 Wireless Sensor Network (WSN)

Wireless networking is a technology that enables communication and access to the Internet between computers and other devices without the use of a cable connection. Wireless sensor networks have benefited the environment, health, commercial, and residential sectors by enabling the communication of devices across short distances. Additionally, it is referred to as an intelligent monitor because it is used to monitor temperature, water level, pressure, and structures such as bridges, buildings, tunnels, and vehicular traffic on highways, among other things [14]. The WSN is suited for monitoring the physical and chemical features of water in remote places at a reduced cost and with fewer manpower. It may be used for water quality monitoring and has several benefits, including mobility, near-real-time data collecting, and data logging [15]. The WSN system supports various wireless communication standards, including Wi-Fi, ZigBee, Ethernet, Bluetooth, and cellular. Through the selected wireless communication standards, the connected devices will enable users to control and supervise the base station [16]. Figure 2 illustrates a typical model system for WSN.

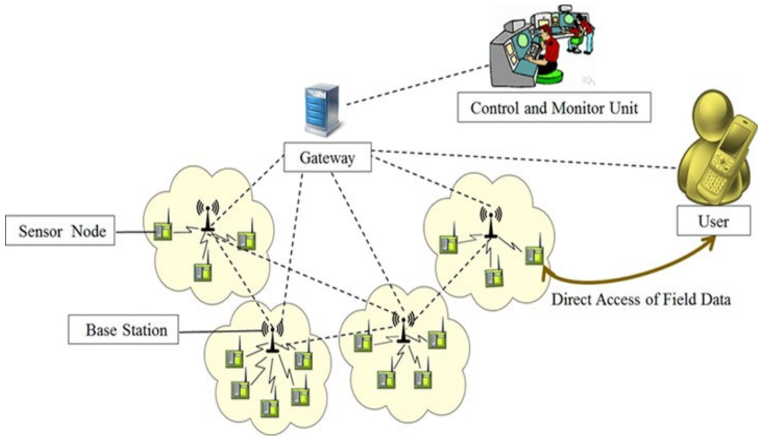


Fig. 2 - Typical model system for WSN [17]

3. Methodology

This online water monitoring system was comprised of three significant sensors, namely an ultrasonic sensor, a pH sensor, and a turbidity sensor, which provide data as analogue signals. Arduino Uno is responsible for translating these analogue signals into digital format and transferring the system's output data to the MyAgriTECH dashboard. The rain gauge was connected to the MyAgriTECH online portal to monitor the rainfall depth. Other components of the system include a Wi-Fi shield that allows Arduino to connect to the Internet through a mobile hotspot, a screw terminal shield, and a mobile phone with an internet connection. Figure 3 depicts the created system, including all of its components. The system installed onsite is shown in figure 4. The 200 cm depth of the RWH storage tank located on KPJ Batu Pahat Specialist Hospital is shown in figure 5.

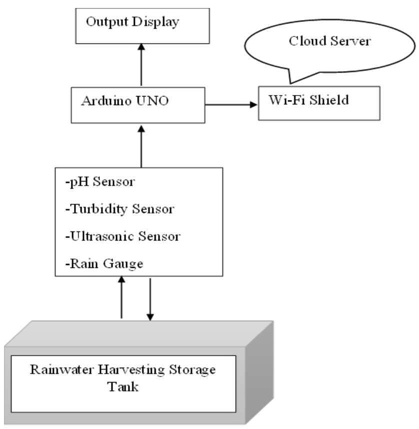


Fig. 3 - System architecture of the designed IoT system of the study

Fig. 4 - Location of IoT system installed at the RWH storage tank

Fig. 5 - Depth of RWH storage tank

3.1 Materials

The materials used to build the IoT system were pH sensor, turbidity sensor, ultrasonic sensor, Adruino Uno, Wi-Fi shield, screw terminal shield, and tipping bucket rain gauge. The pH sensor was used to indicate the acidity and alkalinity of the rainwater collected. The function of turbidity sensor was measuring the turbidity of rainwater by determining the light transmittance and scattering rate. The ultrasonic sensor was used to measure the height of water level in RWH tank. The Adruino Uno was used as a microcontroller board that can be incorporated into a range of electrical projects which were used to operate sensors and LED panel. The Wi-Fi shield was mounted on the Arduino board to utilize the Uno. The screw terminal shield functions as an expansion board, allowing wires to be fastened directly to the threaded terminals. The tipping bucket rain gauge was used to record the rainfall data.

3.2 Methods

The study location was equipped with the built-in IoT system to measure rainfall data from November 2020 to April 2021. The conventional technique requires the user to gather data manually. In contrast, the online water monitoring system provided statistics on the MyAgriTECH Monitoring System display dashboard, including pH, turbidity, water level, and rainfall depth. In addition, it served as a platform for collecting data created by installed scripts, allowing the user to save specific information in the cloud and providing widgets that display output data in a visually appealing style. The user may access the recorded data via a URL link, which can be read on any electronic device equipped with a web browser.

