Preliminary Analysis of Blackwater and Greywater Characteristics in the Jakarta Greater Region Area

N Hafiza¹, A Abdillah¹, B B Islami¹, and C R Priadi¹

¹Environmental Engineering Study Program, Civil and Environmental Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok- Indonesia
Corresponding author: cindy.priadi@eng.ui.ac.id

Abstract. Domestic wastewater contributes about 40% as the source of water bodies pollutants in Indonesia, causing the spread of pathogens and bioaccumulation effects on the environment. The purpose of this study was to analyze the characteristics of household wastewater in Jakarta and Depok in terms of quantity and quality. The average wastewater quantity estimation results from laundry, bathroom, kitchen, and closet were 49 ± 18, 79.1 ± 5, 24.5 ± 12, and 29.9 ± 3 liters/person/day. The qualitative analysis results stated that blackwater tends to have higher concentration on conductivity 1606-2046 μs/cm, TDS 709-1007 mg/L, ammonia 78-167 mg/L, total nitrogen 511-836 mg/L, total phosphorus 16.6-21.3 mg/L, phosphate 33-46.8 mg/L, potassium 32.5-47.9 mg/L, and fecal coliform 430,000-1,600,000 MPN/100 mL compared to other sources. Meanwhile, laundry greywater tends to have higher concentration on COD 559-1991.6 mg/L, MBAS 0.3-0.31 mg/L, aluminum 1.65-5.09 mg/L, sodium 7.5-61.4 mg/L, and silica 17.7-23.2 mg/L compared to other sources. Statistical results show that some parameters have significant difference in average concentration between each source so that these parameters can be considered as source tracer. The high pollutant concentration and quantity leads to high estimation of pollutant load on the river, as water bodies receiver, in Jakarta and Depok, especially on organic and nutrient load.

Keywords: wastewater, pollutant, laundry

1. Introduction
Indonesia, the world fourth largest population country, has many wastewater management problem, including domestic wastewater management [1]. Domestic wastewater contributes 40% as pollutant to river, lake, and other water sources. Groundwater contamination also occurs due to domestic wastewater infiltration to groundwater. Some pollutants in domestic wastewater have long-term chronic effect or bioaccumulation. Even though the concentration is low and does not show direct effect, it still becomes an important consideration because some organisms have high sensitivity to chemicals [2]. Furthermore, the untreated wastewater can lead to microorganism spread from one human to another. Pathogen Escherichia coli is one of the microorganisms of human intestine that produce toxin causing diarrhea to human.

Wastewater primary treatment level in Indonesia has only reached 25% of the total produced wastewater, meanwhile, the other 75% is directly discharged into the river or other water bodies. Therefore, identification of wastewater technology combination is important for planning the
development of municipal wastewater system for urban sanitation strategy in Indonesia. There are some important requirements in planning new wastewater installation, such as able to adapt with changing wastewater characteristics, especially increasing wastewater concentration; and able to comply effluent discharge standards [3].

Domestic wastewater, which consists of blackwater and greywater, from various sources have different physicochemical characteristics. These characteristic differences are caused by several parameters, which are water supply quality, piping, activities of the residents, and household product used. Wastewater influent characteristic affects the type of technology process to be used and the requirement for the treatment operation to run properly [3]. Moreover, determining wastewater characteristics are important consideration in planning treatment technology to be applied.

This study performs characterization towards household wastewater, one of the biggest non-point sources pollutants on river. The data were collected from houses in the city of Jakarta and Depok, which are part of Ciliwung River watershed. Quality and quantity characteristics analysis are made on blackwater and greywater that come from bathroom, laundry, and washing basin. The qualitative results then used to determine the source tracer between greywater, blackwater, and groundwater.

