Wastewater reclamation design from sewerage system for gardening activity in Universitas Pertamina

Pavita Khansa, Evi Siti Sofiyah, I Wayan Koko Suryawan

Faculty of Infrastructure Planning, Department of Environmental Engineering, Universitas Pertamina, Komplek Universitas Pertamina, Terusan Simprug, Jakarta, 12220, Indonesia [+62 21-29044308]

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Abstract. Wastewater recycling is one of the criteria for continuous innovation at the campus level. Reclamation of water from the sewage system for gardening activities is one way to achieve this target at Universitas Pertamina. This study aims to design and verify a water treatment unit from sewage to ready-to-use water for gardening activities. The units needed for the wastewater treatment system are a tank, Horizontal Roughing Filter (HRF), Rapid Sand Filtration (RSF), reservoir, and disinfection. The expected quality of effluent from processing is TDS 278 mg/L; TSS 1.3 mg/L; Turbidity 0.17 NTU; BOD5 0.63 mg/L; COD 6.12 mg/L; Total phosphate 0.95 mg/L; Nitrate 0.07 mg/L; detergent 0.7 mg/L; and total coliform MPN/100mL. Thus, it can meet the criteria for class 4 water according to Government Regulation (PP) Number 22 of 2021. The most important parameter in the sewerage water treatment process is the total coliform which must achieve an efficiency of 99%. This conventional method of water treatment is used because the availability of land is still sufficient, if it is not sufficient, then further processing that is efficient, environmentally friendly, and has economic value is required.

INTRODUCTION

Green Campus is an environment-friendly system that involves campus residents in environmental activities, which must positively impact the environment (Tan et al., 2014; Widiastutti et al., 2019). The efficiency of water electricity uses one indicator of an environment-friendly system (Nurisyah and Nurdin, 1999; Calder and Dautremont-Smith, 2009). To support green open space, it is necessary to use water efficiently and quality. Water use is important to improve conservation programs and protect habitats in universities (Lourrinx and Budihardjo, 2019). Previous research conducted to achieve this status was calculated the carbon footprint of the scope of electricity, transportation, and waste generation (Ridhosari and Rahman, 2020). On the other hand, wastewater is also one of the organic sources that contribute to greenhouse gases and nutrients in the waste, giving eutrophication impacts on water bodies (Sarwono et al., 2022; Sarwono et al., 2017; Sofiyah et al., 2021; Afifah et al., 2020). For this reason, water conservation optimization is needed in the form of wastewater reclamation activities by utilizing all water to archives zero waste in Universitas Pertamina.

To perform good water recovery, wastewater treatment requires processing technology that will consume considerable energy, and it also has a difficult operation such as pretreatment (Suryawan et al., 2021). To
maintain the sustainability of ecology, the purpose of the wastewater treatment system requires minimizing energy loss, reducing the use of energy and water, reducing the formation of waste, and recycling the nutrients. Water recovery can reduce tap water consumption for gardening by about 65.41% (Susana, 2012). Many wastewater treatment designs currently fail to meet quality standards for watering plants and need advanced treatment to improve quality standards (Suryawan et al., 2021; Hasnaningrum et al., 2021; Fadhilah et al., 2020).

This research aims to determine and design an appropriate processing unit to process the sewerage system to meet the classification of water classes that can be used to water the plants. In Indonesia, according to Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Management (attachment VI), water to watering plants need to be in class IV water quality.

METHODOLOGY

Planning for this advanced treatment design is carried out based on the background of the problem, then conducts field studies such as sampling, then characterizes the waste. After characterizing the waste, it is necessary to search for alternative solutions to problems. The chosen alternative is used in the pre-design process, which consists of preliminary sizing and mass balance calculations. The final calculation is to design in the form of detailed engineering design and calculation of bill of quality and budget planning. The design stage can be seen in Figure 1.

