Quality of greywater based on economic class and generation time (a case study of Ciliwung watershed, Indonesia)

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Abstract. Community activities highly influence the generation of greywater, whereas community activities vary from time to time. The difference in economic class of households will also affect the lifestyle, sanitation facilities, and source of clean water used which will impact the quality of greywater. Hence, this study aimed to investigate whether differences in sampling time and economic class of households in developing countries, in particular Indonesia, will affect the quality of greywater generated. Based on laboratory analysis of greywater samples at 15 households at two different times, the results obtained were pH 5.77 - 9.52, DO 0.9 - 5.7 mg/l, COD 42 - 2190 mg/l, Ammonia 0.95 - 22.5 mg/l, and *fecal coliform* $1.7x10^2$ – $1.7x10^7$ MPN/100ml. These results were analyzed using the t-test to determine the significance of the data on greywater generation between morning and afternoon as well as differences in lower middle and higher middle-class. From this analysis, it was discovered that from each parameter there was no significant difference between the greywater quality data shown in the morning and the evening. There was a significant difference in the parameters of DO and COD between samples taken at households with lower middle and higher middle economic classes.

1 Introduction

1.1 Background

River is one of the most frequently used water resources, which is daily used for consumption or other purposes such as business, industry, fishery, animal husbandry, recreational and household activities [1]. The burden of domestic wastewater produced greatly contributes to river pollution, where domestic wastewater accounts for 70%, 15% from offices and commercial areas, and another 15% from industrial waste [2]. The domestic wastewater treatment system that is commonly applied in Indonesia is to separate blackwater and greywater, where blackwater is collected and discharged into a septic tank or other available disposal systems, while greywater will flow and be discharged into drainage canals [3]. 51-53% of greywater in Indonesia is directly discharged into water bodies without any treatment [4]. Greywater consists of wastewater generated from bathing, laundry, kitchen, sinks, and

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also water used for mopping floors, where 60 – 70% of household wastewater produced is greywater [5].

The quantity of greywater produced varies greatly depends on the economic class, including the habits and activities of the community, location, infrastructure, and the standard of living of the community, while the quality of the greywater is usually influenced by the lifestyle of the community and the types of household products used [5]. The quantity of greywater waste varies at each location, where the largest source is from water used for bathing with an average of 79.1 L/person/day, while the least comes from the kitchen or wastewater used for washing dishes amounting to 24.5 L/person/day, with the total greywater waste produced amounting to 152.6 L/person/day [6].

The quantity of greywater also differs between weekends (Saturday and Sunday) and weekdays (Monday – Friday). The highest greywater flow was observed between 07:00 – 10:00 and also at 17:00 – 22:00 on weekdays, which is considered as a peak time where people started going to work and left from work. Whereas late afternoon and midnight were the period when greywater flows the least. [1].

Differences in economic class will likely affect the lifestyle and consumption behavior of a community. Furthermore, this will also affect the sanitation facilities and clean water sources used, which will have eventually influenced the quantity and quality of the greywater produced [7].

1.2 Objective

Previous research up to date only examines the effect of greywater generation time on the quantity of greywater produced. In addition, there has been limited research regarding the effect of differences of economic class on the quality of greywater in developing countries. To control the greywater pollution of surfaces of the water bodies, appropriate intervention strategies are needed. However, unlike general domestic wastewater which have well-documented variations in quality, the variability of greywater in Indonesia is still not fully understood. In this study, an analysis of the effect of time and economic level on the variability of greywater quality with parameters pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Ammonia, and *fecal coliform*, which are significant parameters in greywater, was conducted.

2 Method

2.1 Sampling location and time

The study was carried out in a densely populated residential area with various economic class surrounding the Ciliwung watershed from the upstream to Manggarai Area. The Ciliwung River is classified as a heavily polluted level status according to the quality status of the Polluter Index [8].

Greywater samples were collected from 9 upper middle-class households and 6 lower middle-class households (Fig. 1). Sampling is conducted in each house at 2 different times, in the morning at 07:00 – 09:00 WIB and in the afternoon at 15:00 – 17:00 WIB as a representation of the highest and lowest greywater generation times. Sampling is also limited to weekdays, because activities of the resident on weekdays tend to be identical compared to activities on weekends.