2. Methodology
2.1 Study area
The houses are located in Beji, a sub-district in Depok and Jagakarsa, a sub-district in South Jakarta. The distance between each house is 0.46 kilometers from house 1 to house 2, 0.96 kilometers from house 2 to house 3, and 1.42 kilometers from house 1 to house 3. Each house has different building area, number of residents, number of rooms, and other specification. Specification of house 1, 2, and 3 are reported in Table 1.

| Specification | House 1       | House 2       | House 3       |
|---------------|---------------|---------------|---------------|
| Building area (m²) | 200           | 63            | 70            |
| Number of residents (person) | 3 (2 adults, 1 child) | 6 (5 adults, 1 child) | 4 (3 adults, 1 child) |
| Number of rooms | 2 bedrooms    | 3 bedrooms    | 3 bedrooms    |
|                | 3 bathrooms   | 2 bathrooms   | 2 bathrooms   |
|                | 1 kitchen     | 1 kitchen     | 1 kitchen     |
| Clean water source | Deep well     | Deep well     | Deep well     |

2.2 Determining wastewater discharge
Determining the wastewater discharge was done by giving questionnaire about water usage. The questionnaire consists of water usage details, such as water tap flow, washing machine and toilet flushing water usage volume, frequency of each activity, and data about the number of residents in order to know the water consumption per capita in one day. The estimation calculation of wastewater discharge was done by multiplying the water consumption per capita per day with the percentage of household wastewater generation. Based on regulation from ministry of public works and housing Indonesia, and regulation from Jakarta governor, household wastewater generation is 60-80% of the water usage.

2.3 Wastewater sampling
Number of samples taken from each house are 5 samples, consist of blackwater; greywater that comes from bathroom, laundry, washbasin; and groundwater as the source of clean water. Groundwater sampling was done because the quality of groundwater between the 3 houses is different. The sampling method was based on SNI 6989.59:2008 about wastewater sampling method. The blackwater and groundwater from each house were only taken at one time (grab sampling), meanwhile, the
greywater from each house was taken for several times due to the wastewater fluctuation during activities (composite sampling). Equipment used to take greywater sample was automatic water sampler ISCO 3700. Blackwater, groundwater, and greywater samples were stored on polypropylene bottles, which had already washed following manual by National Field Manual for the Collection of Water-Quality Data U.S Geological Survey 2015.

2.4 Wastewater examination and analysis
Household wastewater were analyzed for 26 parameters which are: temperature, total suspended solid (TSS), total dissolved solid (TDS), conductivity (EC), oil and grease, chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen, total nitrogen, total phosphor, ammonia, phosphate, pH, methylene blue active substances (MBAS), fecal coliform, Fe, Na, K, Cu, Zn, Mg, Al, Pb, Ni, Cl, and, Si. These parameters conducted according to Standard Method APHA 22 2012. The results were statistically evaluated with T-test using IBM SPPSS Statistics software to determine the significance of the difference between the average values.

3. Results and Analysis

3.1 Quantitative household wastewater characteristics analysis
Wastewater discharge estimation obtained by multiplying water tap flow with duration and frequency of shower and washing dishes in a day, and by multiplying volume per wash and per flush of washing machine and toilet with frequency of use in a day. The estimation results are stated in litres/capita/day so that the results for washing clothes and dishes activities (litres/day) should be divided by the number of residents in the house. Percentage of wastewater generation in this study assumed to be 80% of the water usage. The water usage questionnaire results and wastewater discharge estimation are reported in Table 2.

| Table 2. Estimation of Water Usage and Wastewater Flow Rate. |
|-------------------------------------------------------------|
| Characteristics                                               | House 1 | House 2 | House 3 | Average |
| Washing machine                                             |
| Volume per wash (litres)                                    | 226     | 220     | 140     |
| Frequency of use (times/day)                                | 1       | 2       | 1       |
| Kitchen Sink                                                |
| Kitchen sink flow tap (litres/minutes)                      | 6.2     | 9.4     | 4.4     |
| Duration of use (minutes)                                   | 7       | 10      | 5       |
| Frequency of use (times/day)                                | 2       | 3       | 3       |
| Bathroom Tap/Shower                                         |
| Bathroom tap/shower flow (litres/minutes)                   | 5.3     | 4.8     | 4.7     |
| Duration of use (minutes)                                   | 10      | 10      | 5       |
| Frequency of use (times/person/day)                         | 2       | 3       | 3       |
| Closet                                                      |
| Volume per flush (litres)                                   | 8       | 8       | 8       |
| Frequency of use (times/person/day)                         | 4       | 5       | 5       |
| Number of residents (person)                                | 3       | 6       | 4       |
| Water usage estimation (litres/person/day)                  |
| Laundry                                                    | 75.3    | 73.3    | 35      | 61.2    |
| Kitchen sink                                               | 28.7    | 46.8    | 16.3    | 30.6    |
| Characteristics | House 1 | House 2 | House 3 | Average |
|-----------------|--------|--------|--------|---------|
| Bathroom        | 107    | 95.3   | 94.3   | 98.9    |
| Closet          | 32     | 40     | 40     | 37.3    |
| Total water usage | 243.1  | 218.8  | 185.6  | 215.8   |

