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Study on the Water Usage in Office and Laboratory Buildings

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Abstract: This study evaluates the efficiency of water usage in the Department of Environmental Engineering at Universitas Andalas (Unand) by analyzing water consumption volume, identifying potential leaks, and comparing the findings with applicable standards for laboratories and offices. A 1.5-inch water meter was installed at the outlet of the rooftop reservoir on the 4th floor to measure water usage volume, and manual attendance devices were used to record the number of water users in the office and laboratory. Leakage testing was performed using the step test method, where water flow was stopped for 16 hours overnight to monitor changes in the water meter readings, with results indicating no leakage. The study found that the highest water consumption was 39.66 L/person/day in the laboratory and 55.06 L/person/day in the office. Water consumption in laboratories was found to be 100-200 L/person/day according to the standard, while water use in offices slightly exceeds the Indonesian National Standard (SNI) 03-7065-2005 of 50 L/person/day. The study recommends implementing water conservation technologies, such as automatic faucets and dual-flush toilet systems, to reduce water consumption and enhance water efficiency.

Keywords: Laboratory; Leakage; Office; Water Usage.

Introduction

Water is regarded as one of the most essential natural resources (Tong et al., 2024). Natural resources, such as water, must be used wisely and efficiently to ensure environmental sustainability (Maslikhah et al., 2022). Water availability is important for human survival (Geronimo & Geronimo, 2021). A continuous water supply must be provided so consumers can always use sufficient water. Water resource management is necessary to ensure water availability and efficient use. A deep understanding of water consumption patterns is essential for water managers to design efficient distribution strategies, identify potential leaks, and reduce wastage. A deep understanding of water consumption patterns is essential for water managers to design efficient distribution strategies, identify potential leaks, reduce wastage, and address the lack of water pressure during peak usage hours (Rahim et al., 2021). These patterns can vary from building to building, depending on the building characteristics, water users, building functions, and various other cultural, economic, social, and environmental factors (Almeida et al., 2021). Research by Wijaya et al., (2020) on a seven-story lecture building at the Faculty of Sports Sciences, State University of Malang, found a water usage of 96 L/person/day, which is lower than the usage in a two-story building of the Pasuruan Regency Transportation Agency office, which is 129.24 L/person/day (Purnomo & Apriliyya, 2021). Conversely, showed relatively lower water usage at around 27.541 L/person/day in a three-story Kupang City Archives and Library building. This low water usage is because the facility is unused 24 hours a day. This shows that water usage varies throughout the building depending on the activities and lifestyle of the occupants (Padeng et al., 2023).

Water utilization in higher education institutions involves various activities such as office work, research

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in laboratories, and other facilities that require large amounts of water (EL-Nwsany et al., 2019). Universities are complex environments with multiple users, diverse activities, and fluctuating demands (Afiatun et al., 2019). Office spaces, research labs, dormitories, and cafeterias all contribute to water consumption, each with distinct requirements and usage patterns (Ambat, 2022). Therefore, analyzing water usage patterns at the university level is often a challenge (Soares et al., 2023). The potential for inefficiencies, such as water leaks or untracked consumption in various parts of the campus, further intensifies the need for detailed analysis (Raubaba & Hematang, 2017).

One of the largest educational institutions located in western Sumatra Island is Universitas Andalas (Unand), with an area of about 5 km² (Putri et al, 2019). All individuals in the campus environment require a water supply to support their activities, therefore it is important to ensure the adequacy of water availability and quality that meets the requirements (Yasmin et al., 2023). With these demands, Unand has built an independent Drinking Water Supply System (DWSS) called SPAM Unand (Zaky et al, 2021). The water treatment plant (WTP) has a capacity of 90 L/sec. The raw water source comes from Limau Manis River and Ladang Sikabau. The WTP serves several institutional buildings and faculties, including hospitals, student dormitories, student activity centers, faculties, rectorates, and other campus facilities (Komala et al., 2024).

This research was conducted at the Department of Environmental Engineering Building Universitas Andalas in Padang City, West Sumatra, Indonesia. This building has four floors consisting of laboratories and offices. SPAM Unand provides the water supply of this building. SPAM Unand serves around 30,000 academicians and the type A hospital, which has a significant water demand that continues to grow along with the increasing activities at the university.

