Study on fluctuation of water usage in office areas apartments

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Abstract. This study aims to examine the use of clean water in apartments by observing secondary data from nine apartments for 24 hours in 7 days. The results show that in the areas of Jakarta and Surabaya, on weekdays there is a significant increase in water use, namely in the morning at 06.00-08.00 am with a fluctuation range of 7.17%-10.99% and 8.21%-8.34%. Meanwhile, at night at 04.00-08.00 pm with a fluctuation range of 6.2%-12.23% and 7.11%-7.21%. And on weekends there is also a significant increase in water use, namely in the morning at 06:00-08:00 am with a fluctuation range of 6.4%-10.22% and 6.7%-7.27%. Meanwhile, at night 05:00-09:00 pm with a fluctuation range of 6.9%-9.07% and 7.28%-7.35%. It can be concluded that the activities in the apartment vary due to the difference in the percentage of water use. The result data can be used to design water reservoirs in apartments with residential characteristics in office areas.

1. Introduction
Water is a very important requirement in human survival. To meet community water needs, a clean water supply system has been built, especially in urban and rural areas. The rate of population growth is very influential in clean water planning. The more the population, the greater the use of water needed [1]. With limited land, apartments are the choice for residential needs. In addition, locations in office areas are an attraction for easy access for employees or workers. The need for clean water is one of the people's needs in their daily life. In the community, the provision of drinking water with good quality is a top priority. Many countries have set standards including Indonesia [2]. Buildings built in areas with public drinking water facilities are not available, such as in remote areas, mountains or islands, the water supply is drawn from rivers, shallow or deep ground water, etc. In such a case, raw water must be treated in a building or treatment plant to achieve the applicable water quality standards [2].

In the construction of a building, planning is not just architecture and structure, but also requires planning of a piping system [3]. In the use of clean water, the number of residents greatly affects the increase in water use [4]. Maximum hour and daily hour are two terms related to water usage patterns. The variation in changes in water use by consumers from time to time is called fluctuation. Based on fluctuations in water use, planning standards can be determined in terms of peak hours and maximum daily factors so as to optimize air production and improve service [5].

According to [6], the magnitude of the peak hour factor is 1.5 while the maximum daily factor is 1.1. This figure is a planned criterion to facilitate the planning of clean water distribution networks obtained from an empirical approach. This study aims to plan the use of clean water needed from an apartment by looking at the pattern of clean water use from several apartments whose observations are carried out for 24 hours in 7 days.
2. Research methods
This was conducted in nine apartments namely, the Aston Marina [7] Apartment with 1,154 people, the second apartment X [7] Apartment with 851 people, the third apartment is Tamansari Sudirman Executive Residence Apartment [8] which has 3 towers with a height of 18 floors with 900 residents, Fourth, the Merr Apartment [9]. Apartment which has 2 tower with a height of 29 floors which has a residential area of 480 units with a total of 954 people, the fifth apartment is the Manyar [9]. Apartment which has 2 towers with a height of 18 floors and a total number of 778 people, the sixth apartment is the Four Winds [10]. Apartment which has a height of 21 floors and 181 residential units with 279 residents, the seventh apartment Karet Kuningan [11]. Apartment has 648 residential units with 586 residents. All apartments above are for employees and their families.
The data collected consists of primary and secondary data:

- Primary data
  This data is obtained by reading water usage through a water meter for 7 x 24 hours.
- Secondary data
  Obtained from literature. The data are the number of occupants, building plans, and water usage patterns in other apartments that serve as a comparison.

In this study the method used is a comparison based on the amount of water usage of the occupants on average 7 x 24 hours. Noteworthy is the use of water at peak hours or the highest use of water by dividing the use of water per hour in 1 day.

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\text{Water needs} \quad \left( \frac{m^3}{\text{day}} \right) = \frac{\text{Average water usage} \quad \left( \frac{m^3}{\text{day}} \right)}{\text{number of inhabitants}}
\]  

(1)

The source of clean water used is taken from local water company (PDAM) or from Deep Well with piping systems. In this study water source data is taken from water meter data. In this study, apartments are needed in two different regions and in office areas that have a variety of units and occupancy.

3. Results and discussion

3.1. Research sites
Data for the research was located in two different cities, namely Surabaya and Jakarta. The city of Surabaya and the city of Jakarta were chosen because the two cities are close to the business or office area which can be seen from the pictures below.
3.2. Average water discharge needs
Discharge measurement results through direct monitoring on water meters in several apartments for 7 days x 24 hours in a row, so as to obtain the following results are Aston Marina Apartment has an average water discharge requirement of 225 m$^3$/day [7], Apartment X has an average water discharge requirement of 224 m$^3$/day [7], Tamansari Sudirman Executive Residence Apartment has an average water requirement of 223.8 m$^3$/day [8], Merr Apartment needs 253 m$^3$/day [9], Manyar Apartment needs an average of 118 m$^3$/day [9], Four Winds Apartment needs an average of 46.33 m$^3$/day [10], Karet Kuningan apartments average water needs as much as 149 m$^3$/day [11].

