Analysis of pollutant load due to greywater from riverbanks settlement on Ciliwung River segment 2

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Abstract. Greywater from domestic activities on the riverbanks settlement in Indonesia usually channelled directly to the drainage or to the river. It will be decrease the river water quality. The aims of the research are to analyse the pollutant load that enters the drainage channel due to greywater from settlement in banks of Ciliwung River segment 2 and responses of society sanitation habits. The research was conducted at 6 villages are Babakan Pasar, Sukasari, Baranangsiang, Cibuluh, Kedung Badak, and Sempur. Water samples were taken from the drainage channel in the morning and evening, which are considered to represent the peak hours of greywater. Sampling was conducted in May, June and July 2018. Pollutant load based on BOD level in the drainage channel ranges from 4,903.19 - 132,804.33 kg/day. This condition shows the high tendency of pollution due to greywater domestic activities and absence of greywater treatment in residential areas. Almost 50% of the community understand the importance of the need for wastewater management. Community awareness for sanitation habits such as environment community service and maintenance and handling waste in drainage. The conclusion is that greywater treatment in riverbanks settlement is really needed to be applied.

1. Introduction

The rapid growth of population in the urban area has significantly influenced the increase of wastewater generation [1]. Increasing population in urban areas has also increased the need for land as a place to live. As a result of the lack of vacant land in urban areas, settlement built dwellings on the banks of rivers. The impact of the growth of buildings on the banks of the river has resulted in a decrease in the conservation area and a blockage of drainage flow which is useful for flowing rain [2].

The river accepts load of pollutant that come from various sources and big part of the pollutant load is exceeded the permitted threshold so that the entry of pollutant sources causes the declining quality of Ciliwung River [3]. One of the pollutant enters the river are wastewater from households that generally consists of Blackwater from human and animal waste, and greywater from various household activities such as bathing and washing [4]. Some settlements dispose greywater through closed or open drainage [5], without treatment that can cause decreasing in the quality of river water [6]. One of the area that discharges wastewater into the drainage channel is in the Ciliwung River riverbanks in segment 2, Bogor City. The drainage channel is divided into a separate system and a mixed system [7]. In a separate system, wastewater and rainwater are discharged in different channels, while in mixed systems, wastewater and rainwater discharge are mixed in one channel [8]. In countries such as Finland and
Iceland, the disposal system carried out is a separate system [9], but in Indonesia the effluent system is still a mixed system [10].

Uncontrolled rapid development of settlements and mismanagement along the Ciliwung River has caused great impacts on social and environmental aspects of the region [11]. Domestic wastewater discharged into drainage channel will lead to higher content of pollutants in water and causing other problems such as health risks to humans and livestock, loss of oxygen and undesirable changes in aquatic ecosystem [12]. One of the indicator of pollution in river can be based on BOD value, where the accumulation of BOD from pollutant sources will cause a pollution load on the ability of the river to recover, so that it will reduce the capacity of the pollution load [13]. Based on this description, this study was conducted to calculate the pollutant load entering the drainage channel originating from domestic activities, and analyze sanitation activities carried out around the Ciliwung riverbank segment 2.

2. Method

2.1. Data collection

The study was carried out along the banks of Ciliwung River Segment 2, Bogor City. The chosen locations, which is a location inhabited by settlement on the riverbank, were 6 urban villages namely Baranangsiang, Sukasari, Babakan Pasar, Sempur, Cibuluh, dan Kedung Badak.

Water samples carried out on 8 drainages in selected urban villages along the banks of the Ciliwung River in the city of Bogor in May, June and July:

| Urban Villages | Locations | Coordinate |
|----------------|-----------|------------|
|                |           | E          | S          |
| Baranangsiang  | 1         | 106°48'19.7" | 6°36'20.9" |
|                | 2         | 106°48'36.3" | 6°36'48.9" |
| Sukasari       | 3         | 106°48'35.3" | 6°36'49.2" |
|                | 4         | 106°48'10.9" | 6°36'18.3" |
| Babakan Pasar  | 5         | 106°48'18.4" | 6°36'21.5" |
| Sempur         | 6         | 106°47'55.2" | 6°35'25.8" |
| Cibuluh        | 7         | 106°48'30.5" | 6°33'46.1" |
| Kedung Badak   | 8         | 106°48'28.5" | 6°33'44.6" |