Information on water usage from office and laboratory activities is not yet available, while water availability in the treatment plant is limited. Therefore, efficient water resource management is becoming increasingly important. The purpose of this study is to compare the factual water usage with the applicable water usage standard by using data on the volume of water usage (m^3) and the number of water users (people), then determine the total amount of laboratory and office water usage by combining the data. This research is expected to guide the analyzis of water usage in Unand campus buildings. In addition, it is expected to provide recommendations for programs and actions that can overcome problems with water usage.

Method

Study Area

Geographically, Universitas Andalas (Unand) is located at 0°55'23.09″ N to 0°54'47.43″ LS and 100°26'54.94″ East to 100°28'14.04″ East with an altitude of ± 255 meters above sea level and an area of 5 km². The study area of this research is the Unand Environmental Engineering Building, with an area of 9,904 m² consisting of a four-story building, including laboratories and offices. The building is equipped with six laboratories. ± 853 academicians and ± 89 plumbing equipment. This building is part of the SPAM Unand service area. SPAM Unand treats raw water with a capacity of 45 L/sec with raw water sources originating from the Ladang Kabau Intake, which is 2,000 meters away (Zaky et al, 2021). The research location can be seen in Figure 1 and Figure 2.

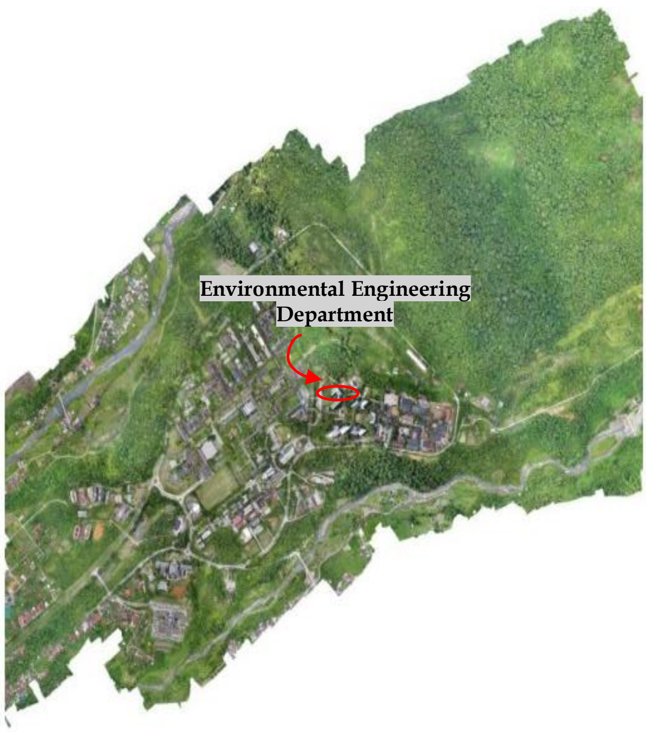


Figure 1. Map of Universitas Andalas
Source: Masterplan Unand, 2020

Water meter Installation

A 1.5-inch mechanical water meter is installed on the rooftop of the 4th floor at the outlet of the reservoir tank towards the laboratory for water meters 1 and 2 towards the office. The function of this water meter is to measure the volume of water entering the Unand Environmental Engineering Building and is useful for helping to manage water usage more efficiently. The water meter has an accuracy standard of ISO 4064 Class B, with an accuracy range of ±2% to ±5%, and the smallest measurable unit is 0.0001 m³/hour. Water meters (WM) for laboratories and offices can be seen in Figure 3.