3.3. Water needs
To plan clean water needs in a building, it can be calculated based on the average number of uses per day per person and the number of inhabitants. The results obtained from the clean water needs of each apartment is Aston Marina Apartment has a water requirement of 0.029 m$^3$/person/day [7], Apartment X has a water requirement of 0.26 m$^3$/person/day [7], Tamansari Sudirman Executive Residence Apartment has a water requirement of 0.25 m$^3$/person/day [8], Merr Apartment has a water requirement of 0.27 m$^3$/person/day [9], Manyar Apartment has a water requirement of 0.15 m$^3$/person/day [9], Four Winds Apartment has a water requirement of 0.17 m$^3$/person/day [10], Karet Kuningan Apartment has a water requirement of 0.25 m$^3$/person/day [11].

3.4. Water use fluctuations
Data on fluctuations in water usage are obtained from monitoring conducted every hour for 7 days. Fluctuations in water usage can be divided into 2, namely water use on workdays and weekends, and fluctuation data from water usage is taken from 2 different cities namely Surabaya City and Jakarta City by having the same water usage pattern, namely in office areas and in the middle city.

Figure 8. (a) Fluctuations in regional water supply in Surabaya on weekdays, (b) Fluctuations in clean water use in Surabaya on weekends.
Table 1. Use of clean water in Surabaya on weekdays and weekends [9].

| Time       | Weekdays |    | Weekdays |    | Weekends |    | Weekends |    |
|------------|----------|----|----------|----|----------|----|----------|----|
| Merr       | Manyar   | Merr| Manyar   | Merr| Manyar   | Merr| Manyar   |
| 00-01 am   | 0.25%    | 0.22%| 0.47%    | 0.94%| 0.22%    | 0.25%| 0.47%    | 0.94%|
| 01-02 am   | 0.24%    | 0.03%| 0.52%    | 0.49%| 0.03%    | 0.24%| 0.52%    | 0.49%|
| 02-03 am   | 0.37%    | 0.20%| 0.40%    | 0.54%| 0.20%    | 0.37%| 0.40%    | 0.54%|
| 03-04 am   | 0.32%    | 0.51%| 0.18%    | 0.45%| 0.51%    | 0.32%| 0.18%    | 0.45%|
| 04-05 am   | 0.62%    | 1.22%| 0.35%    | 0.74%| 1.22%    | 0.62%| 0.35%    | 0.74%|
| 05-06 am   | 7.22%    | 7.43%| 5.65%    | 6.18%| 7.43%    | 7.22%| 5.65%    | 6.18%|
| 06-07 am   | **8.34%**| **8.21%**| 6.92%    | 6.45%| **8.21%**| **8.34%**| 6.92%    | 6.45%|
| 07-08 am   | 6.63%    | 7.96%| **7.27%**| **6.70%**| 7.96%    | 6.63%| **7.27%**| **6.70%**|
| 08-09 am   | 6.43%    | 7.24%| 6.86%    | 6.45%| 7.24%    | 6.43%| 6.86%    | 6.45%|
| 09-10 am   | 5.87%    | 4.97%| 5.57%    | 6.18%| 4.97%    | 5.87%| 5.57%    | 6.18%|
| 10-11 am   | 5.10%    | 4.32%| 4.27%    | 5.57%| 4.32%    | 5.10%| 4.27%    | 5.57%|
| 11-12 am   | 4.63%    | 4.40%| 4.77%    | 4.89%| 4.40%    | 4.63%| 4.77%    | 4.89%|
| 00-01 pm   | 5.39%    | 4.32%| 5.75%    | 5.50%| 4.32%    | 5.39%| 5.75%    | 5.50%|
| 01-02 pm   | 5.43%    | 4.14%| 5.49%    | 4.76%| 4.14%    | 5.43%| 5.49%    | 4.76%|
| 02-03 pm   | 4.54%    | 3.73%| 4.53%    | 4.33%| 3.73%    | 4.54%| 4.53%    | 4.33%|
| 03-04 pm   | 4.82%    | 3.80%| 5.03%    | 3.89%| 3.80%    | 4.82%| 5.03%    | 3.89%|
| 04-05 pm   | 5.12%    | 4.63%| 5.30%    | 5.24%| 4.63%    | 5.12%| 5.30%    | 5.24%|
| 05-06 pm   | 5.89%    | 6.62%| 6.26%    | 7.08%| 6.62%    | 5.89%| 6.26%    | 7.08%|
| 06-07 pm   | **7.21%**| **7.11%**| **7.28%**| **7.35%**| 7.11%    | **7.21%**| **7.28%**| **7.35%**|
| 07-08 pm   | 6.35%    | 7.01%| 7.20%    | 4.78%| 7.01%    | 6.35%| 7.20%    | 4.78%|
| 08-09 pm   | 4.87%    | 6.68%| 5.15%    | 5.23%| 6.68%    | 4.87%| 5.15%    | 5.23%|
| 09-10 pm   | 3.41%    | 3.83%| 3.08%    | 3.48%| 3.83%    | 3.41%| 3.08%    | 3.48%|
| 10-11 pm   | 0.75%    | 0.91%| 1.26%    | 1.66%| 0.91%    | 0.75%| 1.26%    | 1.66%|
| 11-12 pm   | 0.29%    | 0.50%| 0.42%    | 1.13%| 0.50%    | 0.29%| 0.42%    | 1.13%|