2.1.1. Drainage channel debit the channels are rectangular-shape. Calculation of debit in drainage channel can be determined by equation below:

\[ Q = V \times A \]  
\[ A = b \times y \]  
\[ P = b + 2y \]  
\[ R = \frac{A}{P} \]  
\[ V = \frac{1}{n} \left( R \right)^{\frac{2}{3}} \left( S \right)^{\frac{1}{2}} \]
Where:
\[ Q = \text{Channel debit (m}^3/\text{s}) \]
\[ V = \text{Flow speed in the drainage channel (m/s)} \]
\[ A = \text{Flow area (m}^2) \]
\[ b = \text{Channel base width (m)} \]
\[ y = \text{Water level (m)} \]
\[ P = \text{Wetted perimeter (m)} \]
\[ R = \text{Hydraulic radius (m)} \]
\[ n = \text{Manning wall roughness coefficient (concrete: 0,013)} \]
\[ S = \text{slope (%), assumption 1\%} \]

2.1.2. The behavior of riverbank settlement. The activities and habits of the people on the riverbanks are done by observing the area, interviews and questionnaires. The sample communities are the people who live in 6 sample villages on the banks of Ciliwung River Segment 2. The questionnaire distributed aims to obtain data on the sanitation activities and facilities available. The number of samples used in this study determined by using the Slovin formula and using a proportional random sampling technique to make the distribution of questionnaires evenly distributed in the study area:

\[ n = \frac{N}{1 + Ne^2} \]  
\[ n_o = \frac{X}{N} \times N_1 \]

Where:
\[ n \] = Sample sizes
\[ N \] = Population sizes in the study area
\[ e \] = Error standard (0.1)
\[ n_o \] = Number of sample per strata
\[ X \] = Total of sample
\[ N_1 \] = Total of head of the family

2.2. Data analysis

2.2.1. Pollutant load capacity. Pollutant load capacity calculate based on debit and BOD parameter found in drainage channel are used to calculate the pollutant load capacity by equation below:

\[ Lc = C \times Q \times f \]

Explanantion:
\[ Lc \] = Load capacity (kg/day)
\[ C \] = Pollutant concentration (mg/L)
\[ Q \] = Debit (m³/s)
\[ f \] = conversion factor \( \left( \frac{1 \text{ kg}}{1000000 \text{ mg}} \times \frac{1000 \text{ L}}{1 \text{ m}^3} \times 86400 \text{ seconds} \right) = 86.4 \)

2.2.2. The behavior of riverbank settlement. The results of interviews and questionnaires that have been conducted to the settlement in 6 villages in the banks of Ciliwung River segment 2, were graphed and analyzed descriptively based on each question in the questionnaire.
3. Results and discussion

3.1. Pollutant load capacity

Domestic wastes are generally main cause of river water pollution in almost developing countries and led to depletion of oxygen causing the BOD value to increase [14]. The high load of pollutants in the drainage channel shows the high level of pollution produced due to settlement activities. Pollutant load capacity on drainage channels in sampling area can be seen in table below:

Table 2. Pollutant load capacity.

| Samples points | May          |       | June            |       | July          |       |
|----------------|--------------|-------|-----------------|-------|---------------|-------|
| Debit (m³/s)   | BOD (mg/L)   | Pollutant Load (kg/day) | Debit (m³/s)   | BOD (mg/L)   | Pollutant Load (kg/day) | Debit (m³/s)   | BOD (mg/L)   | Pollutant Load (kg/day) |
| 1              | 0.074        | 16214.0 | 104251.5        | 0.172 | 419.3         | 6297.3 | 0.040 | 184.3         | 645.7 |
| 2              | 0.004        | 10777.4 | 3511.1          | 0.001 | 74460.4       | 5907.1 | 0.002 | 35333.3       | 5291.4 |
| 3              | 0.005        | 13214.1 | 5884.5          | 0.003 | 89791.7       | 25341.6 | 0.005 | 19666.7       | 8295.9 |
| 4              | 0.015        | 4245.4  | 5380.9          | 0.020 | 6737.6        | 11427.3 | 0.011 | 1153.8        | 1104.9 |
| 5              | 0.050        | 3178.5  | 13855.2         | 0.069 | 4991.3        | 28592.4 | 0.041 | 511.8         | 1796.3 |
| 6              | 0.026        | 7927.0  | 18096.3         | 0.024 | 5370.4        | 12005.8 | 0.024 | 561.6         | 1186.4 |
| 7              | 0.093        | 280.0   | 2253.4          | 0.466 | 8228.3        | 331467.2 | 0.161 | 4696.7        | 64692.4 |
| 8              | 0.032        | 7612.5  | 21019.3         | 0.069 | 1095.4        | 6019.6  | 0.020 | 409.6         | 721.4 |