Figure 2. Environmental Engineering Building, Unand
Source: Google Earth, 2023

(a) Laboratory WM (b) Office WM

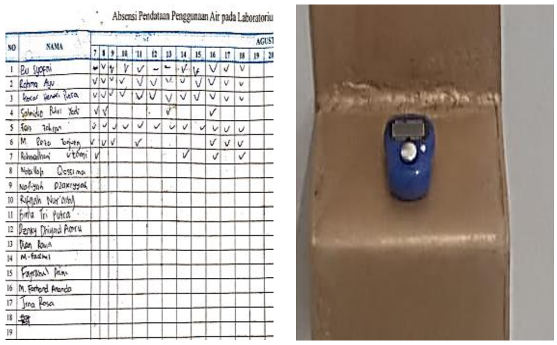
Figure 3. Water Meter (WM) and Piping

Daily attendance recording device

Four manual daily attendance counters were installed in the office in each area that uses water, such as the toilets of lecturers, education staff, and student toilets. The daily attendance device for the office is used by pressing the button on the device, and then the attendance number will appear. Each button on the device represents one water user. The collected data is then summarized daily for further analysis. Meanwhile, the attendance of water users in the laboratory is recorded through attendance on HVS paper, where each water user is required to put their name and complete the attendance. The recording of lab practitioners' attendance is supervised by laboratory assistants who manage the attendance records daily. Attendance data is collected daily and recapitulated until a predetermined time. The attendance recording devices for the laboratory and office can be seen in Figure 4.

Water Usage Measurement

Water usage measurements were taken from July to September 2023. Water usage readings were taken using a water meter to determine the total daily water consumption over a 24-hour period from 07.30 AM to 07.30 AM the next day. Fluctuations of water usage were carried out for 5 days, from 18 September 2023 to 22 September 2023, from 08.00 to 16.00 WIB during working hours. Examples of how to record daily attendance and water usage readings in August 2023 can be seen in Figure 5.



(a) Laboratory (b) Office

Figure 4. Daily Attendance Recording Device

(a) Attendance Counter (b) WM Reading

Figure 5. Example of Daily Recording

Water Leak Identification

The leakage flow rate was identified using the step test method, which is a technique to detect leaks in water piping systems (Widianto & Hadi, 2023). This method is conducted at night to avoid interference from water user activities (Azwar et al., 2021). The process began by temporarily stopping the water flow in the entire piping system by turning off the water taps of all plumbing fixtures in the Environmental Engineering building from 4:00 PM to 8:00 AM (Syarif & Ridwan, 2020). During this period, no water usage occurred in the building, while the water meter at the source remained open to monitor the water flow. The volume of water discharged through the water meter was recorded 16 hours after the water flow was stopped, i.e., at 8:00 AM the next day. Significant differences in the volume of water recorded on the water meter may indicate a leak (Hakim, 2020) as shown in Figure 6. These systematic and detailed observation steps ensure that no unaccounted water loss occurs in the building (Pitaloka & Marsono, 2021).

Numbers of Water Users and Water Meter Volume

The number of water users is obtained from daily attendance records for the laboratory and office, while the volume of water used is obtained through water meter readings. The number of users and the water meter volume are recorded over a 24-hour, from 07.30 AM to 07.30 AM the next day. This data is then used to calculate the average daily water usage per person. Fluctuations in water usage volume can be observed from the water meter volume data.

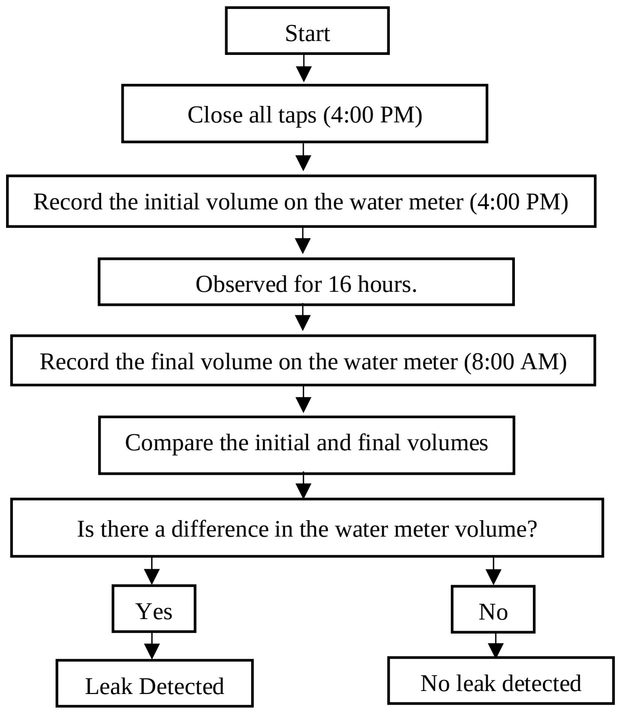


Figure 6. Step Test Method

Determination of Water Usage in Laboratories and Offices

By obtaining the number of water users and the volume of water from the water meter, the water usage per person per day for laboratories and offices can be calculated. The average factual water usage can be calculated by dividing the volume of water by the number of water users. At certain times, water usage will exceed the average water usage, referred to as peak water usage (Purnawan et al., 2022).