Figure 9. (a) Fluctuations in clean water use in Jakarta on weekdays, (b) Fluctuations in clean water use in Jakarta on weekends.
Table 2. Fluctuations in clean water usage in Jakarta on weekdays.

| Time       | Weekdays            |          |          |        |          |          |
|------------|---------------------|----------|----------|--------|----------|----------|
|            | Aston Marina [7]    | Apart X [7] | Tamansari Sudirman Executive Residence [8] | Four Winds [10] | Karet Kuningan [11] | Aston Marina [7] | Apart X [7] | Tamansari Sudirman Executive Residence [8] | Four Winds [10] | Karet Kuningan [11] |
| 00:01 am   | 0.50%               | 1.10%    | 0.00%    | 0.00%  | 1.26%    | 0.50%    | 0.80%    | 0.00%    | 0.00%    | 0.00%    | 0.75%    |
| 01:02 am   | 0.30%               | 0.10%    | 0.00%    | 0.00%  | 0.09%    | 0.20%    | 0.30%    | 0.00%    | 0.00%    | 0.00%    | 0.31%    |
| 02:03 am   | 0.10%               | 0.00%    | 0.00%    | 0.00%  | 0.02%    | 0.00%    | 0.10%    | 0.00%    | 0.00%    | 0.00%    | 0.10%    |
| 03:04 am   | 0.30%               | 0.10%    | 0.00%    | 0.00%  | 0.06%    | 0.20%    | 0.30%    | 0.00%    | 0.00%    | 0.00%    | 0.27%    |
| 04:05 am   | 1.10%               | 0.90%    | 0.00%    | 0.00%  | 1.14%    | 1.40%    | 1.60%    | 0.00%    | 0.00%    | 0.00%    | 1.51%    |
| 05:06 am   | 6.50%               | 4.60%    | 6.48%    | 4.84%  | 5.20%    | 6.70%    | 5.20%    | 2.65%    | 3.83%    | 4.92%    |
| 06:07 am   | 9.00%               | 7.20%    | 10.48%   | 6.36%  | 7.73%    | 8.50%    | 7.50%    | 0.79%    | 6.06%    | 7.00%    |
| 07:08 am   | 7.50%               | 8.80%    | 10.99%   | 7.17%  | 9.48%    | 8.30%    | 9.30%    | 6.69%    | 6.72%    | 8.69%    |
| 08:09 am   | 5.40%               | 7.50%    | 5.54%    | 6.85%  | 8.03%    | 7.40%    | 8.70%    | 10.22%   | 7.62%    | 8.11%    |
| 09:10 am   | 4.50%               | 6.20%    | 5.54%    | 5.86%  | 6.60%    | 5.50%    | 6.80%    | 5.73%    | 6.18%    | 6.41%    |
| 10:11 am   | 3.90%               | 4.90%    | 3.21%    | 4.94%  | 5.43%    | 4.20%    | 5.90%    | 4.71%    | 5.17%    | 5.53%    |
| 11:12 am   | 3.40%               | 3.70%    | 3.21%    | 5.01%  | 4.18%    | 4.20%    | 5.00%    | 5.56%    | 5.21%    | 4.71%    |
| 00:01 pm   | 5.10%               | 3.60%    | 3.21%    | 5.91%  | 4.07%    | 5.50%    | 4.60%    | 6.45%    | 5.39%    | 4.35%    |
| 01:02 pm   | 4.50%               | 3.60%    | 3.63%    | 5.70%  | 3.97%    | 4.50%    | 4.50%    | 9.31%    | 5.58%    | 4.18%    |
| 02:03 pm   | 4.30%               | 2.70%    | 3.63%    | 5.15%  | 2.86%    | 3.40%    | 4.50%    | 7.02%    | 4.92%    | 4.20%    |
| 03:04 pm   | 3.90%               | 2.90%    | 3.21%    | 4.91%  | 3.13%    | 4.30%    | 4.10%    | 5.94%    | 5.06%    | 3.92%    |
| 04:05 pm   | 5.30%               | 3.50%    | 3.63%    | 5.05%  | 3.82%    | 5.50%    | 5.30%    | 5.10%    | 5.16%    | 4.88%    |
| 05:06 pm   | 6.70%               | 5.00%    | 3.63%    | 5.29%  | 5.64%    | 6.30%    | 6.20%    | 9.07%    | 5.28%    | 5.83%    |
| 06:07 pm   | 8.20%               | 7.90%    | 7.66%    | 6.03%  | 8.42%    | 7.30%    | 9.00%    | 8.88%    | 5.46%    | 8.41%    |
| 07:08 pm   | 7.40%               | 6.80%    | 12.26%   | 6.67%  | 7.22%    | 7.00%    | 7.40%    | 6.98%    | 6.23%    | 6.90%    |
| 08:09 pm   | 5.10%               | 4.60%    | 10.29%   | 7.08%  | 4.96%    | 4.50%    | 4.50%    | 4.55%    | 7.47%    | 4.27%    |
| 09:10 pm   | 3.00%               | 3.20%    | 3.39%    | 5.82%  | 3.65%    | 2.20%    | 2.90%    | 0.36%    | 6.12%    | 2.69%    |
| 10:11 pm   | 2.10%               | 1.80%    | 0.00%    | 1.35%  | 2.06%    | 1.50%    | 1.70%    | 0.00%    | 2.53%    | 1.69%    |
| 11-12 pm   | 1.10%               | 0.80%    | 0.00%    | 0.00%  | 0.80%    | 0.80%    | 0.40%    | 0.00%    | 0.00%    | 0.37%    |

