

Residential Water Tanks with IoT: A Solution for Household Water Consumption Monitoring

ABSTRACT

Wasting water has been a big problem in human society throughout the world. It can happen either in developed or developing countries. They tend to waste the water without knowing it. Moreover, people's awareness of the importance of using water wisely is still low. While they think the source of water is limitless, in fact, it is not. In contrast, the availability of freshwater in the world is limited. Furthermore, if the water is overused without reservation, it can trigger the phenomenon of water scarcity. However, the problem of wasting water can be reduced by using the water wisely and efficiently. With the growth of Internet of Things technology, it can help people use water efficiently by monitoring their water consumption. The Internet of Things (IoT) is a network of real-world items that may communicate with other electronic devices and systems via the internet by using sensors, software, and other technologies. IoT devices can be used for the purpose of household or the industrial. This paper focuses on designing and implementing a residential water tank system embedded with the Internet of Things technology for monitoring the water consumption in a household. The system will measure the water consumption from the residential water tank and send the data to a cloud server. Users will then be able to monitor it using a mobile device. With the data, users could change their habits of using water and start to use it wisely. Thus, the water shortage can be prevented.

Keywords: Wasting water; water efficiency, water consumption; residential water tank; internet of things

1. INTRODUCTION

A water shortage occurs when the amount of fresh water available to people is insufficient to meet their demand [1]. It has been faced by many people from different parts of the world. It has also attracted a large number of researchers who are working to solve this problem [2]. Even though the Earth consists of 70% water, the amount of fresh water available is only about 3%. It makes fresh water very important and limited, particularly in big cities in developing countries [3]. In addition, the growth of the population and the impact of urbanization have increased the water demand. Also, the water shortage is made worse in many countries by the growth of agricultural irrigation [4], [5]. Thus, the water crisis may become a threat to the world [1].

In Indonesia, most households get their fresh water from groundwater wells and store it in tanks before using it for daily necessities [6]. In addition, they think that the water is limitless. The truth is that it is not [7]. If it is always used without restriction and not taken care of carefully, it can be depleted [8]. Moreover, one of the reasons that the water shortage is happening is the unwise use of water [9]. In fact, many people tend to use water more than they need and waste it without knowing it. For instance, people tend to keep the faucet in the kitchen or bathroom on after using it, overuse the water when washing cars or other vehicles,

and waste water when taking a bath or shower [6]. These behaviors are driving the world into a water crisis. As a result, the wise use of water plays an important role in alleviating the water shortage [2].

With the advent of the Internet of Things and related technology, it is possible to make things easier [10]. One of them is monitoring household water consumption by integrating the internet of things with a residential water storage tank. By controlling water usage wisely, it can help preserve the environment in general and avoid a water crisis [1]. There have been studies on the use of IoT for water tanks [11]. Several studies [12]–[17] proposed an IoT-based architecture for monitoring water level and quality in a residential water tank. [18] used an ultrasonic sensor to measure the level of water in a tank. The system can be implemented to install tanks underground or overhead. They also used pump switching systems to control the water. In research by Saravanan et al. [19], they designed a system with an internet of things that can distribute water from a tank for people in urban areas who live in apartments or flats. A tank system based on IoT that can fill the water automatically was presented by Durga et al. [20]. It aimed to reduce water waste, save electricity, and improve water distribution efficiency. Other projects focused on an IoT smart system for water tanks with an Android application [21], [22]. They can control and monitor the water level using an Android-based smartphone. Another study created a system with an Arduino for monitoring the color change in the water tank for safe drinking water [23]. It uses pressure sensors, grayscale, and RGB color.

The traditional way to observe the water consumption in a household is by placing a manual water meter in the water tank. This method is still conventional and makes it difficult to monitor the water use. To measure the daily water consumption, it needs to be calculated manually. However, with the IoT's development, it can make it easier for the household to measure and monitor the daily water use. Despite a lot of research that has been done previously, to the best of our knowledge, there is no simple and affordable IoT system for a residential water tank that focuses on measuring water consumption and monitoring it on a mobile phone through a Blynk client application. In this paper, the author contributes some additional aspects compared to the previous studies. Firstly, a simple prototype and affordable system using IoT technology for monitoring the water usage of a household water storage tank are designed. The hardware components that are used in this study are cheap enough that everyone can buy them. In addition, the design system is very simple and dedicated to measuring water consumption. Secondly, the author uses the Blynk IoT platform to monitor water usage data in real-time. The users will be able to see the data on their mobile phones.