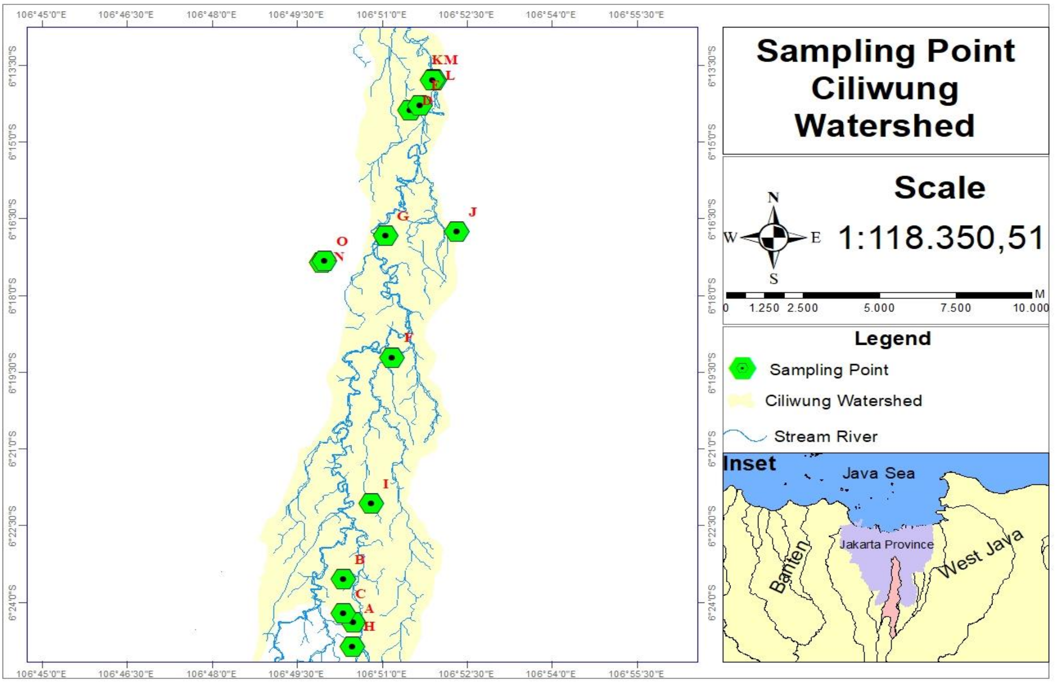

Fig 1. Sampling Location

2.2 Sampling method

Samples were taken from household wastewater which flows directly to sewers or waterways. The samples were then put into bottle containers. The bottle containers used are HDPE bottles for the analysis of COD and ammonia. As for the *fecal coliform* analysis, the samples were stored in separate containers using glass bottles which were sterilized with autoclave.

Samples from greywater sources (bathrooms, kitchens, laundry, etc.) were taken compositely in sterile gallon containers. Mixing of the greywater sample was carried out based on the activities carried out by the respondent at a specified time in order to produce a sample that could represent the quality of the greywater coming out of the sewer. After the sample was collected, the sample was homogenized prior to being put into the bottle containers.

2.3 Sample testing

The samples were tested for pH, DO, COD, ammonia, and *fecal coliform*. The pH and DO parameters were analyzed in-situ using a portable Multisensor Probe. COD, ammonia, and *fecal coliform* parameters were analyzed in the laboratory.

COD and ammonia were analyzed using a spectrophotometer. COD analysis used HR 21259-25 reagent, while ammonia analysis used the Nessler method following the standard method of SNI 06-2479-1991 (Indonesian Standard), respectively. For *fecal coliform*, samples were analyzed using the MPN method following standard method of APHA Ed 20th 9221 E-1998

2.4 Statistical analysis

After laboratory testing, the statistical analysis using Paired Sample T-test was carried out to determine the significant difference of the average value of data collected in the morning and in the afternoon. In addition, an Independent T-test was also conducted to determine the significance of the average value of the independent samples which are classified based on the economic class of the local community. Each statistical test used a confidence level of 95%.