3.3 RWH Equations

It is possible to calculate the entire quantity of water that may be collected by determining the roof's catchment area, A_r. The building in the study area was discovered to be a flat roof. Consequently, the catchment area was calculated using Eq.1 [18], by multiplying the length of the rooftop catchment, L, with width of rooftop catchment, W.

$$A_r = L \times W \qquad (1)$$

The size of the storage tank is often determined by various parameters, including the number of users, the purpose of water consumption, the length of water shortage, the quantity of precipitation, and the size of the catchment area. The storage tank's capacity, which represents the overall household water demand during periods of water shortage, must be compared to the quantity of water accessible from the house's roof during rainy seasons. If the amount of water accessible from the roof is less than the needed capacity of the storage tank, the home may only utilize roof water for a portion of the water shortage time. In this study, the size of the tank, independent of location, is determined by 100 m^2 of roof area, equivalent to 1 m3 or 1000 L of collected rainwater [19]. The size of RWH storage tank can be approximated using Eq 2. In order to obtain the RWH storage tank size (S_t), the roof's catchment area, A_r is multiplied with 0.01.

$$S_t = 0.01A_r \qquad (2)$$

4. Results and Discussion

4.1 MyAgriTECH Online Monitoring System

The output data collected daily were sent to the online water monitoring system. All the data were displayed on the MyAgriTECH online portal. To access MyAgriTECH online portal, an account was registered using a valid email address through the approval of the admin of MyAgriTECH. A verification email was sent to the registered email address to validate the user's identity. After registering successfully, the user can access MyAgriTECH to monitor the data in real-time. MyAgriTECH was designed with a simple and user-friendly interface that was easy for people to use and learn. All the data can be downloaded in three forms: Microsoft Excel Comma Separated Values (CSV) and Portable Document Format (PDF), and Text file (txt), based on the preference of the user to analyze the data. The data collected can be downloaded by choosing the specific period user prefer. Due to the data being recorded at a 10 minutes interval, it was easier to download the data daily to simplify the analysis. Figure 6 shows the interface of the online portal MyAgriTECH monitoring system.

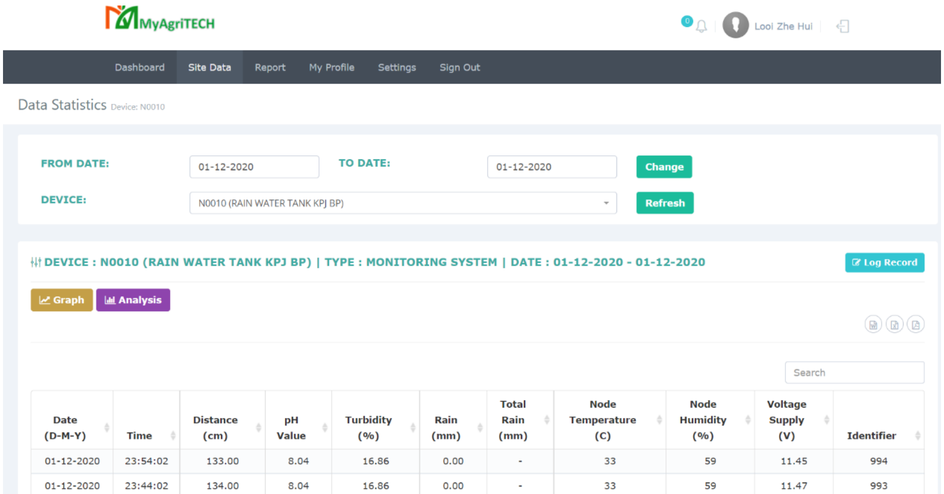
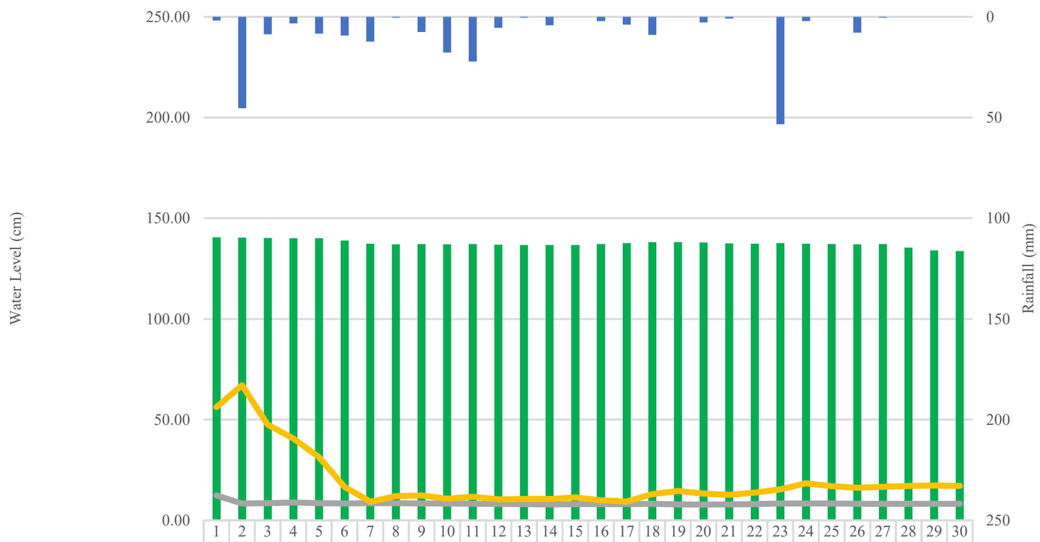