The rest of the paper is presented as follows: The system design in this study is outlined in Section 2. In Section 3, results and discussion are described. Finally, the paper concludes in Section 4.

2. SYSTEM DESIGN

In this section, the author describes the proposed architecture of the system in subsection 2.1. Then, in subsection 2.2, the explanation of how to construct the system for prototyping with affordable hardware is presented. In subsection 2.3., the performance metrics used in the study are provided. Finally, the author shows the experimental setup for this study in subsection 2.4.

Proposed Architecture

The general system of a residential water tank with the Internet of Things is shown in Fig. 1. The system consists of several parts, such as groundwater, a residential water tank, an IoT

system for measuring water usage, an internet gateway, a Blynk cloud server, a user, and a household. Groundwater is the fresh water source for the household. The water will be pumped up and stored in the water tank. Then, it is going to be used later for daily necessities. The water tank is equipped with an automatic water pump and a water level sensor. The pump will work when the water in the tank is empty or below a certain lower-level threshold. If the water has reached a specific upper-level threshold, the pump will shut off. In this study, the author does not discuss the system to fill the tank with water automatically. However, the author only focuses on measuring water usage.

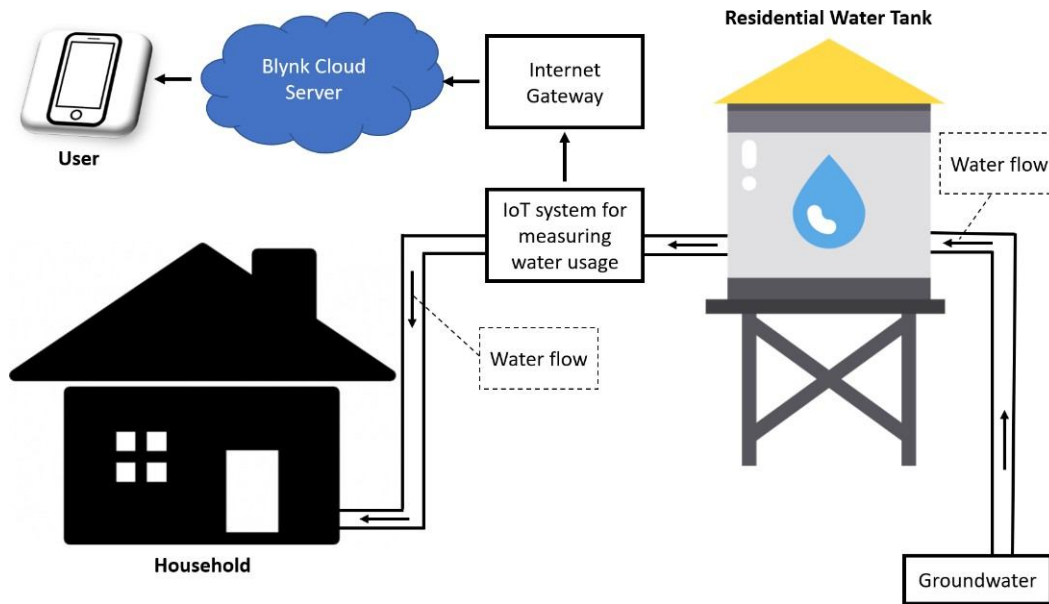


Fig. 1. Architecture design of residential water tank with IoT

If the people in the household need water, they will get it from the water tank. When the water is running, the IoT system will measure the water velocity and volume consumed by the household. This data is sent to the Blynk cloud server through an internet gateway. The user can see this data by accessing the Blynk server with a Blynk client application that is installed on the mobile phone. Also, the user can monitor the water consumption in real-time. As a result, they can make the arrangements based on the data and use water wisely. The components in the IoT system will be explained later in subsection 2.2.