The data from the water meter reading is plotted into a graph, then the highest water usage per hour is determined. A comparison of this value with average water use is a peak value. However, if the number of water users is unknown, the water flow rate can be calculated based on the effective floor area and the occupancy density per floor (Noerbambang and Morimura, 2005). The standard water usage in SNI 03-7065-2005 concerning the Planning Guidelines for Plumbing Systems for offices is 50 L/person/day. For laboratories, the standard water usage is 100-200 L/day, with an average usage period of 8 hours for each staff member (Noerbambang and Morimura, 2005).

1) Actual Water Usage per Person per Day

$$Q = \frac{\text{Water Usage Volume}}{\text{Number of Users}} \tag{1}$$

2) Peak Hour Factor

$$F = \frac{\text{Peak Hour Usage}}{\text{Average Usage per Hour}} \tag{2}$$

Result and Discussion

Water Piping Scheme of Environmental Engineering Building

The study was conducted in the Department of Environmental Engineering Building in Universitas Andalas. The water piping scheme of the Unand Environmental Engineering Building can be seen in Figure 7. The building consists of four floors: the basement, the first, the second, and the third. Six laboratories are located in the basement, first, and second floors. Meanwhile, offices are on the first, second, and third floors.

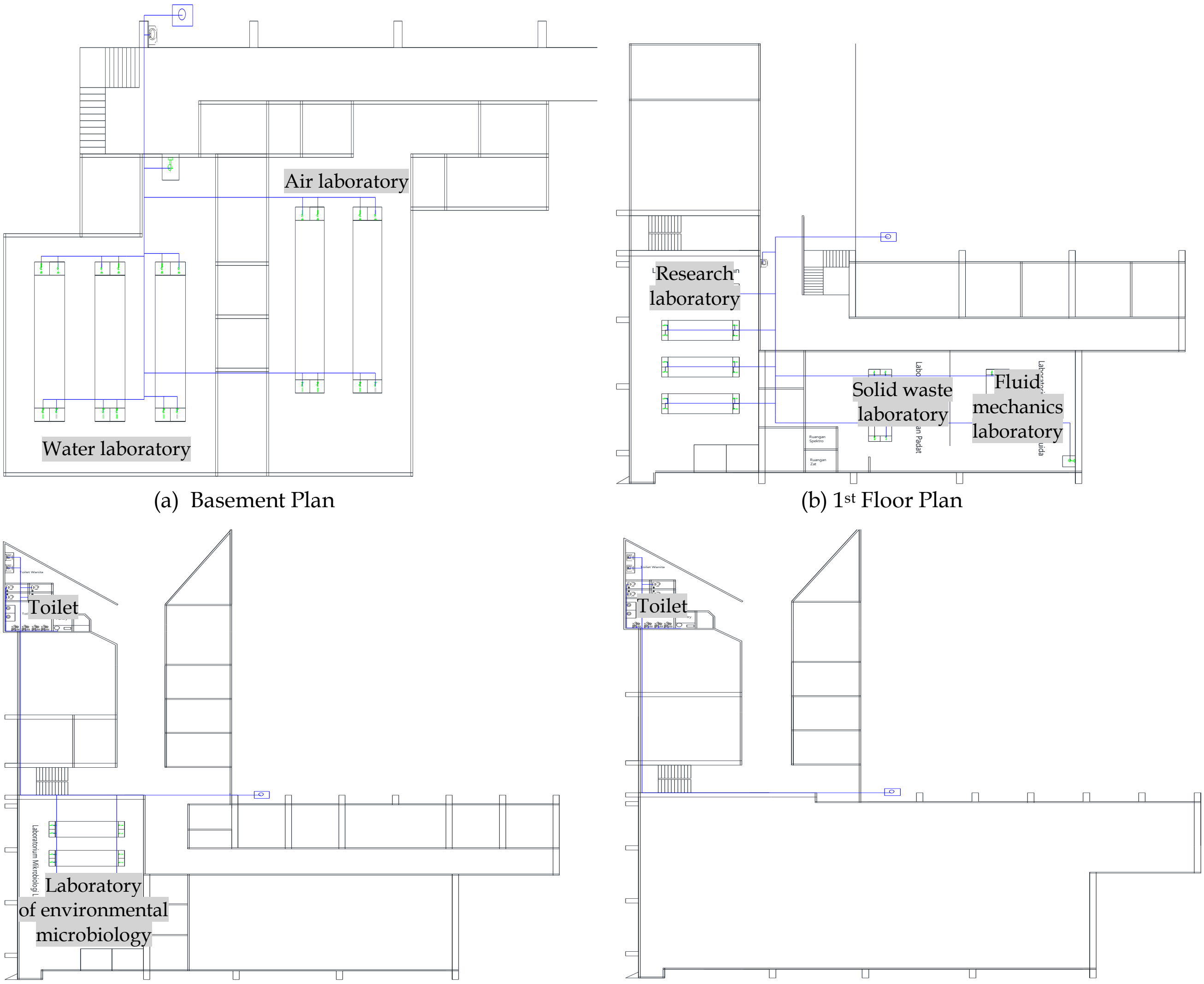
Leak Identification

Leak identification was observed by applying the step test method. Based on Figure 8, Figure 9, and Table 1, the readings of the water meter for the laboratory from 04:00 PM to 8:00 AM remained constant at 23.36 m^3. The same occurred with the office water meter, where from 04:00 PM to 8:00 AM, the reading also remained constant at 17.83 m^3. There was no difference in the volume of water recorded by the laboratory and office water meters during the observation period, leading to the conclusion that there were no leaks. In addition, no sources or signs of leakage were found, so there was no need for leakage control.

Water Usage Patterns