**Wastewater flow rate estimation (liters/person/day)**

|            | Laundry | Kitchen sink | Bathroom | Closet |
|------------|---------|--------------|----------|--------|
| Laundry    | 60.3    | 23           | 85.6     | 25.6   |
| Kitchen sink | 58.7  | 37.5         | 76.3     | 32     |
| Bathroom   | 28      | 13.1         | 75.4     | 32     |
| Closet     | 49      | 24.5         | 79.1     | 29.9   |
| **Total wastewater flow rate (80% of water usage)** | 194.5 | 204.4 | 148.5 | 182.5 |

Greywater from bathroom contributes the most from total wastewater generation estimation, due to the long duration of use. Meanwhile, greywater from kitchen sink contributes the least from total wastewater generation estimation, due to collectively done dish cleaning in each house. The average wastewater generation estimation is 182.5 liters/person/day, which is higher than the maximum standard of wastewater discharge from ministry of environment Indonesia 100 liters/person/day. Compared to previous studies in Oman [4], Jordan [5], Greek [6], and Sweden [7] laundry greywater and bathroom greywater flow rate estimation in this study tend to be higher, because of the use of washing machine. Meanwhile, kitchen sink greywater and blackwater flow rate estimations in this study are about the same as the previous studies.

### 3.2 Qualitative household wastewater characteristics analysis

The wastewater examination results were compared based on the source, blackwater, greywater, and groundwater. Based on table 3, there are several parameters that tend to have higher concentrations in one particular source, especially in blackwater and laundry greywater. Blackwater tend to have higher concentration on conductivity, TDS, ammonia, total nitrogen, total phosphor, potassium, and faecal coliform, while laundry greywater has higher concentration on COD, MBAS, aluminium, sodium, and silica.

High nutrient load on blackwater is due to urine produced by human body. Major sources of nitrogen, phosphor, and potassium on human body come from food, drinking water, and exposure from atmosphere. About 20% of phosphor and 85% of nitrate on human body come from food, especially vegetables and fruits. Vegetables, fruits, meat, and milk are also major source of potassium in urine [8]. Drinking water usually contributes only 2-3% of nitrite and nitrate, however, when the drinking water consumed in large quantities, it will be a significant source of nitrite and nitrate on human body [9]. In this study, the groundwater, which is used as source of drinking water, has high average concentration of total nitrogen, 192 mg/L, exceed the maximum standard of drinking water from ministry of health Indonesia. Faecal coliform is the reliable indicator to identify faecal/faeces contamination. *Escherichia coli* considered as effective faecal indicator because it has no other source in the environment other than faeces.

High concentrations of COD, MBAS, aluminium, and silica on laundry greywater are caused by detergent usage in washing clothes process. High MBAS concentration on greywater laundry indicate the high concentration of anionic surfactant on detergent. Anionic surfactant is one of the cleaning agent chemicals in detergent [10]. The principle of MBAS is the formation of chloroform complex ion between the anionic surfactant and methylene blue [11]. Several compounds of anionic surfactant cannot be easily biodegradable, causing the inhibition of microorganism activity [12] and high concentration of COD. Ca$^{2+}$ and Mg$^{2+}$ ion that come from hard water can decrease cleaning efficiency of surfactant. Therefore, sodium silicate and sodium citrate are used as builders to remove hard water ion from water by softening the water [13].
All of the qualitative parameter results between greywater, blackwater, and groundwater were statistically tested using t-test. The t-test was used to find parameters that have different or higher concentration means between blackwater, groundwater, and 3 sources of greywater, which later were identified as source tracer. According to the t-test results (Table 4), ammonia, total nitrogen, total phosphor, phosphate, potassium, and faecal coliform concentrations from blackwater have significantly higher means compared to other sources. Meanwhile, MBAS, aluminium, and silica from laundry greywater have significantly higher means compared to other sources. The rest of the parameters have the equal concentration means between each source. Tracer compounds give information about contaminant in specific sources, especially in the situation where pathway displacement cannot be confirmed. Results from source tracer identification can help to give effective and efficient respond management to the contaminant.