Pollutant load obtained based on table 2 are high, which is 645.7 kg/day-334167.2 kg/day, due to the quality of greywater caused by settlement activities that enter the drainage channel, which results in a BOD value at the area of the point is high. The high BOD indicates the presence of high organic matter in the wastewater which can be originates from kitchen sink [15]. Organic material is found in waste remnants carried in waste water. In addition, the input of greywater discharged directly into the drainage channel from food stalls and workshops around the study area resulted an increased of pollution levels. High BOD leads to less dissolved oxygen which implies that it is dangerous to continue discharge wastes into the stream because it may lead to complete delection of oxygen in the water [16]. The presence of this pollutant load can indicate a decrease in the quality of the environment around the Ciliwung River. Changes in land use into urban developments are known to increase runoff, which also can transfer pollutants from land to waterbodies [17]. The accumulated flow of water flowing into the Ciliwung River with a high pollutant load value will cause pollutant load on the river's ability to recover, so that it will reduce the capacity of river pollutant load [18].

3.2. The behaviour of riverbank settlement

The behavior and activities of the people living on the banks of the Ciliwung River affect the surrounding environment and also the quality of water in the drainage channel that flows directly towards the Ciliwung River. Total respondents in the study area was 99 respondents.
3.2.1. Environment community service. The presence of individual awareness and all the citizens are so important in carrying out changes in the security environment and hygiene problems, both to the natural environment as well as the social environment [19]. Generally, in all urban villages, respondents who agreed with the existence of routine community service activities, especially in Sempur which reached 74% of respondents agreed with the activity so it can make their living environment clean, beautiful, and free from disease. In the Cibuluh, 25% of respondents were still unsure about the activity because the activity was not carried out routinely. The existence of other activities such as rest, work activities, and other activities with the family is another reason that they feel hesitant with doing the activities.

Based on the results of interviews with settlement on the banks of the river, the urban villages that do not routinely carry out community service said that there is no appeal to do voluntary work every week or every month, so there was a lack of public awareness to do so. Lack of understanding regarding the importance of doing voluntary work in protecting the environment, as well as the existence of other work by settlement causes a lack of participation in conducting community service activities.

3.2.2. Handling and maintaining waste in drainage channel. Drainage in the study area is not fully used as a drainage channel for rainwater, but it is also used for household wastewater. Maintenance of the drainage channel is also needed to maintain the cleanliness of the living environment and can facilitate the flow of rainwater runoff to the water body so that there is no flooding in the area of residence. The presence of garbage in the channel can hamper the flow of water in the drainage channel and can reduce the quality of water in the drainage channel. Even so, some settlement around the riverbank occasionally throw garbage directly both into the drainage channel and into the river due to the habit of settlement.

The results of questionnaires indicate that community awareness of the importance of handling waste in drainage is quite good, especially in the Sempur, which reached 74% of respondents agreed to carry out waste management in the drainage channel. This is because they do not want the water flow in the drainage channel to be blocked and do not want their living environment to be unclean, also do not want their neighborhoods to smell bad. However, in Cibuluh, a response of 25% was doubtful about the handling due to the absence of routine community service activities to clean the drainage channel, as well as a lack of awareness of the settlement about the cleanliness of their living environment, causing a lot of garbage in the drainage channel. Garbage such as litter and other types of discarded solid waste can be contaminated with toxins that can be harmful to environment [20]. In addition, the waste discharged into the drainage can also cause a decrease in the quality of water in the drainage channel. As a result, the dissolved oxygen content in the water is reduced, so that microorganisms in the waters cannot break down decomposed organic matter in the water.