3 Results and discussion

3.1 Greywater quality testing result

The results of the greywater quality parameter test can be seen in Table 1.

Table 1. Greywater Quality Sample Data

Parameter	Unit	Mean	St.Dev	Min	Max	Wastewater Quality Standard
pH	-	7.11	1.04	5.39	9.52	6-9
DO	mg/L	2.70	1.17	0.9	5.7	-
COD	mg/L	811.13	580.00	42	2190	100
Ammonia	mg/L	4.53	4.78	0.96	22.5	10
Fecal coliform	MPN/100 ml	1.29.E+06	4.15.E+06	1.70.E+03	1.70.E+07	-

As shown in Table 1, there were several samples that exceeded the wastewater quality standard issued by the Minister of Environment Regulation in Indonesia [9] for pH and ammonia. Whereas almost all samples exceeded quality standard for COD. There was no wastewater quality standard for DO and *fecal coliform*. Whereas the biological parameter listed in the existing quality standards is total coliform, specifically $3.0x10^3$ MPN/100ml. where this number includes the presence of *fecal coliform* bacteria. However, the average value of pH, COD, and ammonia that were obtained exceed the quality standard.

The economic class was classified based on the income of the head of the family, the house building area, the number of floors, the type of sanitation, and the source of clean water used. Data regarding this matter were obtained through direct interviews with respondents and online questionnaires using Google Forms. The sources of greywater differ for each respondent or sample point, this is due to varying household activities during the appointed time. The differences in these sources affect the parameters of the resulting greywater.

3.2 Effect of greywater generation time on greywater quality

The generation of greywater can occur throughout the day, making it difficult to determine whether the quality of the generated greywater is the same at any given time or not. Thus, it is necessary to see the effect of greywater generation time on each parameter.

The most activity at each sample point is bathroom activity, only at point D in the morning and afternoon, as well as point M in the morning which does not carry out bathroom activities when the sample is taken. The source of graywater taken at points G. K, L, M, N and O is taken from the lower middle economic class houses. Major greywater sources of these houses are from kitchen and bathroom. Points A, B, D, H, I, J, K, and L have the same activity in the morning and afternoon although there are different activities at each point.

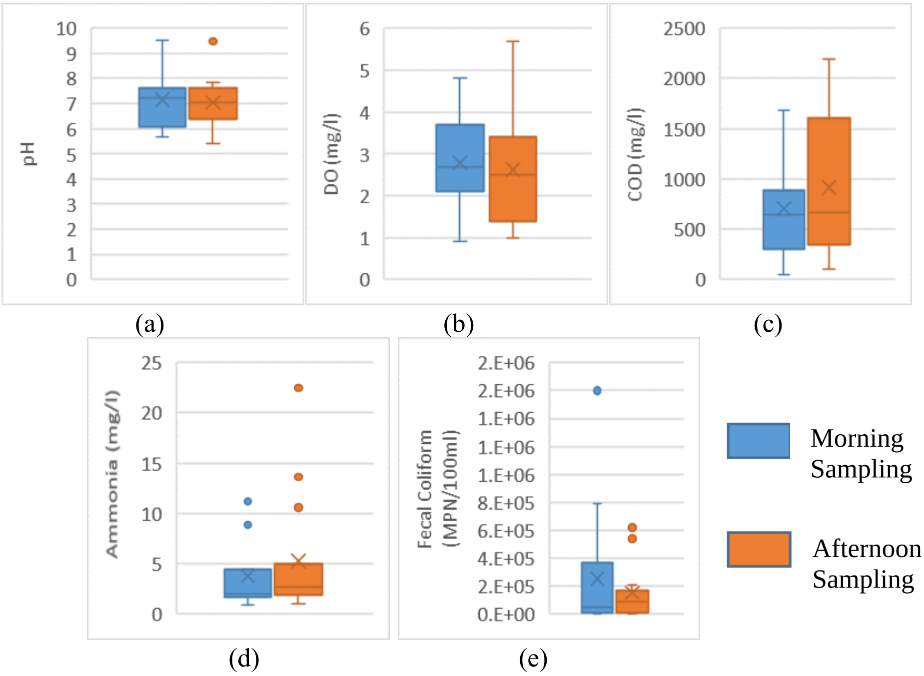

Fig 2. Greywater Quality Variability Based on Generation Time (a) pH (b) DO (c) COD (d) Amoniak (e) *Fecal Coliform*