The flowchart for the system is presented in Fig. 2. At the beginning, the system will initialize and calibrate all the hardware. Then, it is going to check the water flow sensor and LCD 16x2 I2C. If the sensor and LCD work without problem, it will check the water. Otherwise, it goes back to the initialization process. If there is a flow of water, it means that the water is being consumed, and the system will measure it using the flow water sensor. If not, it will jump back to check the sensor and LCD process. It will also measure the water velocity. Then, the LCD will display the data. In addition, the system will send the data to the Blynk cloud server and forward it to the Blynk client on a smartphone. The data can be viewed and monitored by the user via the smartphone. Finally, the system will end.

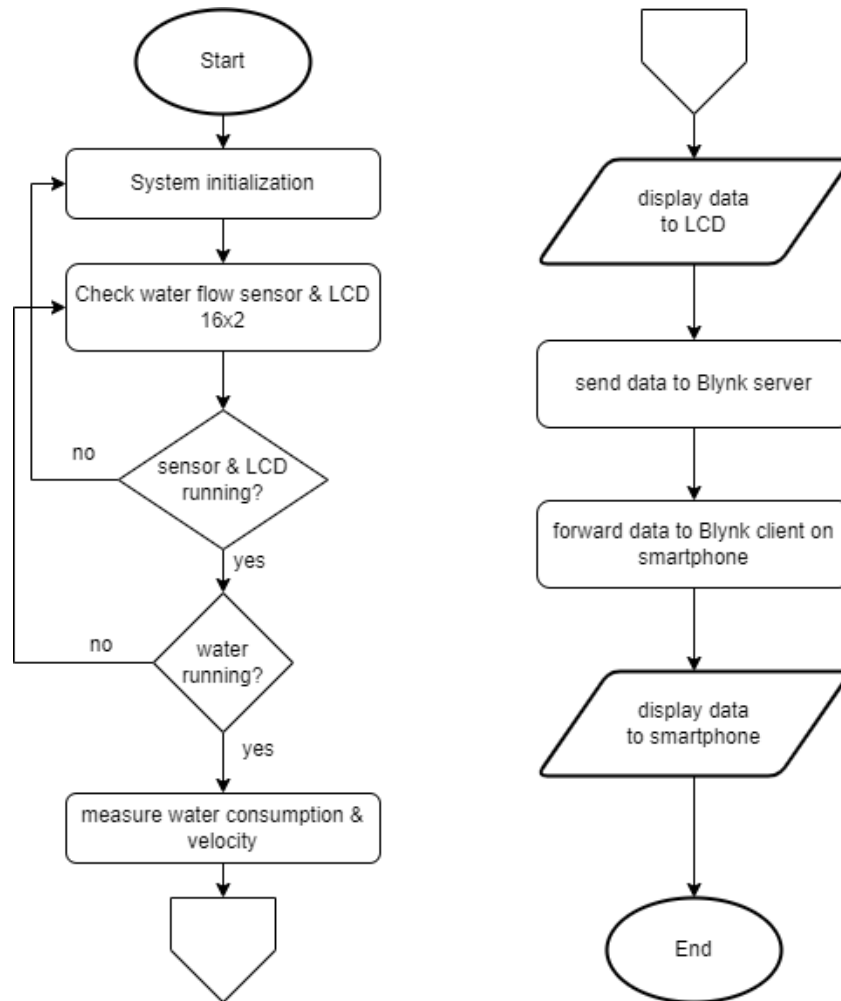


Fig. 2. Flowchart of residential water tank with IoT

The flowchart for the system is presented in Fig. 2. At the beginning, the system will initialize and calibrate all the hardware. Then, it is going to check the water flow sensor and LCD 16x2 I2C. If the sensor and LCD work without problem, it will check the water. Otherwise, it goes back to the initialization process. If there is a flow of water, it means that the water is being consumed, and the system will measure it using the flow water sensor. If not, it will jump back to check the sensor and LCD process. It will also measure the water velocity. Then, the LCD will display the data. In addition, the system will send the data to the Blynk cloud server and forward it to the Blynk client on a smartphone. The data can be viewed and monitored by the user via the smartphone. Finally, the system will end.

Prototyping

The ESP32 microcontroller, a water flow sensor, a breadboard, a charger (5 V) with cable, a jumper cable, and a 16x2 LCD with I2C are the system's components. Also, the details are presented in a list in Table 1.