4. Conclusion
Pollution in the drainage channel due to greywater will affect the pollutant load. The high pollution shows the high pollutant load entering the channel. The lack of community participation in managing environmental hygiene, such as community service activities that are not routinely carried out in several villages, as well as the habit of disposing of garbage in the drainage can cause water quality in the drainage channel to decrease. The more people dispose of waste to the channel, the higher the pollution in the water body that occurs, so the greater the load level of the pollution. Therefore, it is necessary to have good management of greywater for settlement on the banks of Ciliwung River segment 2. This can be done by making communal WWTPs, as well as encouraging the community to manage greywater and protect the surrounding environment.

References
[1] Wijaya I M W and Soedjono E S 2018 Domestic Wastewater in Indonesia: Challenge in the Future Related to Nitrogen Content International Journal of GEOMATE 15 32
[2] Wulandari A P 2009 The Slums at the Riverbanks and a Challenge for Cultural Change Informal Settlements and Affordable Housing 3 44
[3] Mukhaiyar R 2017 Digital Image And Remote Sensing Image As A Data For An Identification Of A Quality Of A Non-Point Source Pollutant In Ciliwung River, Indonesia International Journal of GEOMATE 12 142

[4] Naidoo S and Olaniran A O 2013 Treated Wastewater Effluent as a Source of Microbial Pollution of Surface Water Resources International Journal of Environmental Research and Public Health

[5] Domfeh K A and Bawole J N 2009 Localizing and Sustaining Poverty Reduction: Experiences from Ghana Management of Environmental Quality: An International Journal 20 490-505

[6] Abebaw M 2014 Impacts of Household Wastewater on the Environment: The Case of Debre Markos Town, Amhara Regional State, Ethiopia Asian Journal of Social Sciences and Management Studies 1 88-89

[7] Kusumo W 2019 Penanganan Sistem Drainase Kecamatan Jati Kabupaten Kudus (Semarang: UNDIP)

[8] Butler D and Davies J W 2011 Urban Drainage (London: Spon Press)

[9] Lindholm O G and Bjerkholt J T 2007 Dimensioning of Sewerage and Drainage Systems in the Nordic Countries VANN 2 110

[10] Anonim 2013 Downstream Impacts Of Water Pollution In The Upper Citarum River, West Java, Indonesia Economic Assessment Of Interventions To Improve Water Quality

[11] Fauzi R R 2015 Domestic Waste and Riverbank Settlements Upgrading Program, Case Study: Ciliwung River:Jakarta. Managing the Sustainable Built Environment (Sydney: UNSW)

[12] Wijaya I M W and Soedjono E S 2018 Physicochemical Characteristic of Municipal Wastewater in Tropical Area: Case Study of Surabaya City, Indonesia IOP Conf. Series: Earth and Environmental Science 135 1

[13] Nugraha D and Lintang C 2007 Identifikasi Daya Tampung Beban Cemaran BOD Sungai dengan Model Qual2e (Studi Kasus Sungai Gung, Tegal–Jawa Tengah) Jurnal Presipitasi 3 93-101

[14] Effendi H, Muslimah S and Permatasari P A 2018 Relationship between land use and water quality in Pesanggrahan River IOP Conf. Series: Earth and Environmental Science 149 7

[15] Ling T, Dana M J, Bostam S and Nyanti L 2012 Domestic Wastewater Quality and Pollutant Loadings from Urban Housing Areas Iranica Journal of Energy & Environment 3 130

[16] Edith M and Sunday I 2014 Assessing the Impact of Waste Dump on Paiko River Water Quality in Gwagwalada Area Council of Abuja, Nigeria American Journal of Science and Technology 1 307

[17] Pullaniikkatil D, Palamuleni L G and Ruhiga T M 2015 Impact of land use on water quality in the Likangala catchment, southern Malawi African Journal of Aquatic Science 40 277

[18] Nugraha W D 2008 Identifikasi Kelas Air dan Penentuan Daya Tampung Beban Cemaran BOD Sungai Dengan Model Qual2e (Studi Kasus Sungai Serayu, Jawa Tengah) Jurnal Presipitasi 5 31

[19] Iskandar A A 2018 Pentingnya Memelihara Kebersihan Dan Keamanan Lingkungan Secaraartisipatif Demi Meningkatkan Gotong Royong Dan Kualitas Hidup Warga Jurnal Ilmiah Pena 1 79

[20] Tarekgn M M and Truye A Z 2018 Causes and Impacts of Shankila River Water Pollution in Addis Ababa, Ethiopia Environ Risk Assess Remediat 2 21