As shown in Figure 2 (a), the pH concentrations had an almost identical distribution. Based on the results of the t-test, a P value of 0.741 ($p > 0.05$) was obtained, which means that there was no significant effect of morning and afternoon time on pH. Even though relatively similar results were obtained, the pH concentrations obtained varied. The greatest pH concentration is located at Location C in the morning, and the lowest is at Location N in the afternoon. The concentration of carbon dioxide (CO_2) dissolved in could be one of the factors that affects pH [10], the higher carbon dioxide, the more acidic pH of the water will be. Carbon dioxide can come from the atmosphere and air surrounding the polluted water.

The pH parameter of the greywater obtained is influenced by the sampling method used which are taken directly from household wastewater or directly taken from the source so that CO_2 contamination from the atmosphere will be reduced. Aside from that, fluctuating pH concentrations can also be caused by activities such as the use of soap or detergent from laundry, stated by [6] greywater from laundry has the highest pH of ± 8.2.

The DO concentration varies between 0.9 – 5.7 mg/l, this concentration is still categorized as low. The temperature will affect the photosynthetic process of aquatic organisms, where the greater amount of DO, the better water quality will be [11]. As shown in Fig 2 (b), the highest concentration is discovered in the afternoon. The lowest concentration is at location K, where it can be assumed that greywater at location K contains many microorganisms that require dissolved oxygen to decompose organic matter [12].

COD is related to DO, the higher amount of organic pollutant, the higher oxygen needed to decompose those pollutant (COD), then the lower amount of oxygen dissolve in water. Fig 2 (c) shows that the distribution between the morning and afternoon samples is not too different, where the higher results in afternoon time are due to the lower DO values obtained.

Statistical tests on the DO and COD parameters resulted in P values of 0.606 and 0.22 ($p > 0.05$), respectively, there was no significant effect of morning and afternoon times on both parameters. These can be caused by uncertain fluctuation amount of organic substance as the result of their activity between morning and afternoon.

Ammonia generally comes from an animal or human feces and urine or from runoff of organic matter that has been decomposed [13]. Based on this, the greatest possibility of having high ammonia concentrations is from bathroom activity. The highest concentration of ammonia is in location E. The low ammonia concentration in the morning can be caused by temperature, because at a certain optimum temperature, the growth of aerobic microorganisms will be affected resulting in a nitrification process [14].

The growth of *fecal coliform* bacteria is highly affected by the concentration of pH, temperature, BOD, COD, and DO. The high level of COD at location K is related to the high concentration of *fecal coliform*. *Fecal coliform* in the morning tends to be high due to the ambient temperature because the growth rate of bacteria will be faster at around 37^{o}C [15]. In Fig 2 (e) the highest data at location K is considered as an outlier, so it is not included in the graph so that the distribution of the data is more visible.

Fig 2 (d) (e) shown the distribution of the data of ammonia and *fecal coliform* is not too different, the statistical tests that resulted in P values for both parameters 0.390 and 0.474 ($p > 0.05$) respectively, both parameters did not produce significant results in morning and afternoon. Although the temperature is one of the factors for the high levels of ammonia and *fecal coliform*, the most influential factor is the activities carried out at any given time.

The F value test was carried out as a further test to examine the quality of greywater parameters variability data. The results showed that only DO and COD parameters obtained $F > F_{crit}$, which indicates that although the average of both parameters are not significantly different, they have different variability. Thus, the greywater quality in the morning and afternoon can vary greatly, ranging from highly polluted to relatively good.

3.3 Effect of economic class on greywater quality

Differences in economic class will affect the behavior of a community, sanitation quality and sources of clean water used. Some of these things will affect the quality of greywater as a result.