Table 1. Hardware components of the prototype	
Component	Model
Microcontroller	ESP32 DevKit V1
Water flow sensor	YFS201 ¾ inch
Breadboard	MB-102 830 point
Charger / cable	DC 5 Volt / 1 meter
Jumper cable set	Dupont jumper cable
LCD	16x02 I2C

Fig. 3 shows the schematic of the system for a residential water tank using IoT, and it is pretty simple. The microcontroller (i.e., ESP32 DevKit V1) is powered by a 5V charger. The water flow sensor and LCD need a power supply of 5 volts and get their power from ESP32. The sensor has three pinouts, namely VCC, GND, and Data Pulse. The VCC and GND are connected to pins VCC and GND of the ESP32 through the breadboard. The Data Pulse connects to GPIO23 of the ESP32. Meanwhile, the sensor consists of four pins, such as VCC, GND, SDA, and SCL. VCC and GND of the LCD are connected to VCC and GND of the ESP32. SDA goes to GPIO21, and SCL links to GPIO22 of the ESP32.

The ESP32 works as the brain of the system. It processes all input and output from the system. It has 30 pins that can be used. There are 15 ADC (i.e., analog to digital converter) and 2 DAC (i.e., digital to analog converter) channels, 2 UART interfaces, 25 PWM outputs, 3 SPI & 1 I2C interfaces, and 9 touch pads. Also, it has 25 GPIO pins which are functioned for different purposes. For communication, it is embedded with a WiFi and Bluetooth BLE modules.

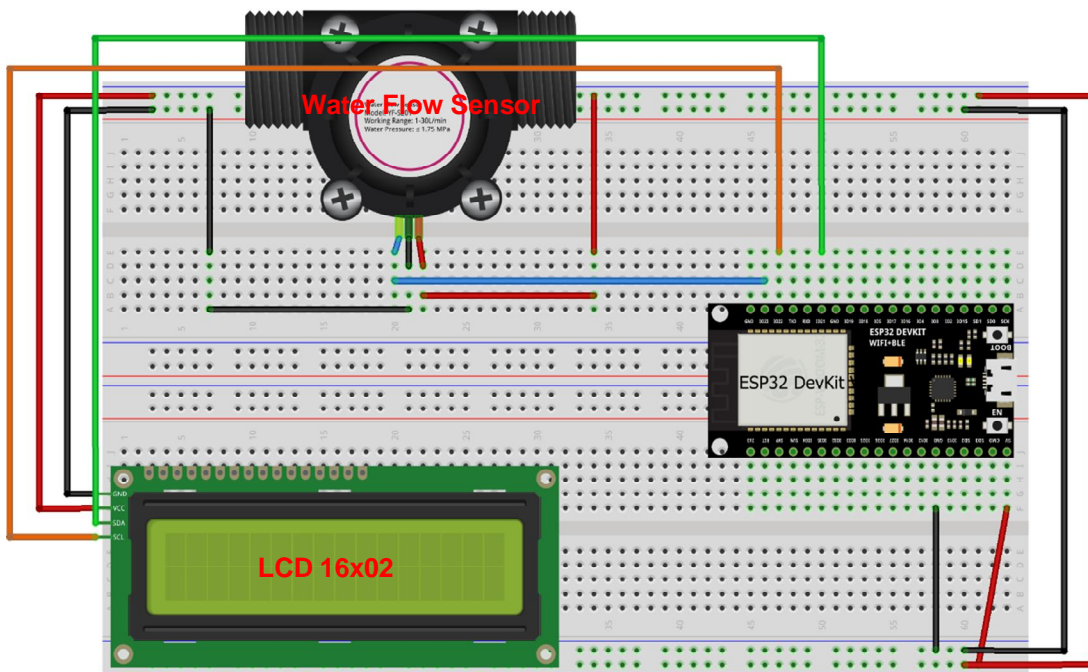


Fig. 3. Schematic of residential water tank with IoT

The flow water sensor model is YF-S201 with a hall effect sensor mechanism. A pinwheel sensor inside it measures how much liquid has passed through it, and it is positioned in line with your water line. A built-in magnetic hall effect sensor generates an electrical pulse with each rotation. Because the hall effect sensor is protected from the water pipe, it can remain dry and safe. If better than 10% precision is desired, thorough calibration will be needed. But it's fantastic for simple measurement chores.

