THE FLUCTUATION OF DOMESTIC WASTEWATER DISCHARGED FROM OFFICE BUILDING

*Vandith Va¹, Ahmad Soleh Setiyawan¹, and Prayatni Soewondo¹

¹Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Indonesia

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ABSTRACT: The domestic wastewater from office building has been recognized to be different to other sources of wastewater discharge. The objectives of this research were to know the fluctuation of quantity, fluctuation of quality, and the peaking factor of wastewater discharge. The samples were taken from hourly sampling and daily sampling from 7 am to 5 pm and from Monday to Friday during the working time. The results showed that wastewater discharge varied over time and the quantity of Blackwater, greywater and mixed wastewater were ranging from 20.4 to 22.6, 18.7 to 23.3 and 39.61 to 49.93 liter/person/day, respectively. The quality of mixed wastewater varied over time such as for COD, TN, and TP was 252.45±88.96, 85.42±24.08 and 3.01±1.92 mg/L (mean± standard deviation), respectively. The low concentrations were in the afternoon after lunch time. The peaking factor of Blackwater, greywater and mixed wastewater discharge were 1.67, 1.6 and 1.83 at the beginning of working time and the praying time of Muslim Indonesian culture, respectively. It is proposed that domestic wastewater from office building has specific characteristics and the findings of this research can be served as useful information for designing of domestic wastewater treatment system for office buildings.

Keywords: Domestic wastewater, Fluctuation of domestic wastewater, Office building, Peaking factor

1 INTRODUCTION

There are many developing countries that have difficulties in managing their domestic wastewater, generally, in the big cities. Indonesia also faces many challenges about domestic wastewater management, which includes Blackwater, greywater and mixed wastewater.

Indonesia has sewerage systems, which serve around 2.13% of the national population [1]. Untreated domestic wastewater could make a problem of environmental deterioration in rivers, lakes and other public water bodies. It has been increasing considerably over the past decade and the main sources of water pollution are domestic wastewater [1].

Bandung City is one of 13 cities in Indonesia that already has an off-site system with limited service against the total population. The wastewater treatment plant, which is called Bojongsoang wastewater treatment plant (WWTP), has a capacity of 89,000 m³/day and covers treatment for the Eastern part of the city. Only around 35% of the population is connected to the treatment plant. In regard to the area also about 30% of Bandung is covered with the sewer [2]. Nowadays, the operation of Bojongsoang WWTP is not effective because existing work capacity is only 40,000 m³/day. The treatment plant is also suffering to people living around that area, who take water directly from the open sewer channel and ponds for irrigation [15]. Wastewater generated from various office building has been recognized to be different from other sources of wastewater. Installation of appropriate wastewater treatment technology at the initial source of pollution can solve the specific problem of wastewater. There is a little information about characteristics of office building wastewater. To implement the appropriate on-site office building wastewater treatment system, the research on characteristics of domestic wastewater needs to be considered in advance. Therefore, this research was to know the fluctuation of quantity, fluctuation of quality and the peaking factor of wastewater discharged from office buildings in Bandung, West Java, Indonesia.

2 METHOD

Location and period of research, data collection, data analysis, analytical method, and data analysis were described in this part.

2.1 Location and Period of Research

Two office buildings in Bandung, West Java, Indonesia have been selected for this research. Building A is located at St. Tamansari, Bandung, and building B is located at St. Japati, Bandung as presented by Fig. 1.

The period of this research took about five months started from December 2017 to April 2018.



Fig.1 (a): Building A is located at St. Tamansari, Bandung with 53 persons and (b): Building B is located at St. Japati, Bandung with 900 persons.

2.2 Data Collection

Wastewater characteristic is widely used for wastewater treatment plant and on-site domestic wastewater treatment plant. WWTP and on-site WWTP have important roles to solve water environmental problems. Fig. 2 (a) showed the quantity of blackwater sampling and Fig. 2 (b) showed the greywater sampling generated from building A. To know the quantity of Blackwater, the bucket has capacity of 21.6 litters used and it was pursed out when it was full of blackwater manually hourly from 7 am until 5 pm and from Monday to Friday. To know the quantity of greywater, the bucket with a capacity of 9 litters used and it was pursed out when it was full of greywater hourly manually from 7 am until 5 pm and from Monday to Friday. Fig. 3 (c) showed the quality of mixed wastewater sampling and Fig. 3 (d) showed the quantity of mixed wastewater sampling from building B. To know the fluctuation of the quality of mixed wastewater, the grab samples were taken from the inlet points. The points before it was mixed in the septic tank every hour from 7 am until 5 pm with a small bucket of 0.5 litters