The distribution of pH (Figure 3 (a)), is not very different between the higher middle and lower middle-class economic classes. The statistical analysis resulted in P value of 0.923 ($p > 0.05$) means that there was no significant effect between the two economic classes. The high pH can be affected by alkalinity, which can come from washing machine detergent [16]. Meanwhile, the lowest pH comes from kitchen activities due to the degradation of leftover food and oil under anoxic conditions [17]. The tools used will also affect the resulting pH concentration, such as using a washing machine and dishwasher will increase the pH concentration because of high soap usage [1]. In developing countries such as Indonesia, the use of washing machines is widespread, including both the lower middle and higher middle-class households because the prices are relatively affordable, while the use of dishwashers is still rarely due to the time and price efficiency, which can be very costly.

Figure 3 (c) and (d) show data distribution between DO and COD parameters. Statistical tests carried out on these parameters resulted in P values of 0.012 and 0.028 ($p < 0.05$) respectively, there is a significant difference in data between the DO and COD parameters. There are more activities in the kitchen in countries with low incomes compared to countries with high incomes. Countries with high incomes tend to use dishwashers that use less water and are more likely to eat out compared to countries with low incomes, where people tend to wash manually and cook more often at home [1]. Khanam & Patidar (2022) [5] stated that kitchen and laundry activities are High Pollutant load Greywater (HGW) which related to the amount of DO and COD concentration. Laundry activities require a lot of detergent. Kitchens are the largest source of organic matter, because they contain oil and food scraps.

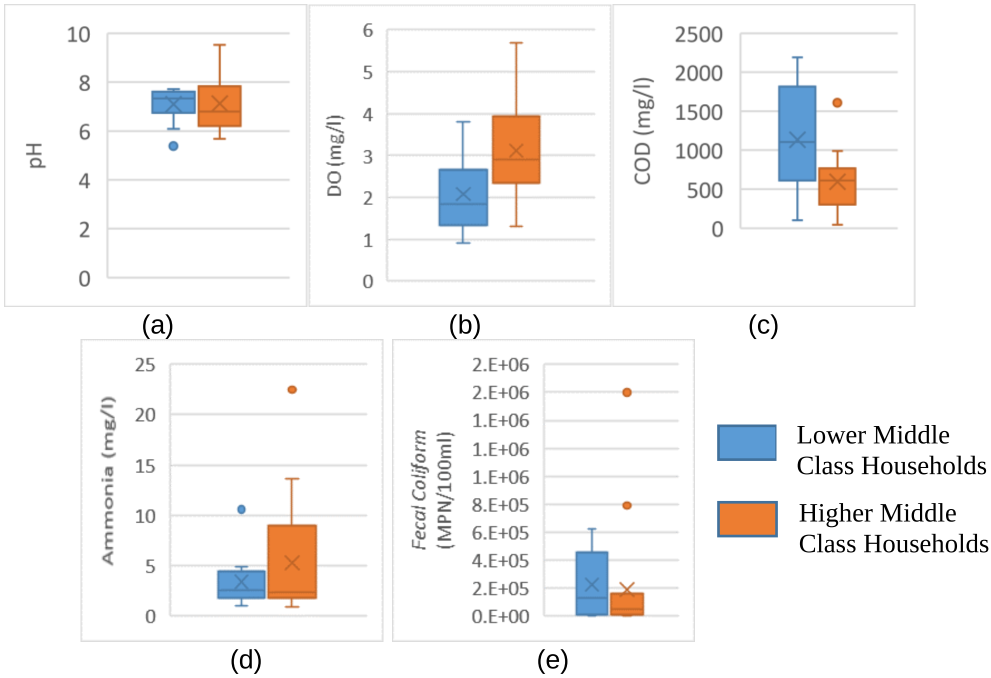

Fig 3. Greywater Quality Variability Based on Economic Class (a) pH (b) DO (c) COD (d) Amoniak (e) *Fecal Coliform*

The main source of ammonia comes from nitrogen substances. In daily activities, the source of nitrogen comes from bathroom and laundry activities which use a lot of cleaning products [1]. Ammonia can also be carried into the groundwater from leachate that infiltrates into the ground [18]. In this case, many lower middle households still use groundwater as the source of clean water, therefore their source water had the potential to be polluted by ammonia because of the presence of waste surrounding their environment. On the other hand, the statistical test results for the ammonia parameter yielded a P value of 0.386 ($p > 0.05$), there was no significant difference in water samples with different economic classes.