![Figure 1 Wastewater treatment design methods](image)

Samplings and Parameters

The Wastewater Management installation for drainage water in the area of Universitas Pertamina buildings is designed based on considerations including the quality and discharge of water in the drainage channels and land conditions in the Complex Universitas Pertamina buildings Wastewater Treatment Plant (WWTP) unit design criteria. Rainy and dry seasons can affect drainage water’s discharge and quality (Khansa et al., 2020). The rain will increase drainage water discharge, but it can reduce the pollutant parameters concentration due to dilution (Universitat Politècnica de València, 2015). Conversely, the drainage water discharge will be smaller with little rainfall intensity, and the quality will be worse with a high pollutant concentration in the dry season. Parameters that become the main focus in the WWTP design are the parameters of BOD₅, COD, TDS, TSS, pH, NO₃ as N, Surfactants, Total Phosphate as P, and Total Coliform to meet Ministry of Environment and Forestry Regulation No. 68 of 2016 concerning domestic wastewater quality standards. Land conditions of the Complex of Universitas Pertamina buildings will affect the land availability used for WWTP design considerations.

Google Maps Pro software was used as the area and elevation measurements. Sampling requires tools following SNI 6989.59:2008 concerning Water and Wastewater-Section 59: Methods for sampling wastewater. Tools and materials needed when testing the quality of drainage water refer to each parameter standards as follows: BOD₅ testing refers to SNI 6989.72:2009; COD testing refers to SNI 6989.2:2009; TSS testing refers to SNI 06-6989.3:2004; The pH test refers to SNI 06-6989.11-2004; TDS testing was conducted by the conductometry method; NO₃ testing as N refers to the Standard Method 4500-NO₃-E; Total P testing refers to the Standard Method 4500-P; Surfactant testing refers to SNI 06-6989.51-2005; Turbidity testing with a turbidimeter, and Total Coliform Testing refers to the Standard 9221 B.
Wastewater Treatment Design

The choice processing unit is determined by adjusting the needs affected by the type of parameters that require processing, the extent to which the parameters exceed the existing quality standards, and the efficiency of each processing technology. The calculation basis for preliminary sizing can be seen in equation 1 (Metcalf and Eddy, 2004). Where \( V \) is the building volume unit, \( t_d \) is the detention time, and \( Q \) is the wastewater discharge. Efficiency can be found based on equation 2 (Mihelcic, 1998). As for calculating mass balance, it can be seen in equation 3. \( \frac{dm}{dt} \) is the change in the mass of the wastewater parameters entering the treatment unit process. \( m_{in} \) is the mass that goes in while \( m_{out} \) is the mass that comes out. To get \( m_{reaction} \), it is done by means of literature studies to look for efficiency removal (Mihelcic, 1998).

\[
V = HRT \times Q \tag{1}
\]

\[
\% \text{removal} = \frac{m_{in} - m_{out}}{m_{in}} \times 100 \tag{2}
\]

\[
\frac{dm}{dt} = m_{in} - m_{out} - m_{reaction} \tag{3}
\]

A BOD\textsubscript{5}/COD ratio will influence the processing type. If the ratio indicates that wastewater is non-biodegradable, which is <0.3 (Srinivas, 2008), then the treatment will be physical, such as sedimentation and filtration. Media variation can be applied if wastewater is treated enough with granular filtration. Filtration is needed; this type of filtration can be a variant. Whereas wastewater has a ratio value of >0.3 then biological treatment will be used with varying types of technology. Technology selection consideration can be seen from the processing efficiency, head loss if available, price, and ease of operation and maintenance. If Total Coliform's parameter exceeds the quality standard, the disinfection unit will be involved as an additional treatment.