From the measurement results it can be seen that the peak hours of weekdays and weekends in the two cities occur twice each, on workdays it is higher than weekends in the two regions, namely during workdays peak hours in the Surabaya City area apartments occur at 6:00 to 7:00 am in the morning and 06:00-07:00 pm at night. While the peak hour weekend occurs at 7:00 to 8:00 am in the morning and 06:00-07:00 pm at night. In apartments in the Jakarta City area, peak hours on workdays occur at 06:00 - 09:00 am and at 07:00-08:00 pm. Meanwhile, on weekends the peak hours occur at 06:00 - 09:00 am and 06:00-07:00 pm.

4. Conclusions

- From the overall apartment water use patterns it can be seen, the average peak hours on workdays occur in the range of 06:00-08:00 am in the morning and 06:00-09:00 pm at night. While the peak hour weekends occur in the range 06:00-08:00 in the morning and 06:00-07:00 pm in the evening.
- Jakarta area apartments on workdays the morning at 06:00 - 08:00 with a fluctuation range of 7.17%- 0.99% and at night on 04:00-08:00 pm with a fluctuation range of 6.2%-12.23%. In the apartment which experiences a peak hour at 04:00 pm occurs because the area is including an area that has a lot of expatriates. On weekends, in the morning at 06:00 - 08:00 am with a fluctuation range of 6.4%-10.22% and at night on 05:00-09:00 pm with a fluctuation range of 6.9%-9.07%.
• Surabaya area apartments on workdays, in the morning at 06:00-07:00 am with a fluctuation range of 8.21%-8.34% and at night on 06:00-07:00 pm with a fluctuation range of 7.11%-7.21%. On weekends in the morning at 07:00-08:00 am with a fluctuation range of 6.7%-7.27% and at night on 06:00-07:00 pm with a fluctuation range of 7.28%-7.35%.

• Water needs for the Jakarta area which is the water requirement for each person in one occupancy are Aston Marina Apartment at 0.029 m$^3$/person/day, Apartment X as much as 0.26 m$^3$/person/day, Tamansari Sudirman Executive Residence Apartment as much as 0.25 m$^3$/person/day, Merr Apartment at 0.27 m$^3$/person/day, Manyar Apartment at 0.15 m$^3$/person/day, Four winds Apartment at 0.17 m$^3$/person/day, Brass rubber Apartment at 0.25 m$^3$/person/day.

• From the data, more water is used on weekends compared to workdays because occupants have more activity in residential than on workdays.

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