Ammonia had the highest concentration in the higher middle-class households (Figure 3 (d)), bathroom and laundry activities are more frequent. According to Shaikh & Ahammed (2020) [1], countries with high economic levels tend to use a bathtub to bathe and washing machine which uses more water. The variability of ammonia concentrations in the lower middle-class households indicates that groundwater conditions in those classes tend to be acceptable.

The number of *fecal coliform* bacteria is strongly influenced by habits and lifestyle. [16] explained that the high level of *fecal coliform* bacteria is affected by the low level of awareness of cleanliness from the community. Households with many children generally have a high concentration of *fecal coliform* bacteria due to the habit of using the toilet improperly (urinating not in the closet hole) and from washing used baby diapers. [19]. The statistical test results on differences in economic class resulted in a P value of 0.162 ($p > 0.05$), which means that there was no significant difference in both economic classes.

In this case, the lower middle-class households still have a high awareness of cleanliness, even though the work done by their activity still has the potential to carry *fecal coliform* bacteria in their wastewater. Having children or pets will also influence a higher number of *fecal coliform* bacteria in the wastewater of higher middle-class households. These caused the data comparison between both classes not to produce significant results.

The F value test was also carried out to examine the quality variability of the resulting greywater in different economic classes households. The results showed that DO, COD, and *fecal coliform* parameters obtained $F > F_{crit}$, which indicates that although the average of both classes are not significantly different, they have different variability. Thus, the greywater quality in the lower middle and higher middle-class households can vary greatly, ranging from highly polluted to relatively good.

4 Conclusion

The quality of greywater is strongly influenced by activities, lifestyle, sanitation facilities, and the source of clean water. Through examining, the difference in wastewater generation time can be seen that for all parameters (pH, DO, COD, ammonia, and *fecal coliform*) had no significant difference between morning and afternoon samples, this was because community activities morning and afternoon vary greatly depending on their needs and habits. In the comparison of economic differences, only DO and COD had significant differences in the results obtained, which was caused by differences in kitchen usage that affect in high organic matter. According to the F value test, the DO and COD parameters in the morning and afternoon, as well as the DO, COD, and *fecal coliform* parameters in both economic classes resulted in $F > F_{crit}$, which indicated that the quality of the greywater in both groups can vary greatly from very polluted to relatively good.

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References

1. Shaikh, I. N., & Ahammed, M. M. (2020). Quantity and quality characteristics of greywater: A review. *Journal of Environmental Management*, *261*(March), 110266. https://doi.org/10.1016/j.jenvman.2020.110266
2. Harahap, J., Gunawan, T., Suprayogi, S., & Widyastuti, M. (2021). A review: Domestic wastewater management system in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *739*(1). https://doi.org/10.1088/1755-1315/739/1/012031
3. Firdayati, M., Indiyani, A., Prihandrijanti, M., & Otterpohl, R. (2015). Greywater in Indonesia: Characteristic and Treatment Systems. *Jurnal Tehnik Lingkungan*, *21*(2), 98–114. https://doi.org/10.5614/jtl.2015.21.2.1
4. Widyarani, Wulan, D. R., Hamidah, U., Komarulzaman, A., Rosmalina, R. T., & Sintawardani, N. (2022). Domestic wastewater in Indonesia: generation, characteristics and treatment. *Environmental Science and Pollution Research*, *29*(22), 32397–32414. https://doi.org/10.1007/s11356-022-19057-6
5. Khanam, K., & Patidar, S. K. (2022). Greywater characteristics in developed and developing countries. *Materials Today: Proceedings*, *57*, 1494–1499. https://doi.org/10.1016/j.matpr.2021.12.022
6. Hafiza, N., Abdillah, A., Islami, B. B., & Priadi, C. R. (2019). Preliminary Analysis of Blackwater and Greywater Characteristics in the Jakarta Greater Region Area. *IOP*