Fig. 6 - MyAgriTECH data interface shows collected data of water level (distance), pH value, turbidity and rainfall

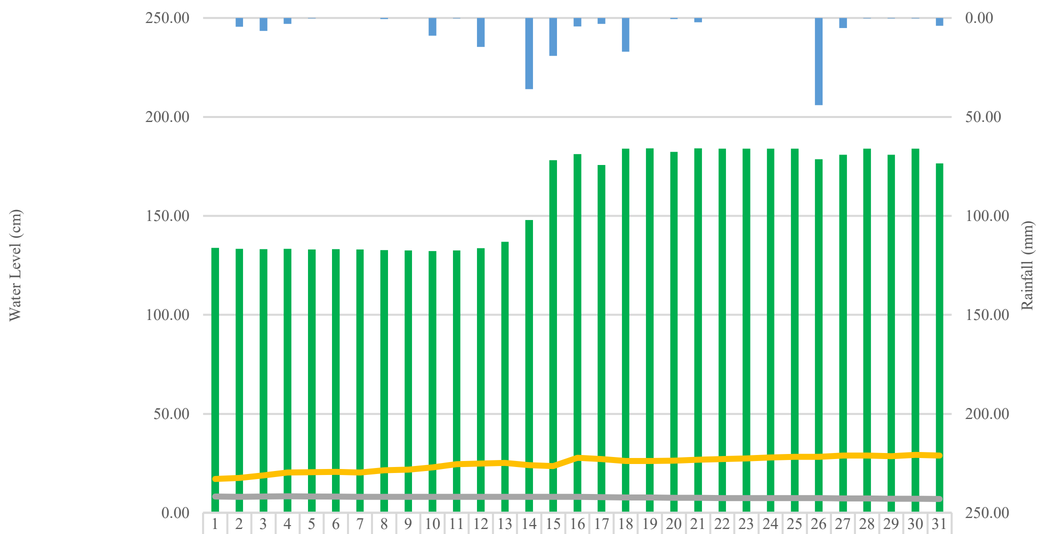
4.2 Relationship of Water Level, pH, Turbidity with Rainfall

The relationship of water level, pH and turbidity with the rainfall depth was analyzed and presented through the graphs. Figure 7 to figure 12 shows a connection between the water level of the RWH storage tank, pH, turbidity of rainwater and rainfall depth from November 2020 to April 2021.



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Water Level (cm)	140	140	140	139	140	138	137	137	137	137	137	136	136	136	136	137	137	138	138	138	137	137	137	137	137	137	137	135	134	133
Rainfall (mm)	1.8	45	8.7	3.3	8.4	9.2	12	0.3	7.6	18	22	5.4	0.3	4.2	0	2.1	3.9	9	0	2.7	0.9	0	53	2.1	0	7.8	0.3	0	0	0
pH	12.	8.4	8.4	8.8	8.5	8.3	8.5	8.4	8.3	8.3	8.2	8.1	8.1	7.9	8.0	8.1	8.0	8.2	7.9	7.8	7.9	8.0	8.4	8.3	8.3	8.2	8.2	8.2	8.2	8.1
Turbidity (NTU)	56.	67.	47.	40.	31.	16.	9.2	12.	12.	10.	11.	10.	10.	10.	11.	9.9	9.3	12.	14.	13.	12.	13.	15.	18.	16.	16.	16.	17.	17.	17.

Fig. 7 - Relationship between water level, pH, turbidity and rainfall in November 2020



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Water Level (cm)	133	133	133	133	132	133	133	132	132	132	132	133	136	147	178	181	175	184	184	182	184	183	183	184	183	178	180	183	180	183	176
Rainfall (mm)	0.0	4.5	6.6	3.0	0.3	0.0	0.0	0.6	0.0	9.0	0.3	14.	0.0	36.	19.	4.2	3.0	17.	0.0	0.6	2.1	0.0	0.0	0.0	0.0	44.	5.1	0.3	0.3	0.3	3.9
pH	8.1	8.0	8.1	8.3	8.2	8.1	8.0	8.0	7.9	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.8	7.7	7.7	7.6	7.5	7.4	7.3	7.3	7.3	7.3	7.3	7.2	7.1	7.0	6.9
Turbidity (NTU)	17.	17.	18.	20.	20.	20.	20.	21.	21.	22.	24.	24.	25.	24.	23.	27.	27.	26.	26.	26.	26.	27.	27.	28.	28.	28.	28.	28.	28.	29.	28.