A 2x16-character LCD module with a yellow backlight is called the LCD 16x2. It can show 16x2 characters on two lines. To communicate with the host microcontroller, it employs an I2C interface. Projects requiring the display of text, data, or ASCII characters of any kind employ this cost-effective LCD. Connect to the serial data line, ground, VCC, SDA, and SCL (serial clock line). This 5 VDC device can be located at either 0x27 or 0x3F on the I2C bus.

Performance Metrics

In this paper, the author wants to measure the amount of water that is consumed as well as the water velocity. The measurement unit for water usage is the cubic meter (i.e., m³). The cubic meter to liter conversion formula is as follows:

$$1 \text{ m}^3 = 1,000 \text{ liters} \quad (1)$$

Meanwhile, the unit of measurement for water velocity or flow rate is liters per minutes (i.e., *lpm*) that is defined as

$$lpm = \frac{L}{min} \quad (2)$$

where *lpm* is the flow rate of water, *L* is the amount of water in liters, and *min* is the time, in minutes, it takes to fill 1 liter of water.

Furthermore, if the household obtains its water supply from a water utility company, the monthly water bill can be calculated using the following equation:

$$W_{cpm} = W_{upm} \times P_{pcm} \quad (3)$$

where W_{cpm} is the water cost per month, W_{upm} is the water usage in a month, and P_{pcm} is the price of water per cubic meter (i.e., m³). However, in this case, where the water source is groundwater, the monthly cost is free.

Experimental Setup

For this experiment, the author will implement the system and measure how much water a family uses by using the prototype. The household consists of five people, namely two adults and three children. The children range in age from 6 to 13 years. The author will conduct the experiment by running the system for a week, 24/7. The people in the household are going to use the water as usual for daily activities, such as washing machines, dishes, cooking, taking showers, washing vehicles, etc. The illustration is seen in Fig. 4. The system will measure the daily water usage for a week and show its statistics. Then, it will approximate the cost of the

water consumed. The data is sent to the Blynk server. Finally, the user can see and monitor the data from a smartphone by using Blynk client apps.

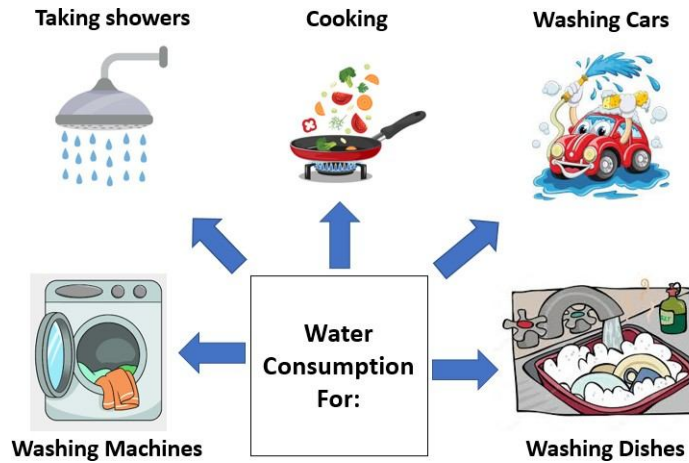


Fig. 4. Water daily usage for household in the experiment scenario

3. RESULTS AND DISCUSSION

The experimental results are explained in this section. The purpose of the experiment is to observe the water usage of a household. If the household overuses the water and wastes it, they can reflect on the way they use the water and start using it wisely and efficiently.