Conference Series: Earth and Environmental Science, *366*(1). https://doi.org/10.1088/1755-1315/366/1/012029

7. Oteng-Peprah, M., de Vries, N. K., & Acheampong, M. A. (2018). Greywater characterization and generation rates in a peri urban municipality of a developing country. *Journal of Environmental Management*, *206*, 498–506. https://doi.org/10.1016/j.jenvman.2017.10.068
8. Dinas Lingkungan Hidup, D. J. (2021). *Laporan Pemantauan Kualitas Lingkungan Air Sungai Provinsi DKI Jakarta*. 157.
9. Menteri Lingkungan Hidup dan Kehutanan. (2016). Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia Nomor R: P.68/Menlhk-Setjen/2016 Tentang Baku Mutu Air Limbah Domestik. *Peraturan Menteri Lingkungan Hidup Dan Kehutanan Republik Indonesia*, 1–13.
10. Novita Dwi Yanti. (2016). Penilaian Kondisi Keasaman Peraiaran Pesisir dan Laut Kabupaten Pangkajene Kepulauan pada Musim Peralihan I. *Skripsi Fakultas Ilmu Kelautan Dan Perikanan, Universitas Hasanuddin, Makassar*, 1–56.
11. Sari, E. K., & Wijaya, O. E. (2019). Penentuan Status Mutu Air Dengan Metode Indeks Pencemaran Dan Strategi Pengendalian Pencemaran Sungai Ogan Kabupaten Ogan Komering Ulu. *Jurnal Ilmu Lingkungan*, *17*(3), 486.
12. Sidabutar, E. A., Sartimbul, A., & Handayani, M. (2019). Secara administratif Teluk Prigi terletak. *Journal of Fisheries and Marine Research*, *3*(1), 46–52.
13. Hermawan, Y. I. ., & Wardhani, E. (2021). Analisis Dampak Limbah Domestik Terhadap Kualitas Air Sungai Cibeureum, Kota Cimahi. *Prosiding Simposium Nasional Teknologi Insfrastruktur Abad Ke-21*.
14. Satria, A. W., Rahmawati, M., & Prasetya, A. (2019). Pengolahan Nitrifikasi Limbah Amonia dan Denitrifikasi Limbah Fosfat dengan Biofilter Tercelup. *Jurnal Teknologi Lingkungan*, *20*(2), 243. https://doi.org/10.29122/jtl.v20i2.3479
15. Naillah, A., Yulia Budiarti, L., & Heriyani, F. (2021). Literature Review : Analisis Kualitas Air Sungai Dengan Tinjauan Parameter pH, Suhu, BOD, DO Terhadap Coliform. *Homeostatis*, *4*(2), 487–494.
16. Oteng-Peprah, M., Acheampong, M. A., & deVries, N. K. (2018). Greywater Characteristics, Treatment Systems, Reuse Strategies and User Perception—a Review. *Water, Air, and Soil Pollution*, *229*(8). https://doi.org/10.1007/s11270-018-3909-8
17. Bakare, B. F., Mtsweni, S., & Rathilal, S. (2017). Characteristics of greywater from different sources within households in a community in Durban, South Africa. *Journal of Water Reuse and Desalination*, *7*(4), 520–528. https://doi.org/10.2166/wrd.2016.092
18. Morrissy, J. G., Currell, M. J., Reichman, S. M., Surapaneni, A., Megharaj, M., Crosbie, N. D., Hirth, D., Aquilina, S., Rajendram, W., & Ball, A. S. (2021). Nitrogen contamination and bioremediation in groundwater and the environment: A review. *Earth-Science Reviews*, *222*(September), 103816. https://doi.org/10.1016/j.earscirev.2021.103816
19. Blanky, M., Rodríguez-Martínez, S., Halpern, M., & Friedler, E. (2015). Legionella pneumophila: From potable water to treated greywater; quantification and removal during treatment. *Science of the Total Environment*, *533*, 557–565. https://doi.org/10.1016/j.scitotenv.2015.06.121