The initial step in observing the water usage patterns in the Environmental Engineering Building at Unand is to collect data on the number of water users and the water consumption volume recorded by the water meter. Table 2 shows the average daily water use recorded in July, August, and September 2023.

Only water discharge was recorded in July, while the number of water users was not recorded as the equipment had not been installed then. Therefore, the daily water usage per person was determined based on August and September. The number of water users in August and September was 19 and 125 in the laboratory, and 27 and 30 in the office, respectively. In the laboratory, practical sessions and research activities are typically carried out (Mohzana et al., 2023). Varying water usage patterns result in differences in peak factors for laboratories and offices (Wichowski et al., 2019).



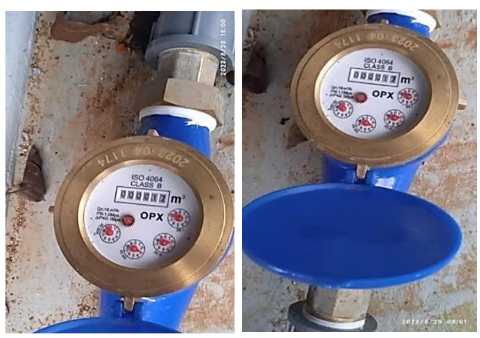
(a) Basement Plan (b) 1st Floor Plan

(c) 2nd Floor Plan (b) 3rd Floor Plan

Figure 7. Water Piping Scheme of the Department of Environmental Engineering Building

(a) 04:00 PM (b) 08:00 AM

Figure 8. Observation of the Laboratory Water Meter for Leakage



(a) 04:00 PM (b) 08.00 AM

Figure 9. Observation of the Office Water Meter for Leakage

Table 1. Leak Identification

Water meter	4.00 PM	08.00 AM
Laboratory	23.36 m^3	23.36 m^3
Office	17.83 m^3	17.83 m^3

Table 2. Average Daily Water Users (People)

Month	Laboratory	Office
July	-	-
August	19	27
September	125	30

Note: - = Not measured

Due to these activities, the number of water users in September increased compared to August. Table 3 shows that the average daily water usage volume per person for July, August, and September is 1.25, 0.77, and 2.23 m^3/day for the laboratory, and 0.88, 1.14, and 1.68 m^3/day for the office. The volume of water usage in the laboratory in August was relatively low because the semester break was ongoing. The water usage increased from August to September in the laboratory, and from July to September in the office. This was due to the start of the new academic year and the implementation of lecture activities, including practical sessions. Observations of water usage were conducted over 5 days, from 18 September 2023 to 22 September 2023, from 08:00 AM to 04:00 PM.