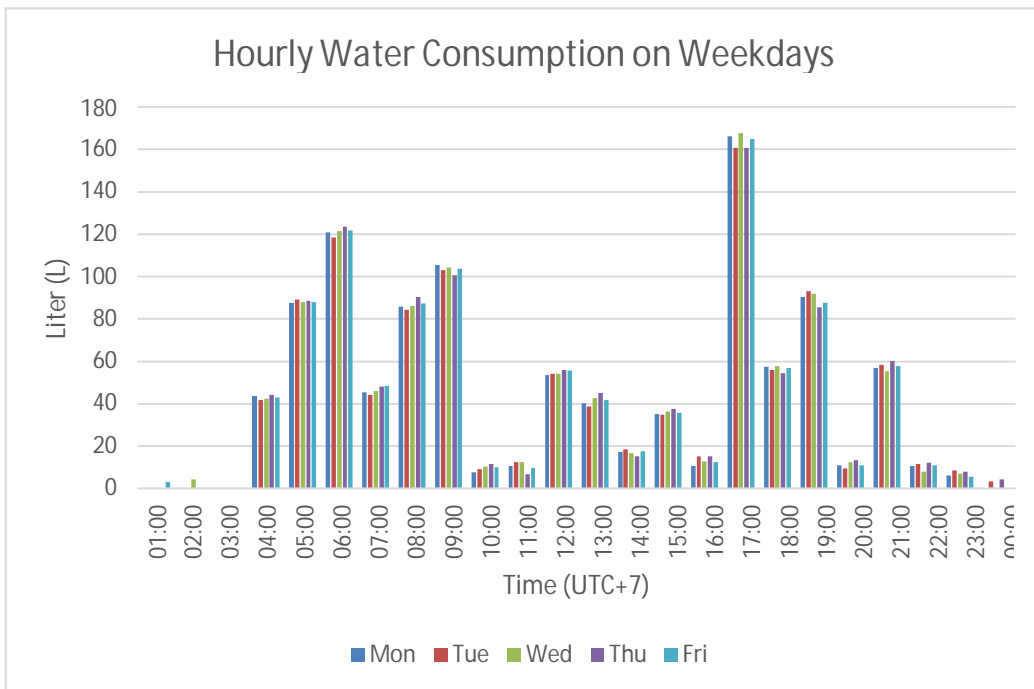


Fig. 5. Hourly water usage of the household on weekdays

Fig. 5 depicts the results of household water consumption on weekdays, from Monday to Friday. The water usage is monitored every hour from 01:00 to 00:00. The system calculates how much water is used each hour and provides it on the graphic. The household is a good Muslim family that performs five prayers a day. **Even though the children are still young in age, they are taught to perform the prayer every day.** Around 3:30 a.m., they begin their activities by preparing to perform the dawn prayer, called *fajr salaah*. As a consequence, they need to use water to perform a wudhu (i.e., a technique for cleaning certain body parts). **It is seen from the graphic that they (i.e., the father, mother, and three children) need around 40 liters of water daily for wudhu, brushing their teeth, taking a pee, etc.** The amount of water consumed increases until 6 a.m., then goes down at 7 a.m. Usually, the father and the children take a morning shower between 5 and 6 a.m. Meanwhile, the mother prepares to cook. That is why water consumption is quite high at that time, which is approximately 120 liters. Then the water usage goes up to 100 liters until 9 a.m. The mother uses it for watering the plants and the washing machine. From 10 a.m. to 4 p.m., the water consumption is low and varies between 10 and 58 liters. The highest water usage on weekdays is at 5 p.m., when all family members take showers. Then it goes down again until 12 p.m.

The water consumption for the weekend can be seen in Fig. 6. Even on weekends, the household still begins its activities around 3:30 a.m. by performing the dawn prayer. The peak of water usage in the morning, which is roughly 350 liters, is at 7 a.m., when household members take showers. It is different from weekdays, when they take showers at 6 a.m. The second highest water consumption in the morning is at 8 a.m. It is time to wash the car, motorcycle, and bicycle. Then, from 9 a.m. to 4 p.m., it goes down and up. The household water usage is quite high again at 5 p.m., when they take afternoon showers. Moreover, water is needed quite a bit during the prayer times, such as at 4 a.m., 12 a.m., 3 p.m., 6 p.m., and 7 p.m. After 7 p.m., the water consumption decreases.