Fig. 8 - Relationship between water level, pH, turbidity and rainfall in December 2020

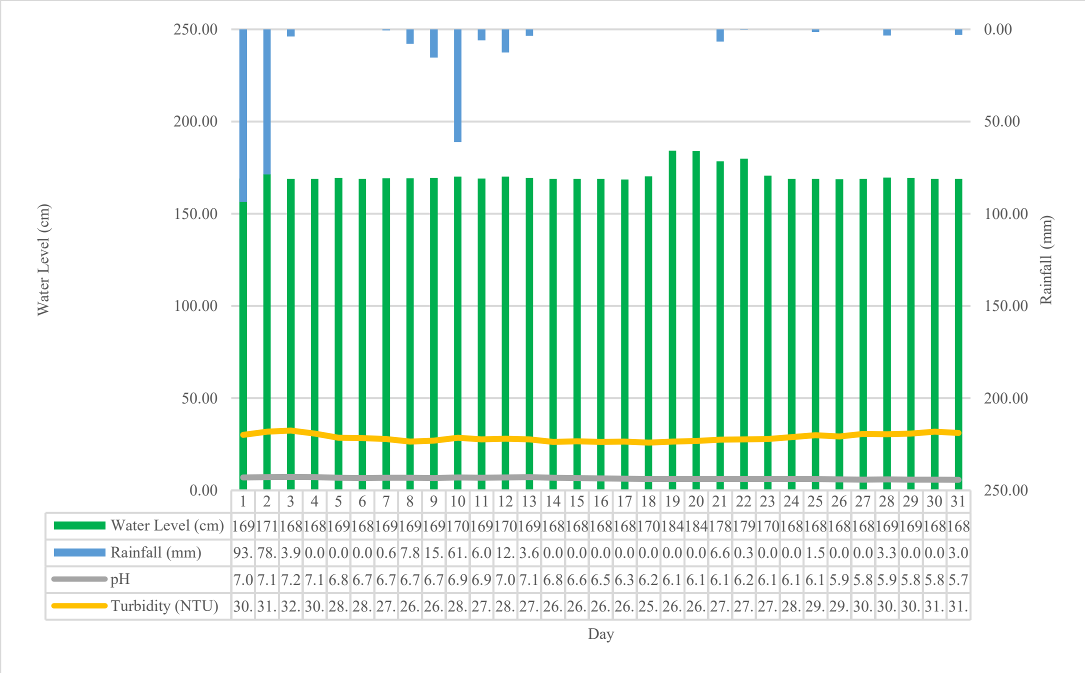


Fig. 9 - Relationship between water level, pH, turbidity and rainfall in January 2021

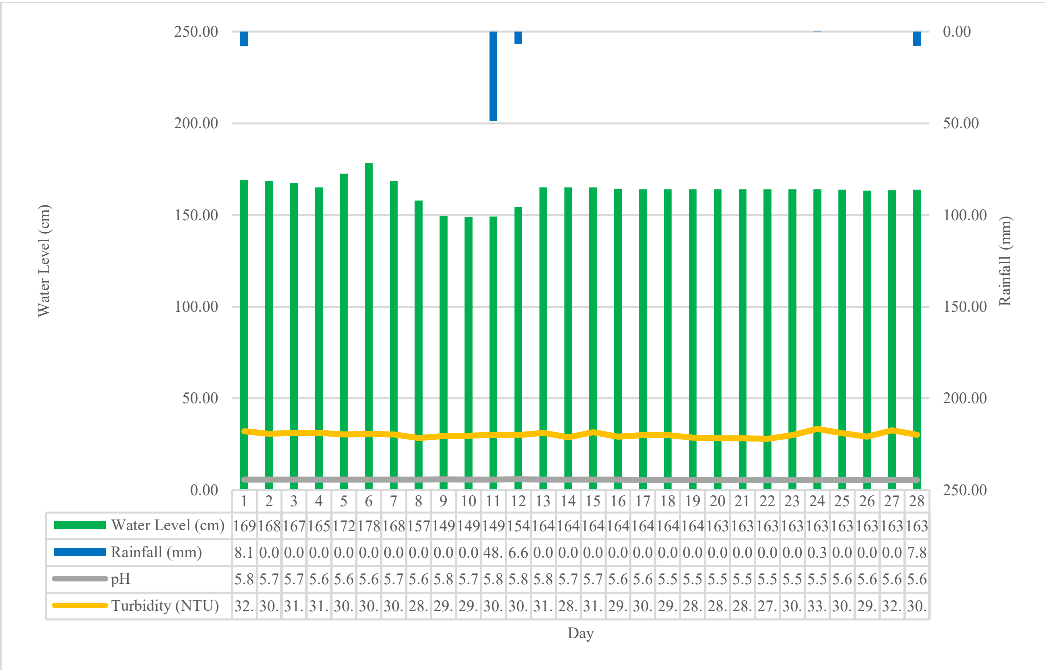


Fig. 10 - Relationship between water level, pH, turbidity and rainfall in February 2021