Table 3. Average Daily Water Consumption Volume

Month	Laboratory (m^3/day)	Office (m^3/day)
July	1.25	0.88
August	0.77	1.14
September	2.23	1.68

The water meter recorded over 8 working hours, as shown in Figures 10 and 11 The peak water usage occurred on Thursday, 21 September 2023, from 08:00 AM to 10:00 AM. During this time, there was no water usage in the laboratory as practical activities and research had not started. However, an increase was observed from 20 m^3 to 20.5 m^3 between 10:00 AM and 11:00 AM and from 20.5 m^3 to 21 m^3 between 02:00 PM and 03:00 PM. This was due to practical sessions for second-year students and research conducted by final-year students that required water during these periods. Meanwhile, there was no increase in water usage in the office from 08:00 AM to 11:00 AM, as office activities and classroom lectures were ongoing. However, an increase was recorded from 19.5 m^3 to 20 m^3 between 11:00 AM and 12:00 PM and from 20 m^3 to 21.5 m^3 between 02:00 PM and 03:00 PM. This is due to office activities shifting to lunch breaks from 11:00 AM to 12:00 PM, thus increasing water usage. An increase also occurred between 02:00 PM and 03:00 PM, where restroom usage increased and preparations for the noon prayer followed the lunch activity. From 03:00 PM to 04:00 PM, there was no increase in water usage, as most students had left the campus, marking the end of office activities in the Environmental Engineering Building at Unand.

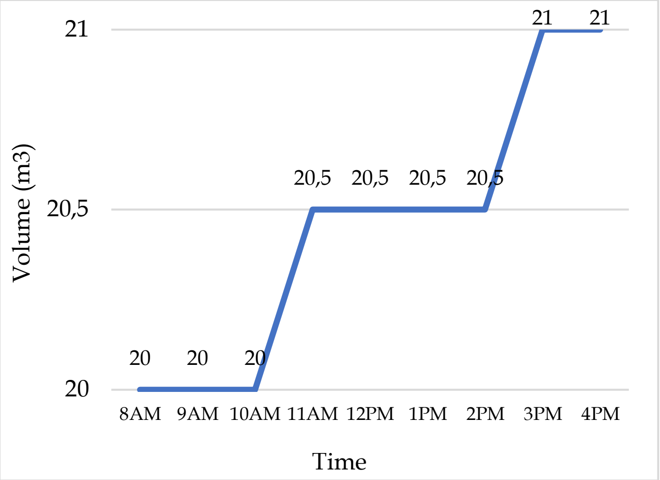


Figure 10. Laboratory Water Usage Pattern

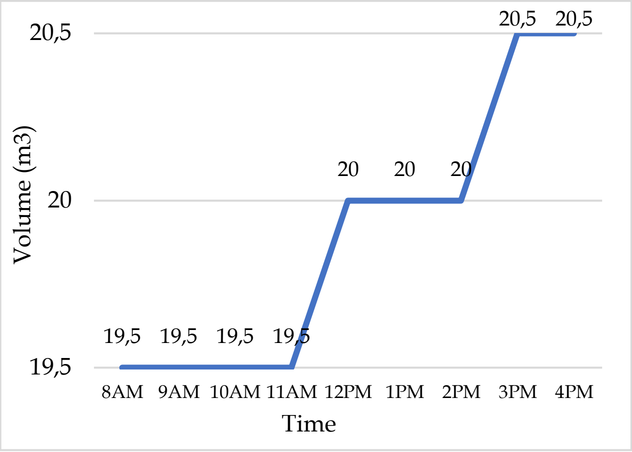


Figure 11. Office Water Usage Pattern

Peak Hour Water Usage

Table 4 shows the peak factor in laboratory and office is 4. The average hourly water consumption for laboratories and offices is 0.125 m^3/h. Meanwhile, the peak hour water consumption for laboratories and offices is 0.5 m^3/h.