RESULT AND DISCUSSION

Characterizing of the Sewerage Wastewater

Based on Table 1, there are two attention parameters above the quality standard class 4: BOD\textsubscript{5} and Total Coliform parameters. Each concentration at high and low discharge conditions, 21.67 mg/l, and 19.33 mg/l for BOD\textsubscript{5} parameters and 27.33 mg/l and 72.66 mg/l for Total Coliform parameters exceeding the quality standard in Government Regulation/Peraturan Pemerintah (PP) Number 22 of 2021. Thus, wastewater treatment that can reduce the concentration of the two parameters is needed so that wastewater can meet the quality standards of watering plants.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Quality standard Class 4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS</td>
<td>mg/l</td>
<td>2 000</td>
<td>252.83</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>400</td>
<td>44.50</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>BOD\textsubscript{5}</td>
<td>mg/l</td>
<td>12</td>
<td>20.50</td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>100</td>
<td>80.50</td>
</tr>
<tr>
<td>Total phosphate</td>
<td>mg/l</td>
<td>5</td>
<td>1.67</td>
</tr>
<tr>
<td>Nitrate</td>
<td>mg/l</td>
<td>20</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Surfactant</td>
<td>mg/l</td>
<td>-</td>
<td>0.39</td>
</tr>
<tr>
<td>Total Coliform</td>
<td>MPN/100ml</td>
<td>10 000</td>
<td>50 000</td>
</tr>
</tbody>
</table>
The BOD/COD ratio in both conditions, which is 0.25, shows that wastewater has non-biodegradable properties because the ratio is less than 0.3 (Srinivas, 2008; Suryawan et al., 2021). Domestic wastewater containing detergents or non-biodegradable surfactants can also affect the BOD/COD ratio (Morel and Diener, 2006). Physical parameters, in this research, are not a major problem. In this research, TDS, TSS, and turbidity were relatively low. While the nutrients in the form of total phosphate and nitrate parameters meet the quality standard. If not treated, the nutrient parameters are very risky to cause eutrophication, the explosion of algal populations in the waters.

The wastewater discharge at Universitas Pertamina calculated based on the plumbing tools unit load contributing facilities for greywater, and yellow water is 1 236. The calculation results of wastewater discharges can be seen in Table 2. The intensity of rainwater in South Jakarta is 206.04 mm/hour. Thus rainwater discharge obtained is 2 497 m$^3$/s (with a runoff coefficient of 0.563 and a land area of 7.7 hectare (ha)).

<table>
<thead>
<tr>
<th>Name of Plumbing Tool</th>
<th>Total</th>
<th>Unit</th>
<th>Fixture Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urinoar</td>
<td>94</td>
<td>units</td>
<td>4</td>
<td>376</td>
</tr>
<tr>
<td>Sink</td>
<td>168</td>
<td>units</td>
<td>2</td>
<td>336</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>54</td>
<td>units</td>
<td>2</td>
<td>108</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>1</td>
<td>units</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Shower</td>
<td>123</td>
<td>units</td>
<td>2</td>
<td>246</td>
</tr>
<tr>
<td>Ablution</td>
<td>82</td>
<td>units</td>
<td>2</td>
<td>164</td>
</tr>
<tr>
<td>Clothes</td>
<td>2</td>
<td>units</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Total: 1 236

The land area is one of the design determinants. The land area owned is 40.9 m x 38 m or equivalent to 1 554.2 m$^2$. The wastewater discharge served is 9 850 m$^3$/day, with a composition of 62.8% wastewater and 37.2% rainwater. The units used in alternative two are the collection tanks, bar screen, horizontal roughing filter (HRF), rapid sand filter (RSF), and disinfection. HRF will replace the sedimentation unit function, which reduces turbidity to prevent clogging.

Pre-design

To determine the WWTP waste treatment design's effectiveness required pre-design comprising the step of mass balance calculations and preliminary sizing. The mass balance is calculated based on the wastewater quality's examination results in the largest load conditions. The largest concentration of each parameter will be used as the WWTP influent concentration. This aims to determine each unit's ability to treat the lowest quality waste to meet the quality standards of Government Regulation (PP) Number 22 of 2021 concerning Implementation of Environmental Protection and Management (attachment VI), water to watering plants need to be in class IV water quality. Mass balance is calculated based on the allowance percentage of each unit for certain parameters in Table 3. Determination of removal efficiency is carried out based on literature studies with the same wastewater quality approach.