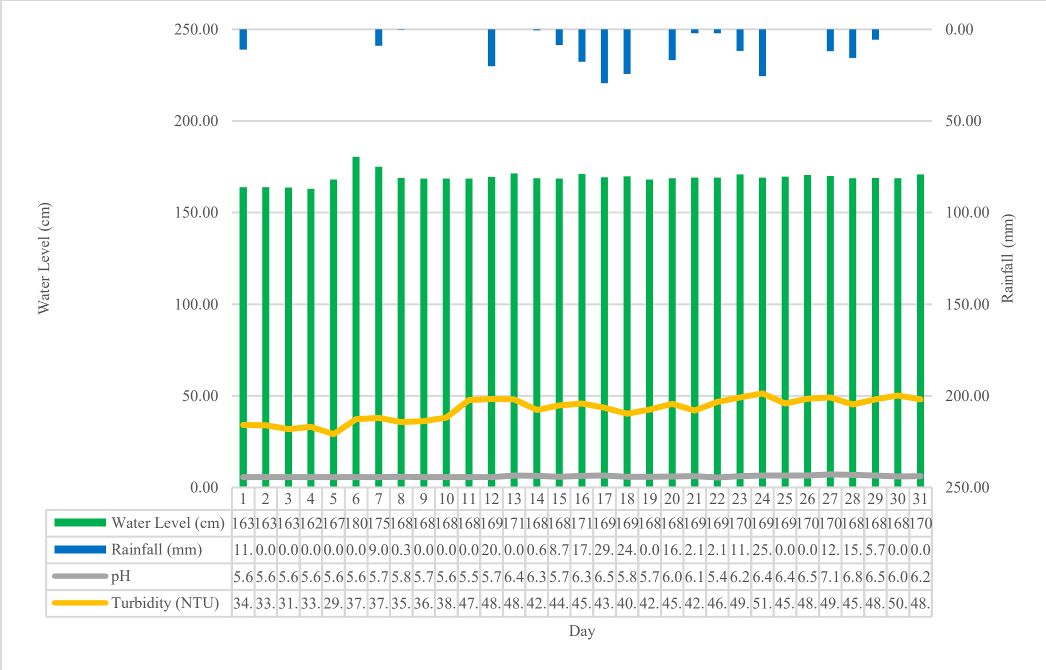


Fig. 11 - Relationship between water level, pH, turbidity and rainfall in March 2021

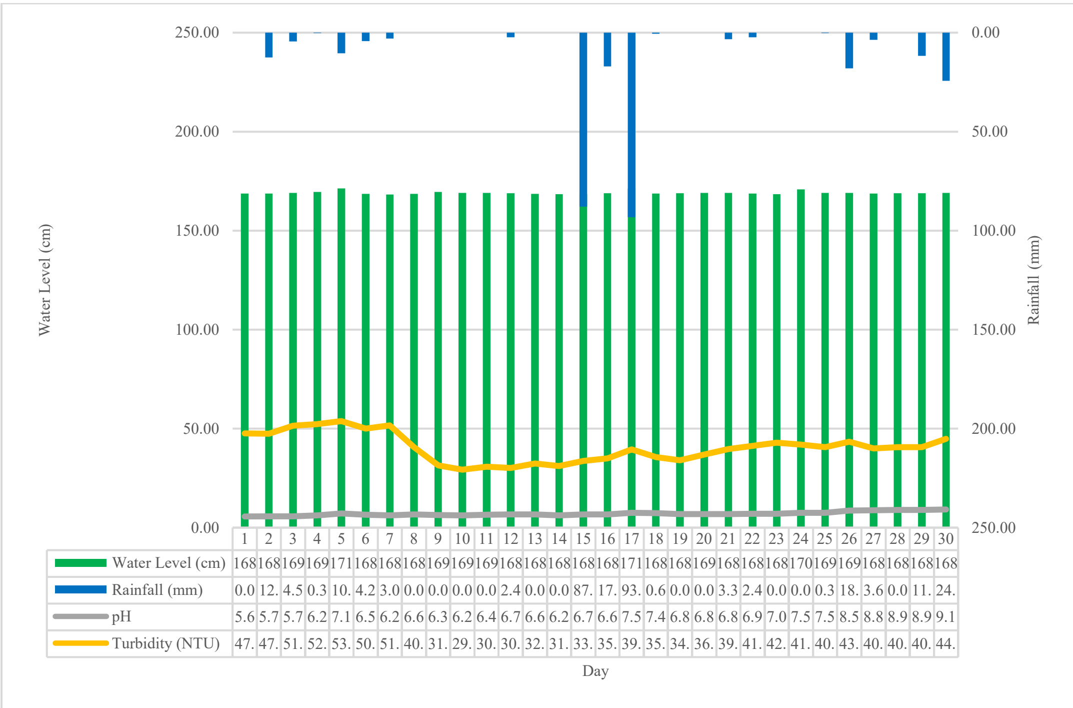


Fig. 12 - Relationship between water level, pH, turbidity and rainfall in April 2021

As observed from the figures above, the water level did not differ much due to the low usage of rainwater collected. The pH value varied between acid, neutral and alkaline due to the combination of industry activity and rainfall events. The further explanation was discussed in section 4.3. The trend of decreasing NTU value was shown from figure 7 until figure 12 whenever a rainfall event occurred.