Fig.2 (a): quantity sampling of blackwater generated from building A, (b): Quantity of greywater sampling from building A. (c): a sampling of quality of mixed wastewater from building B measurement and (d): the quantity of mixed wastewater sampling from building B measurement.

and mixed it in the bigger container of 5 litters to measure in the laboratory of the department of environmental engineering at Institut Teknologi Bandung (ITB). There is no commercial activity in these two buildings. Blackwater is the wastewater generated from the closet and urinals, while the greywater is the wastewater generated from lavabo, ablution, kitchen, and shower. Moreover, the number of people working in building A and Building B were 53 and 900 persons, respectively. To know the quantity of mixed wastewater, the width, depth and length of the final compartment of the septic tank were known and the level of wastewater was measured manually by using metering hourly from 7 am until 5 pm on Thursday and Friday.

2.3 Analytical Method

The following parameters were determined according to the standard method for the examination of water and wastewater: COD: Chemical Oxygen Demand (SMEWW 5220-B), BOD: Biochemical Oxygen Demand (SMEWW-5210-B), TN: Total Nitrogen (SMEWW 4500-B), and TP: Total Phosphorous (SMEWW 4500-P-D) [11].

2.4 Data Analysis

This part was discussed the peaking factor calculation, parameters analysis, and statistical analysis.

2.4.1 Peaking Factor Calculation

Peaking factor is equal to maximum flowrate divided by average flowrate based on Eq.1 [9].

$$\boldsymbol{PF_{max}} = \frac{\boldsymbol{Q_{max}}}{\boldsymbol{Qavg}}$$

(1)

Where Qmax is maximum flowrate, PFmax is peaking factor and Qavg is average flow rate.

2.4.2 Parameter Analysis

The parameters of mixed wastewater quality in this research are such as COD, BOD, TN, and TP and quantity of wastewater generated from office buildings as they are considered to be the main parameters for designing of the wastewater treatment system.

2.4.3 Statistical Analysis

Mean and standard deviation is shown in this part below,

a. Grand Mean

The grand mean of a set of samples is the total of all the data values divided by the total sample size based on Eq.2.

$$\bar{X}_{GM} = \frac{\sum x}{n} \tag{2}$$

a. Standard Deviation

$$s = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}} \tag{3}$$

S Sample standard deviation,

 $\frac{\sum}{\overline{X}} \qquad \text{Sum of...,} \\ \text{Sample mea}$

 \overline{X} Sample mean, n = number of scores in sa ample A standard deviation is a number used to tell how measurements for a group are spread out from the average (mean) or expected value. A low standard deviation means that most of the numbers are very close to the average. A high standard deviation means that the numbers are spread out based on Eq.3.

3 RESULTS AND DISCUSSION

The fluctuation of quantity, fluctuation of quality and a peaking factor of wastewater discharge were discussed in this part.

3.1 Fluctuation of Quantity of Wastewater Discharge

The fluctuation of Blackwater, fluctuation of greywater and mixed wastewater discharge were discussed in this part.

3.1.1 Fluctuation of Blackwater Discharge

The fluctuation of blackwater from office building A was measured on January 22, April 04, and April 06, 2018. Based on Fig .3, people may use much water in the morning at 7 am when they first came to the office. Blackwater was getting down from 8 am until 10 am and It showed that people may not use much water because they were working at that time. It was increasing at 11 am. Perhaps, the men started to use urinals and toilets before they were going to pray. Wastewater discharge showed the high point at 13 pm because they may use urinals and toilets after the lunch break and it was getting down again as it was the time to work. By the way, it was getting up



Fig.3 The fluctuation of blackwater from building A was measured (January 22^{nd} , 2018), (April 04^{th} , 2018) and (April 06^{th} , 2018).



Fig. 4 The fluctuation of greywater discharge from building A was measured (January 17th, 2018) (April 04th, 2018) and (April 06th, 2018).

16 pm because they may use the urinals and toilets before coming back home. In respect of the volume of the future wastewater, the development should, of course, be taken into account, the quantity of blackwater discharge from building A was $21.64 \pm 1.15 \text{ l/p/d}$ (mean \pm standard deviation) and average of blackwater discharge from household was 28.5 l/p/d conducted by Palmaquist and Hanaux (2005) [3]. This indicated that the quantity of blackwater from office building was lower than the quantity of blackwater from the household.