High household wastewater discharge and contaminant concentrations lead to high pollutant load. Greywater generally contribute higher percentage of pollutant load compared to blackwater due to the higher flow rate average. Blackwater only contributes higher percentage of pollutant load in some parameters, such as nitrogen, phosphor, and faecal coliform compared to greywater due to the higher contaminant concentration on blackwater source. Continuously increasing pollutant load continuously in river, as the receiving water body, will decrease the river’s self-purification and decrease the river water quality [1].

With the same method applied for packing material selection, bulrush/cattail (*ekor kucing*) and water hyacinth were selected as vegetation for constructed wetland and macrophyte pond (see also Table 2).

Table 3. Household Wastewater Quality Parameters Examination Results.

| Parameter       | Unit | Blackwater | Laundry Greywater | Bathroom Greywater | Kitchen sink Greywater | Groundwater |
|-----------------|------|------------|-------------------|--------------------|------------------------|-------------|
| **Physically Parameter** | | | | | | |
| Temperature °C | 28.7± 0.8 (28.3) | 27.8 ± 2.7 (28.5) | 27.6 ± 3 (28.1) | 29.4 ± 5.5 (30.5) | 29 ± 0.8 (29.4) | |
| Conductivity μs/cm | 1,858 ± 226.7 (1,921) | 1,382 ± 991 (1,256) | 424.3 ± 262 (293) | 321.3 ± 183.1 (316) | 59.1 ± 102.4 (0.01) | |
| TSS mg/L | 184.3 ± 76 (143) | 144 ± 58.1 (162) | 102.7 ± 101.3 (62) | 126.7 ± 93.5 (111) | | |
| TDS mg/L | 840.3 ± 152.1 (805) | 726 ± 485.5 (728) | 228.3 ± 167.3 (144.2) | 155.8 ± 62.9 (143.4) | 86.7 | |
| Oil and Grease mg/L | 14 ± 16.9 (5.6) | 30 ± 35.7 (17) | 9.6 ± 8.5 (5) | 56.1 ± 72.7 (24.6) | 0.5 | |
| **Chemical Parameter** | | | | | | |
| pH | 7.4 ± 0.4 (7.26) | 8.2 ± 1.4 (7.69) | 6.3 ± 1.3 (6.7) | 6.5 ± 1.3 (6) | 5.5 ± 1.5 (4.98) | |
| Ammonia NH₃ mg/L | 111.8 ± 48.2 (90.5) | 3.1 ± 2.6 (1.75) | 6.3 ± 6.8 (4.25) | 2.1 ± 1.8 (1.34) | 0.7 ± 0.9 (0.35) | |
| Total Nitrogen mg/L | 653.3 ± 166.2 (613) | 268 ± 134 (268) | 195.7 ± 60.9 (217) | 242 ± 85.3 (202) | 192 ± 42.5 (215) | |
| Total Phosphor mg/L | 18.4 ± 2.6 (17.2) | 2.2 ± 1.9 (1.91) | 2.3 ± 1.9 (1.38) | 1.4 ± 0.8 (1.03) | 0.4 ± 0.2 (0.38) | |
| Phosphate mg/L | 37.6 ± 8 (33) | 9.4 ± 1.2 (9.92) | 8.4 ± 4.4 (8.09) | 7.4 ± 10.1 (2.96) | 5.8 ± 8.5 (0.96) | |
| COD mg/L | 508.6 ± 140.1 (436.5) | 1,384.5 ± 740.8 (1,602.8) | 419.3 ± 81.1 (440) | 736.7 ± 414.9 (834.4) | 160.7 ± 26.8 (154.4) | |