Table 4. Water Consumption at Peak Hour

Location	Average per hour	Peak hour	Peak hour factor
Laboratory	0.13 m^3	0.50 m^3	4
Office	0.13 m^3	0.50 m^3	4

Peak hour factors in educational buildings range from 1.909 to 3.09, indicating greater variability (Afiatun et al., 2019). Compared to the research of Wicaksi & Mardyanto (2019), the peak hours and average water consumption in two-star hotel buildings are 47 m^3, 12.37

m^3 with a peak factor of 3.48 - 3.96, while in three-star hotel buildings are 4 m^3, 1.28 m^3 with a peak factor of 2.34 - 3.91. On the other hand, the peak factor in laboratories and offices in this study is higher despite the relatively lower water usage compared to hotels with more intensive activities such as cooking, washing dishes, and cutlery, as well as the activities of guests and hotel employees. While, laboratory activities mostly come from the distillation and washing of glassware, accounting for 7.5% of the total campus water consumption (Araújo & Salvador, 2020). Educational institutions often use more water per person than private or governmental workplaces, although water usage indicators vary by kind of organization (Aroonsrimorakot & Phuynongpho, 2017).

Determination of Water Usage Rate for Laboratory and Office

The water usage rate can be determined based on daily water volume and the number of water users found. Tables 5 and 6 show the daily (factual) water usage in August and September, amounting to 39.66 and 17.80 L/person/day for the laboratory. Meanwhile, the factual water usage for the office in August and September was 42.30 and 55.06 L/person/day, respectively. Table 7 shows the total water usage in August and September, amounting to 81.96 and 72.86 L/person/day, respectively.

Table 5. Laboratory Water Consumption

Month	Water consumption (L/person/day)	Water consumption standard (L/person/day)*
July	-	100-200
August	39.66	100-200
September	17.80	100-200

Note: - = not measured
* = Noerbambang dan Morimura, 2005

Table 6. Office Water Consumption

Month	Water consumption (L/person/day)	Water consumption standard (L/person/day)*
July	-	50
August	42.30	50
September	55.06	50

Note: - = not measured
* = SNI 03-7065-2005

Table 7. Recapitulation of Laboratory and Office Water Usage

Month	Laboratory (L/p/d)	Office (L/p/d)	Total (L/p/d)
August	39.66	42.30	81.96
September	17.80	55.06	72.86

Figure 12 shows that the actual daily water usage in the laboratory for August and September was recorded at 39.66 and 17.80 L/person/day, respectively. Compared to the standard laboratory water usage criteria listed in Noerbambang and Morimura (2005), which is around 100-200 L/person/day, the laboratory water usage does not exceed the standard limit.

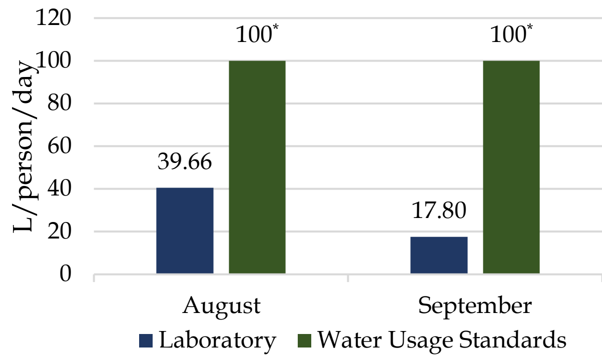


Figure 12. Comparison of Actual Laboratory Water Usage with Waiter Usage Standards
Note: * = Noerbambang dan Morimura, (2005)

In Figure 13, the actual daily water usage in the office for August was 42.30 L/person/day, which is still below the standard water usage according to SNI 03-7065-2005, set at 50 L/person/day. However, in September, the actual daily water usage in the office increased to 55.06 L/person/day, exceeding the standard water usage for the office according to SNI 03-7065-2005, which is set at 50 L/person/day.