3.1.2 Fluctuation of Greywater Discharge

Based on Fig. 4, the quantity of greywater discharge was high at 7 am and it was getting down from 8 am until 10 am. It showed that people may not use much water because they were working at that time. It was increased from 11 am until 1 pm because they may start to wash their hands, face, and legs before they prayed for Muslim Indonesian culture and after break time. The peak discharge showed a high point at 3 pm, which was 198 l/h because both men and women may be preparing themselves to pray at that time. The average of greywater discharge from household was 66 l/p/d conducted by Palmaquist and Hanaux (2005). In addition, the greywater production from household wastewater in Bandung city, Indonesia conducted by Firdayati et al. (2010) [4] was found to be 60 to 178 l/p/d. However, the average of the quantity of greywater discharge from office building was 20.76 l/p/d. This indicated that the quantity of greywater discharge from office building of this research was lower than the wastewater discharge from household conducted by Palmaquist and Hanaux (2005) and Firdayati et al. (2010).

3.1.3 Fluctuation of Quantity of Mixed Wastewater Discharge

Based on Fig. 5, the mixed wastewater, which was measured on Friday showed that the and wastewater generation was 4330 l/h at 7 am and it was getting down from 8 am to 10 am. Perhaps this showed that some people seemed to use much water when they arrived at their office in the morning. The wastewater generation was increased from 10 am to 12 am, which was the peak discharge of wastewater generation. This indicated that people may use much water before they prayed on Friday for Muslim Indonesian culture. From 1 pm and 2 pm, the wastewater was getting down again because of the working period. By the way, the wastewater generation was increasing at 3 pm. This indicated that people may use a bit high water before they prayed at 3:30 pm.

The wastewater was getting down again at 4 pm as it may be the time to come back home. Moreover, the quantity of wastewater discharge per person per day is 49.93 l/p/d with the number of people 900 persons. Based on Fig. 5 again, the mixed wastewater which was measured on Thursday showed that the wastewater generation was 3604.99 l/p/d at 7 am and it was getting down from 8 am to 10 am. Perhaps, this indicated that some people seemed to use much water when they arrived at their office in the morning. The wastewater generation was increased from 10 am to 12 am, which was the peak discharge of wastewater generation. This means that the people may use much water before they prayed for Muslim Indonesian culture. It was increasing at 3 pm. This showed that people may use higher water before they prayed at 3:30 pm.

The wastewater was getting down again at 4 pm as it may be the time to come back home. Comparing with the fluctuation of quantity of wastewater discharge from household, which has been conducted in Japan (Iyo *et al.* 2010) [10], the fluctuation of quantity of wastewater discharge from household is different to the quantity of wastewater discharge from an office building in this research. The quantity of mixed wastewater discharge from office building per person per day is 39.61 l/p/d with the number of 900 persons.

Moreover, the fluctuation of quantity of mixed wastewater from this research was quite similar to the previous research, which was conducted Va *et al.* (2018) [14] and it was high during the praying time. The quantity of mixed wastewater discharge from office building B was varying from 39.61 to 49.93 l/p/d with mean \pm standard deviation (44.77 \pm 7.3). Moreover, the average of the quantity of mixed wastewater from household found to be 44.5 l/p/d. The mixed wastewater from office building was lower than the quantity of mixed wastewater from household, which was conducted by Palmaquist and Hanaux (2005).



Fig.5 The fluctuation of quantity of mixed wastewater discharge from building B was measured (February 2^{nd} , 2018) and (March 22^{nd} , 2018).

3.2 Fluctuation of Quality of Mixed Wastewater Discharge

As can be seen in Fig. 6, the peak COD concentration was at 10 am about 432 mg/L, while the low COD concentration was at 4 pm about 106 mg/L with mean \pm was standard (252.5 \pm 89). It indicated that the difference of COD concentration in each hour may be due to the activities of people working in the office building. Based on Fig. 7, BOD/COD ratio of mixed wastewater varied over time from 7 am until 5 pm with the average concentration of 0.4.

The low BOD/COD concentration was at 10 am. Average of BOD/COD ratio of blackwater found to be 0.5, while the average of BOD/COD ratio of greywater was found to be 0.2. Maybe, the combination of blackwater and greywater could make the BOD/COD ratio of mixed wastewater become low because of the high contribution of greywater to mixed wastewater. based on Va *et al.* (2018) [5]. However, the high BOD/COD ratio found to be 0.6 and it was at 2 pm. Perhaps, people were working in that building used closets around that time after their lunch break.



Fig. 6 Variation of COD concentration hourly from 7 am until 5 pm, which was measured on Thursday, March 22^{nd} , 2018.