| Parameter  | Statistical Results (Sig: 95%) | Parameter  | Statistical Results (Sig: 95%) |
|------------|--------------------------------|------------|--------------------------------|
| Temperature| B=G=L=T=K                      | MBAS       | L>B=T=K=G                      |
| Conductivity| B=L>G=L=T=K                   | Iron (Fe)  | B=G=L=T=K                     |
| TSS        | B=G=L=T=K                      | Sodium (Na)| B=G=L=T=K                     |
| TDS        | B=G=L=T=K                      | Potassium (K)| B>K=T=L=G                   |
| Oil and Grease| B=G=L=T=K                | Copper (Cu) | B=G=L=T=K                    |
| Ph         | B=G=L=T=K                      | Zinc (Zn)  | B=G=L=T=K                     |
| Ammonia (NH₃)| B=G=L=T=K                | Magnesium (Mg)| B=G=L=T=K                   |
| Total Nitrogen| B=G=L=T=K                 | Aluminium (Al)| L>G=T=K=B                  |
| Total Phosphor| B=G=L=T=K                   | Lead (Pb)  | B=G=L=T=K                     |
| Phosphate  | B>T=K=L>G                     | Nickel (Ni)| B=G=L=T=K                     |
| COD        | B=G=L=T=K                      | Chloride (Cl)| B=G=L=T=K                   |
| BOD        | B=G=L=T=K                      | Silica (Si)| L>B=G=T=K                    |
| Fecal Coliform | B=G=L=T=K                |                        |                                |

B = Blackwater  
G = Groundwater  
L = Laundry greywater  
T = Bathroom greywater  
K = Kitchen sink greywater  
= Different with one source only

Table 4. Statistical T-Test Results.

| Parameter            | Statistical Results (Sig: 95%) | Parameter            | Statistical Results (Sig: 95%) |
|----------------------|--------------------------------|----------------------|--------------------------------|
| temperature          | B= G= L= T= K                  | MBAS                 | L > B= T= K = G                 |
| conductivity         | B = L > G = L = T = K         | iron (Fe)            | B = G = L = T = K               |
| TSS                  | B = G = L = T = K             | sodium (Na)          | B = G = L = T = K               |
| TDS                  | B = G = L = T = K             | potassium (K)        | B > K = T = L = G               |
| oil and grease       | B = G = L = T = K             | copper (Cu)          | B = G = L = T = K               |
| ph                   | B = G = L = T = K             | zinc (Zn)            | B = G = L = T = K               |
| ammonia (NH₃)        | B > G = L = T = K             | magnesium (Mg)       | B = G = L = T = K               |
| total nitrogen       | B = G = L = T = K             | aluminium (Al)       | L > G = T = K = B               |
| total phosphorus     | B = G = L = T = K             | lead (Pb)            | B = G = L = T = K               |
| phosphate            | B = T = K = L > G             | nickel (Ni)          | B = G = L = T = K               |
| COD                  | B = G = L = T = K             | chloride (Cl)        | B = G = L = T = K               |
| BOD                  | B = G = L = T = K             | silica (Si)          | L > B = G = T = K               |
| fecal coliform       | B = G = L = T = K             |                     |                                |

B = Blackwater  
G = Groundwater  
L = Laundry greywater  
T = Bathroom greywater  
K = Kitchen sink greywater  
= Different with one source only
4. Conclusion
The quantitative analysis results stated that the average flowrate of household wastewater estimation in this study is 182.5 L/person/day, which consist of 29.9 L/person/day of blackwater and 152.6 L/person/day of greywater. The source that has the highest wastewater contribution is bathroom greywater, due to the long duration of the shower. The qualitative analysis results revealed that blackwater and laundry greywater tend to have higher average concentration compared to other sources in some parameters, which can be considered as source tracers. Wastewater source tracers were determined using statistical T-test. Based on the T-test results, ammonia, total nitrogen, total phosphor, phosphate, potassium, and faecal coliform were considered as tracers for blackwater. Meanwhile, MBAS, aluminium, and silica were considered as tracers for laundry greywater. The high flow rate and high contaminant concentrations of household wastewater lead to high pollutant load. Greywater contributes higher pollutant load in most of parameters, because of the higher flow rate. Blackwater contributes higher pollutant load only in some parameters, such as nitrogen and phosphorous, because of the higher concentration in the source.

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