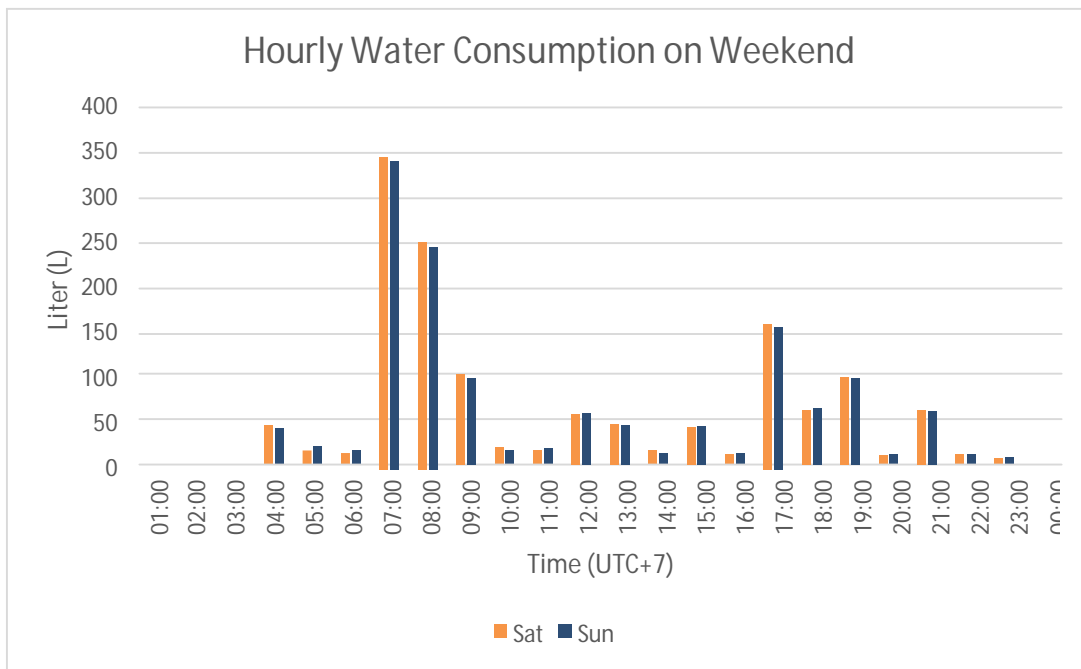


Fig. 6. Hourly water usage of the household on weekend

Fig. 7 presents the daily water usage of the household for a week from Monday to Sunday. It can be seen that water consumption during the week is lower than during the weekend. During the week, the daily water usage is about 1062 liters. Meanwhile, over the weekend, it reaches around 1378 liters. They use more water on the weekends to wash the car, motorcycle, and bike.

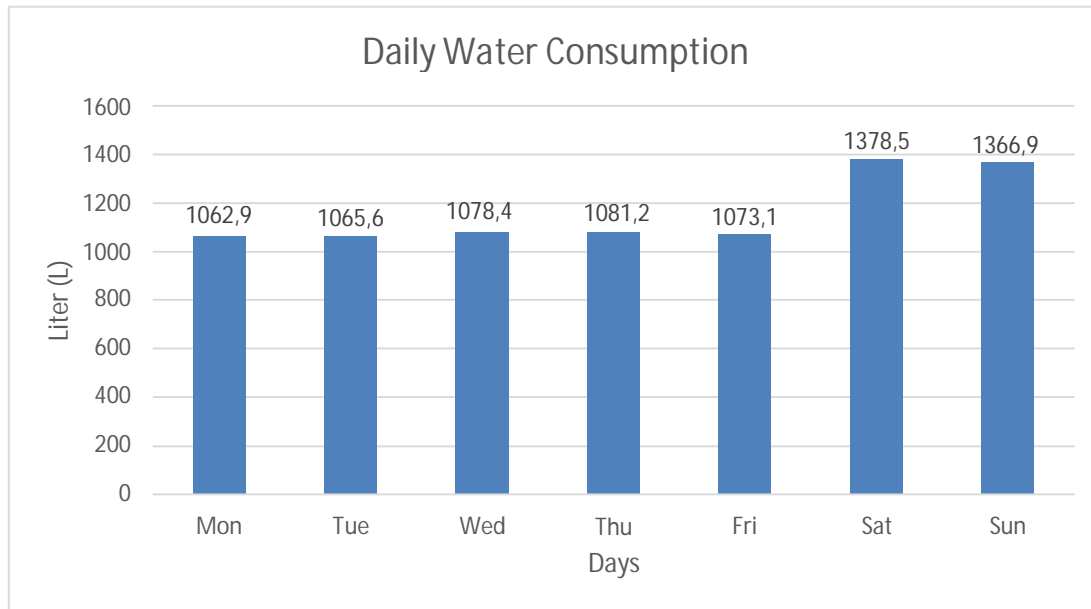


Fig. 7. Daily water usage of the household for a week

Table 2 shows the cost calculation of daily water usage for a week. It is assumed that the price of water per m³ is IDR 3540. This is applied to the Yogyakarta region in Indonesia. Also, the tariff is for households. It is shown from the table that the daily water usage varies from 1.0629 m³ to 1.3669 m³. Therefore, the daily cost is roughly between IDR 3,762 and IDR 4,838. Then, it can be calculated that the cost for a week is about IDR 28,697.37. Also, the household needs around 8.1066 m³ of water each week for their daily activities.