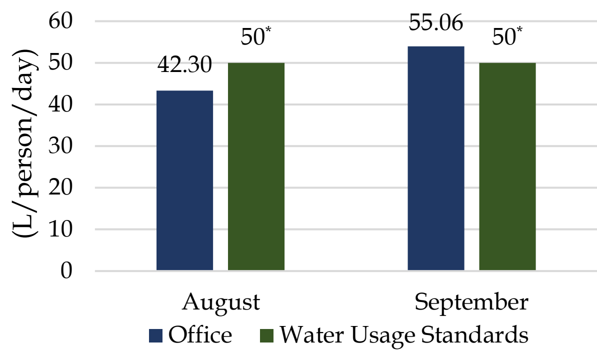


Figure 13. Comparison of Actual Office Water Usage with Waiter Usage Standards
Note: * = SNI 03-7065-2005

Toilet flushing is typically associated with the highest water consumption in a building (Kusumawardhana et al., 2021). The higher water usage in the office in September could be due to the uncontrolled use of conventional taps and toilets with manual flushing systems resulting in overflow and excessive water consumption. According to Purnomo & Apriliyya's study (2021), the average water usage was recorded at 129.24 L/person/day, exceeding the standard set by SNI 03-7065-2005 due to excessive water usage attributed to seated toilets with manual flush systems and squat toilets. Latuconsina et al., (2017) reported that water consumption during ablution (wudhu) decreased from 3.62 liters using manual taps to 3.38 liters with automatic taps, resulting in a water saving of 0.024%. Automatic taps for hand washing can be installed at high water usage points (Yudo, 2018), such as in laboratories and public toilets. Using water-saving toilets with a dual flush system can reduce water consumption by 25-30% (Purnomo & Apriliyya, 2021).

Water usage across the four floors of the Environmental Engineering Building at Unand, which includes laboratories and offices, remains within reasonable limits compared to water usage in other studies. In Wijaya et al., (2020), reported that water usage in the seven-story lecture building of the Faculty of Sports Science at the State University of Malang reached 96 L/person/day. This high consumption is influenced by the number of occupants, consisting of 43 staff and lecturers and 32 classrooms, each accommodating approximately 50 students. Larger buildings with intensive academic and sanitary activities require higher water consumption. A much higher amount of water usage was reported (Purnomo & Apriliyya, 2021), reaching 129.24 L/person/day in a two-story office building at the Transportation Department of Pasuruan Regency. This amount was due to additional facilities such as handwashing stations and disinfectant sprays implemented as part of health protocols during the pandemic, with a total occupancy of 150 people. It reveals that health policies and building regulations can significantly influence water consumption patterns.

Meanwhile, in Tanelaph et al., (2020), water usage was approximately 27.541 L/person/day in a three-story building at the Archives and Library of Kupang City, which housed 61 occupants. The lower water usage is likely influenced by activities requiring minimal water usage, such as administrative work, and the limited availability of water-intensive facilities. The comparative analysis of water consumption in various types of buildings shows that water consumption is influenced by several main factors, namely the size and function of the building, the number of occupants, and the type of activities carried out. The larger and more diverse the facilities available in a building, the higher the water demand to satisfy its activities. In addition, a larger number of occupants also contributes significantly to the increase in water consumption, as each individual has different water needs.

Conclusion

Research conducted at the Universitas Andalas Environmental Engineering Department Building confirmed no leaks in the piping system. Water consumption in the laboratory, which was recorded at 39.66 L/person/day, is within the recommended limit. However, water consumption in the office, 55.06 L/person/day, exceeds the standard set by SNI 03-7065-2005, which is 50 L/person/day. This finding indicates an inefficiency in water management in the office. The increased water use is attributed to manual faucets and flush toilets, resulting in uncontrolled water consumption and wastage. Installation of automatic faucets and water-efficient toilets such as dual flush systems is recommended to address this. In addition, implementing a fingerprint-based attendance system will improve the accuracy of water user records enabling more accurate analysis of water consumption trends in laboratories and offices.

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Author Contributions

Conceptualization and final writing, P. S. K.; field observations and editing, A. N.; program design and data analysis, by R.; methodology development and data collection for the writing process, A. S. N.

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Conflicts of Interest

The authors affirm that no conflicts of interest are associated with this research.

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