4.3 Water Level

As shown in figure 7, the water level maintained almost the same, from 140 cm in early November to 133 cm at the end of November 2020. The usage was 0.7 m3 or 700 litres. The lowest and highest water level for November 2020 can be observed from figure 7, which was 133.72 cm and 140.49 cm. The overall highest water level of RWH storage tank was recorded at 184.11 cm on 21st December 2020, whereas the overall lowest water level was at 132.15 cm on 10th December 2020, as clearly shown in figure 8. Compared to the other months, both the highest and lowest water levels were in December 2020. In January of 2021, as shown in figure 9, the water level hit its lowest point of 168.53 cm and its highest peak of 184.10 cm. February 2021's minimum and maximum water levels were 149.06 cm and 178.47 cm, respectively, as illustrated in figure 10. In March 2021, the water level varied, with its lowest point measuring 162.94 cm and its highest point measuring 180.49 cm. In April 2021, the lowest point water level was 168.27 cm and reached its highest height of 171.36 cm in the same month, as shown in figure 12.

From the results observed, the water level of RWH storage tank did not differ much due to minimizing gardening usage. The plants around KPJ Batu Pahat Specialist Hospital were watered by the collected precipitation directly or by the rainwater whenever it was raining. The tank is constructed with an overflow pipe if there is persistently heavy rainfall. This line allows any surplus water that has accumulated in the tank to be drained away through the building's outside drainage system [20]. This means when the RWH storage tank has sufficient water, the remaining rainwater in the RWH storage tank was drained to prevent overflow, thus the peak water level of collecting rainwater in the RWH tank was maintained at 185 cm.

4.4 pH

As observed from the pH trend as shown in the figures on Section 4.2, the pH readings were mainly in alkaline conditions from the beginning of November 2020 (Figure 7) to December 2021 (Figure 8). In November 2020 (Figure 7), the pH readings ranged from 7.84 to 12.38. In December 2020 (Figure 8), the pH reading ranged from 6.97 to 8.32. The rainwater collected was more prone to neutral and alkaline due to the lesser emission of gases from the vehicles and factories, which produced nitrogen oxides and sulphur dioxide that caused acid rain. In fact, this phenomenon was due to the worldwide pandemic Covid-19 that emerged in 2020. To safeguard against the spread of Covid-19, the Malaysian government enacted Movement Control Order (MCO), limiting the citizens' daily activities. Consequently, the whole industrials and educational sectors were temporarily shut down, and everyone was compelled to remain at home. Thus, the combustion of coal and oil for producing electricity and the exhaust gases released from vehicles that causes nitrogen oxides and sulphur dioxide in the air was significantly reduced.

However, the pH readings started to change from alkaline and neutral to acidic conditions from January 2021 until April 2021 (Figure 9 to figure 12) due to the implementation of the Recovery Movement Control Order in Malaysia. In January 2021, the pH varied between 5.74 and 7.29. In February 2021 (Figure 10), the pH ranged from 5.57 to 5.86, which remains in acid condition due to lesser rainfall was occurred in February 2021. The pH varied from 5.45 to 7.13 in March 2021 (Figure 11), and in April 2021 (Figure 12), the pH fell between 5.65 and 9.18. The pH variations were caused by the mixing of rainfall that dropped through the roof system with leaves, dust, and bird droppings. These particle depositions contributed to the changes in pH. Water with a pH below the criterion may adversely affect the vehicle, such as steel corrosion when used to wash a car. Acidic water was also detrimental to plant life if used for agriculture [21].

4.5 Turbidity

For the turbidity data recorded from November 2020 to April 2021 (Figure 7 to figure 12), the turbidity sensor recorded a value ranging from 9.25 NTU to 67.11 NTU over the measurement duration. The turbidity readings were within the acceptable range for raw water, which was 1000 NTU [22]. The trend of decreasing NTU value was shown from figure 7 until figure 12 whenever a rainfall event occurred. This phenomenon was due to the contaminant on the roof being flushed away by precipitation. As the period of rain increases, the particles were flushed away; hence, turbidity decreases as rain duration increases. However, several precautions should be taken while using the turbidity sensor. The factors affecting the results were the light source, detecting angle, and sensitivity of the turbidity sensor. The ability of a turbidity sensor to monitor a wide range of turbidity depends on three essential design factors: source of illumination, detector angle, and sensitivity. The longer the path length, the greater the detection limit or the instrument's capacity to detect tiny turbidity changes at extremely low turbidity levels. However, a large measurement range is sacrificed with an extremely long path length. Thus, if one needs to measure up to 10,000 units, a method with poor sensitivity at extremely low turbidity levels (usually below 1 unit) most likely be used.