Table 2. Daily water consumption cost calculation for a week

Day	Liter (L)	Meter Cubic (m ³)	Price/m ³ (IDR)	Cost (IDR)
Mon	1,062.9	1.0629	3,540	3,762.67
Tue	1,065.6	1.0656	3,540	3,772.22
Wed	1,078.4	1.0784	3,540	3,817.54
Thu	1,081.2	1.0812	3,540	3,827.45
Fri	1,073.1	1.0731	3,540	3,798.77
Sat	1,378.5	1.3785	3,540	4,879.89
Sun	1,366.9	1.3669	3,540	4,838.83

Fig. 8 presents the display of water usage monitoring from the Blynk client on a smartphone. The system provides the data of current water used (current), flow rate, water cost (current), water cost (month), water consumption (month).

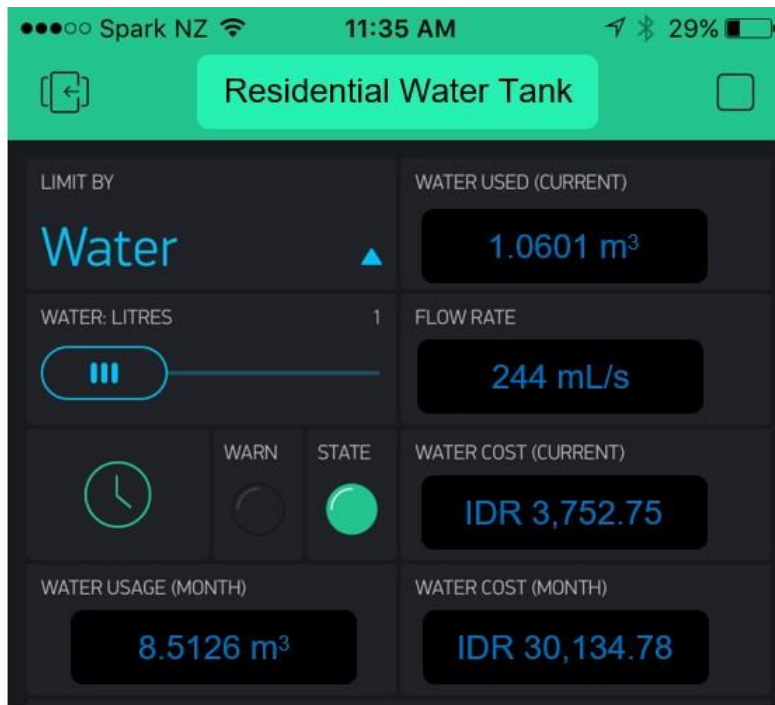


Fig. 8. Water consumption monitoring from Blynk client on smartphone

4. CONCLUSION AND FUTURE DIRECTION

In this paper, a monitoring system for water consumption from the residential water tank in a household is designed and implemented. The system will measure the daily water use of the household, which consists of five people, namely two adults and three children. The data on water consumption will be sent to the Blynk cloud server for monitoring purposes. The household can see the data on the server through a smartphone that has been installed with a Blynk client application. The experimental result demonstrated that the system is able to do its job by measuring and sending the water use data to the server successfully. The results also showed that the household consumed about 8.1066 m³ of water each week, which cost around IDR 28,697.37. Moreover, they tend to use water more on the weekend for washing vehicles such as cars, motorcycles, and bikes. Therefore, it can be concluded that the daily household water consumption can be monitored by the system. The data on water consumption will increase the household's awareness of using water wisely and efficiently. By using water as needed with reservations, it can prevent a shortage of water.

Currently, the system can only measure water consumption. However, for future research, it can be added with extra features, for instance, a notification system with SMS (i.e., short message service), WhatsApp, or Telegram, a water level measuring system, a water leakage detection system, etc.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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