As can be seen in Fig. 8, the peak TN concentration was at 7 am about 114 mg/L, while the low TN concentration was at 10 am about 41 mg/L

with mean \pm standard deviation (85.42 \pm 24.08) and perhaps they used urinal when they came to work in the morning. As can be seen in Fig. 9, the peak TP concentration was at 11 am about 8.2 mg/L, while the low TP concentration was at 7 am about 0.99 mg/L with mean \pm standard deviation (85.16 \pm 3.01 \pm 1.92) and it showed the high significance in a different hour because it may be due to people's activities. Based on Fig. 6, Fig. 8 and Fig. 9, the peak COD, TN and TP concentrations were higher than COD, TN and TP



Fig. 7 The fluctuation of BOD/COD ratio hourly of mixed wastewater generated from office building B, which was measured on Thursday, March 22nd, 2018.



Fig. 8 Th fluctuation of TN concentration of mixed wastewater from building B, which was measured on Thursday, March 22nd, 2018.



Fig. 9 The fluctuation of TP concentration of mixed wastewater from building B, which was measured on Thursday, March 22nd, 2018.

concentrations of office building wastewater, which was conducted in Thailand by Bouted and Ratanatamskul (2018) [6] and typical domestic wastewater Tchobanoglous *et al.* (2014) [8]. Moreover, comparing with the characteristics of wastewater generated office building from Campus conducted by Va *et al.* (2018) [12], [13], the nutrient

Table	1	The	peaking	factor	of	blackw	ater	and
greywa	ater	from	building	A, and	1 a j	peaking	facto	r of
mixed	wa	stewa	ter discha	rge fro	m b	uilding I	В.	

No	BW	GW	MW
Min flowrate (l/p/d)	20.38	18.66	39.61
Min flowrate (l/p/d)	22.62	23.26	49.93
Peaking factor	1.67	1.6	1.83

Note: BW: Blackwater, GW: Greywater, MW: Mixed Wastewater, Min: Minimum, Max: Maximum

concentration from an office building in this research was higher than the concentration of nutrient obtained from office building wastewater in Campus.

3.3 The Peaking Factors of Wastewater Discharge

Based on Table 1, the peaking factor of wastewater discharge is equal to maximum flow rate divided by the average flow rate of Blackwater obtained to be 1.67 with the peaking discharge was 3.66 l/p/h. Moreover, the quantity of greywater varied over time and a peaking factor of greywater discharge obtained to be 1.6 and the peaking discharge was 3.76 l/p/h. The quantity of mixed wastewater discharge varied over time with peaking factor of mixed wastewater discharge found to be 1.83 and the peak discharge was 9.15 l/p/h. The peaking factors of Blackwater, greywater, and mixed wastewater from office building wastewater in this research were lower than the peaking factor for wastewater flows from individual residences. small commercial establishments, and small communities [8] and this may be because of the differences of activities and facilities used between office building within individual residences. Moreover, based on Table 1, the average quantity of blackwater is equal to 43 l/p/d higher than the average quantity of greywater generated from building A from this research. This may be most people from office building use mostly toilets and urinals. Moreover, the average of the quantity of mixed wastewater generated office building B from this research was 44.47 l/p/d.

4 CONCLUSIONS

The fluctuation of quantity, fluctuation of quality and the peaking factor of wastewater generated from office buildings were evaluated. The domestic wastewater from office building has specific characteristics with high concentration of nutrient and low organic matter as it contained 106 to 432 mg/L COD, 41.23 to 113.91 mg/L TN, and 0.99 to 8.21 mg/L TP with the average of COD:TN: TP ratio was 84:28:1. The quantity of wastewater varied over time and the quantity of Blackwater, greywater and mixed wastewater were ranging from 20.4 to 22.6, 18.7 to 23.3 and 39.61 to 49.93 l/p/d, respectively. The quality of mixed wastewater varied over time and COD, BOD, TN, and TP were 252.45 ± 88.96, 80.40 \pm 38.26, 85.42 \pm 24.08, and 3.01 \pm 1.92 mg/L (mean \pm standard deviation) because of activities inside the building, respectively. The peaking factors of Blackwater, greywater, and mixed wastewater were 1.67, 1.6 and 1.83, respectively at the beginning of working time and the praying time of Muslin Indonesian culture. It is proposed that domestic wastewater from office building has specific characteristics and high concentrations of nutrient that is required the appropriate advanced technology for treating this kind of wastewater. The finding of this research can be served as useful information for the design of a domestic wastewater treatment system and operation for office buildings.

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