4.6 Rainwater Harvesting Storage Tank Size Estimation

The results computed from the estimated size and the actual size of RWH storage tank located on the rooftop of KPJ Batu Pahat Specialist Hospital were five times larger than the estimated size based on Eq. 2. The actual volume of RWH storage tank was 20 m^3 or equivalent to 20000 *l*, compared to the estimated volume of 5 m^3 or equal to 5000 litres.

The RWH storage tank was designed for outdoor usage instead of indoor usage. However, the larger size of the RWH storage tank was used due to the high rainfall available around the location. The result computed from the water demand was 3960 *l* per month, while the water supply (rainwater collected) was 76973 *l* per month, and the water supply was higher than the water demand and the size of RWH storage tank. By collecting more rainwater in the RWH storage tank, the quantity of rainfall entering the drainage system was minimized, preventing floods [23, 24]. Thus, the rooftop was encouraged to install sufficient RWH storage tanks if there were enough spaces on the roof.

5. Conclusion

The IoT device is a computer concept that outlines the idea of common physical items being linked to the Internet and able to identify themselves to other devices. This study monitored the water level and water quality in RWH storage tank via an IoT device. An IoT device was successfully built to monitor the water level, pH value, turbidity of the RWH storage tank and rainfall depth. The data was uploaded to the server, and the data can be monitored via the online portal of MyAgriTECH. The water level obtained ranged from the lowest value of 132.15 cm on 10th December 2020, to the highest value of 184.11 cm on 21st December 2020. The pH value recorded throughout the six months ranged from 5.45 to 12.38, whereas the lowest turbidity and highest turbidity was 9.25 NTU and 67.11 NTU, respectively. The second objective was achieved by determining the optimum tank size by using the formula given. The optimum size of RWH was 5 m^3 corresponding to the rooftop catchment area. However, the water supply (rainwater collection) was higher than the calculated water demand. Thus, the water tank installed was at a larger size at 20 m^3.

It can be concluded that the use of IoT device in monitoring water levels and water quality in RWH tank can be implemented due to RWH system is indeed one of the alternatives to solve the problem of water supply. With the usage of IoT, real-time tracking and monitoring can be performed to predict unusual activities such as heavy rainfall that might cause an overflow. For future work, the system should be installed at different sizes of rainwater tank and locations. The results would be useful for designing the components of the RWHS.

Acknowledgement

We would like to convey our gratitude to those who tirelessly provided advice and assistance during the period of this study to guarantee that this research met its desired objectives. This research was supported by Ministry of Higher Education (MOHE) through Fundamental Research Grant Scheme (FRGS/1/2020/WAB02/UTHM/02/8).

References

[1] Müller, J. (2021). Domestic metered water consumption in Malaysia 2012-2019, Statistics Malaysia, Apr. 07, 2021. https://www.statista.com/statistics/796354/domestic-metered-water-consumption-malaysia/ (accessed Dec. 05, 2021).

[2] Kumpulan Perubatan Johor Healthcare Berhad, (2019). "Sustainability_Report_2019," 2019. Accessed: Jan. 03, 2022. [Online]. Available: https://kpj.listedcompany.com/misc/ar2019/Sustainability_Report_2019.pdf

[3] Aminnuraliff, M. (2021)."Tujuh kawasan alami gangguan bekalan air," Sinar Harian, Sep. 03, 2020. Accessed: Feb. 04, 2021. [Online]. Available: https://www.sinarharian.com.my/article/99472/EDISI/Selangor-KL/Tujuh-kawasan-alami-gangguan-bekalan-air

[4] Lani, N. H. M., Yusop, Z. and A. Syafiuddin, (2018). "A review of rainwater harvesting in Malaysia: Prospects and challenges," Water (Switzerland), vol. 10, no. 4. MDPI AG. doi: 10.3390/w10040506.

[5] Chamhuri, S., Ara Begum, R., Ahmed, F. and Siwar, C. (2005) "JFAE (Food & Health-PartA) Vol3-1 (2005),". [Online]. Available: www.world-food.net

[6] Nambi Malarvizhi C. A. and Chitra, M. (2020). Analysing the Economic Performance and Projecting for Future: The Case of Malaysia, Shanlax International Journal of Economics, vol. 8, no. 3, pp. 83–87, Jun. 2020, doi: 10.34293/economics.v8i3.3222.

[7] Salam M. A. et al., (2020). Trace metals contamination potential and health risk assessment of commonly consumed fish of Perak River, Malaysia, PLoS ONE, vol. 15, no. 10 October, Oct. 2020, doi: 10.1371/journal.pone.0241320.

[8] Utsev, J. T.and Aho, M. I. (2012). Water Shortage and Health Problems In Benue State-Nigeria: Impacts And Prospects For Solutions, International Journal Of Scientific & Technology Research, vol. 1, no. 8, 2012, [Online]. Available: www.ijstr.org

[9] Nobre, C. A., Marengo, J. A., Seluchi, M. E., Cuartas, L. A. and Alves, L. M. (2016). Some Characteristics and Impacts of the Drought and Water Crisis in Southeastern Brazil during 2014 and 2015. Journal of Water Resource and Protection, vol. 08, no. 02, pp. 252–262, 2016, doi: 10.4236/jwarp.2016.82022.

[10] Mohamed, N. N. (2019). Egyptian Food Insecurity Under Water Shortage and Its Socioeconomic Impacts. in Conventional Water Resources and Agriculture in Egypt, A. M. Negm, Ed. Cham: Springer International Publishing, 2019, pp. 245–273. doi: 10.1007/698_2018_239.

[11] Lee, I. .and Lee, "K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises," Business Horizons, vol. 58, no. 4, pp. 431–440, Jul. 2015, doi: 10.1016/j.bushor.2015.03.008.

[12] Asghari, P., Rahmani, A. M. and Javadi, H. H. S. (2019). Internet of Things applications: A systematic review. Computer Networks, vol. 148, pp. 241–261, Jan. 2019, doi: 10.1016/j.comnet.2018.12.008.
[13] Patel, K. K., Patel, S. M. and Scholar, P. G. (2016). Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges. [Online]. Available: http://ijesc.org/
[14] Rashid, B. and Rehmani, M. H. (2016). Applications of wireless sensor networks for urban areas: A survey. Journal of Network and Computer Applications, vol. 60. Academic Press, pp. 192–219, Jan. 01, 2016. doi: 10.1016/j.jnca.2015.09.008.
[15] Demetillo, A. T., Japitana, M. V. and Taboada, E. B. (2019). A system for monitoring water quality in a large aquatic area using wireless sensor network technology. Sustainable Environment Research, vol. 1, no. 1, 2019, doi: 10.1186/s42834-019-0009-4.
[16] Myint, C. Z., Gopal, L.and Aung, Y. L. (2017). Reconfigurable smart water quality monitoring system in IoT environment," in Proceedings - 16th IEEE/ACIS International Conference on Computer and Information Science, ICIS 2017, Jun. 2017, pp. 435–440. doi: 10.1109/ICIS.2017.7960032.
[17] Alzubi, O. A. (2022). Quantum readout and gradient deep learning model for secure and sustainable data access in IWSN. PeerJ Computer Science, vol. 8, p. e983. doi: 10.7717/peerj-cs.983.
[18] National Hydraulic Research Institute of Malaysia (NAHRIM), "NAHRIM Technical Guide No. 2: The Design Guide For Rainwater Harvesting Systems," 2016.
[19] Department of Irrigation and Drainage (DID) Malaysia, Urban stormwater management manual for Malaysia. Department of Irrigation and Drainage (DID) Malaysia, 2012. Accessed: Jan. 04, 2022. [Online]. Available: https://www.water.gov.my/jps/resources/PDF/MSMA2ndEdition_august_2012.pdf
[20] Nasif, M. S. and Roslan, R. (2016). Effect Of Varying Roof Run-Off Coefficient Values And Tank Size On Rainwater Harvesting System's Water Savings In Malaysia. vol. 11, no. 22, [Online]. Available: www.arpnjournals.com
[21] Sivaramanan, S. "Acid rain, causes, effect and control strategies," (2015). doi: 10.13140/RG.2.1.1321.4240.
[22] Muhamad, M. A. and Abidin Z. (2016) Water Quality Assessment of Rainwater Collected from Rooftop at UTM," 2016.
[23] Che-Ani, A. I., Sairi A., Zain, M .and Tahir, M. (2009). Rainwater Harvesting as an Alternative Water Supply in the Future Economic Analysis of Coastal Vulnerability to Sea Level Rise and Cost Benefit Analysis of Climate Change Adaptation Measures in the Coastal Areas View Project Building Inspection and Management View project Rainwater Harvesting as an Alternative Water Supply in the Future. [Online]. Available: http://www.eurojournals.com/ejsr.htm
[24] Jan, F., Min-Allah, N., Saeed, S., Iqbal S. Z. and Ahmed R (2022). "IoT-Based Solutions to Monitor Water Level, Leakage, and Motor Control for Smart Water Tanks". Water, 14(3), 309.
[25] Ibrahim, R. N. ., & Ahmad, N. A. . (2022). Stormwater Drainage Design (Case Study: UTHM Campus). Journal of Advancement in Environmental Solution and Resource Recovery, 2(1), 1–7. Retrieved from https://penerbit.uthm.edu.my/ojs/index.php/jaesrr/article/view/11532
[26] Azwan, A., Norazman, A. F., Seswoya, R., & Pa'ee, F. (2021). Ponds in UTHM: Water Criteria and Quality. Journal of Advancement in Environmental Solution and Resource Recovery, 1(1), 1–8. Retrieved from https://penerbit.uthm.edu.my/ojs/index.php/jaesrr/article/view/10026