The limitations of the research examining all parameters in treating wastewater also make literature necessary for each parameter. The calculation is done by multiplying the incoming concentration for each unit and multiplying by the removal efficiency for each unit (Mihelcic, 1998). Mass balance is used to study the reactor's hydraulic flow characteristics and describe the changes that occur in the WWTP units (equation 3). The basic concept in calculating mass equilibrium uses energy conservation; energy cannot be created or destroyed but can change form. The mass balance principle in the wastewater treatment process is that the
influent that enters the treatment will be the same as the total effluent (Metcalf and Eddy, 2004). Calculation of mass balance for each wastewater treatment unit in Table 3 and Figure 2 (based on equation 3).

Table 3 The estimation of wastewater quality at maximum load conditions from literature review

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Influent</th>
<th>Bar Screen</th>
<th>HRF</th>
<th>RSF</th>
<th>Disinfection</th>
<th>Government Law No. 22 of 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS (mg/L)</td>
<td>278</td>
<td>278</td>
<td>278</td>
<td>278</td>
<td>278</td>
<td>27800</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>56</td>
<td>56</td>
<td>37.968</td>
<td>96.57%</td>
<td>1.302</td>
<td>1.302</td>
</tr>
<tr>
<td>Turbidity NTU</td>
<td>22</td>
<td>22</td>
<td>3.3</td>
<td>95.7%</td>
<td>0.165</td>
<td>0.165</td>
</tr>
<tr>
<td>BOD(_5) (mg/L)</td>
<td>25</td>
<td>25</td>
<td>11.5</td>
<td>94.50%</td>
<td>0.633</td>
<td>0.633</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>91</td>
<td>91</td>
<td>30.576</td>
<td>80.7%</td>
<td>6.115</td>
<td>6.115</td>
</tr>
<tr>
<td>Total phosphate (mg/L)</td>
<td>3</td>
<td>3</td>
<td>2.154</td>
<td>55.91%</td>
<td>0.950</td>
<td>0.950</td>
</tr>
<tr>
<td>Nitrate (mg/L)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.066</td>
<td>-</td>
<td>0.066</td>
<td>0.066</td>
</tr>
<tr>
<td>Detergent MPN/100 mL</td>
<td>0.7</td>
<td>0.7</td>
<td>-</td>
<td>0.7</td>
<td>-</td>
<td>0.7</td>
</tr>
<tr>
<td>Total Coliform</td>
<td>92000</td>
<td>92000</td>
<td>92000</td>
<td>90-96%</td>
<td>4000</td>
<td>4000</td>
</tr>
</tbody>
</table>

Figure 2 Mass balance wastewater treatment system in Universitas Pertamina

Preliminary sizing produced for each processing unit can be seen in Table 4. Preliminary calculations are obtained from equation 1. The HRT for each unit is from design criteria and width planning. The land used is the land, which does not change the green open space in the complex building of Universitas Pertamina. Land utilization is related to buildings, roads, sports and art infrastructure, parking lots, parks, and other open...
spaces. Therefore, land utilization design should consider the balance between the land area for the buildings and the green open space/Ruang Terbuka Hijau (RTH). Ideally, a least 30% of the campus area is intended for green space (Amba, 2015).

Table 4 The calculation results of land requirements for each unit in the wastewater treatment plant design

<table>
<thead>
<tr>
<th>Unit</th>
<th>Width (m)</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection tank</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Bar Screen</td>
<td>0.6</td>
<td>1.6</td>
</tr>
<tr>
<td>HRF</td>
<td>5</td>
<td>1155</td>
</tr>
<tr>
<td>RSF</td>
<td>2</td>
<td>85.75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1263.35</strong></td>
</tr>
</tbody>
</table>

**Detail Engineering Design**

It is planned that there will be two collection tanks with an additional redundancy tank that will be used when cleaning the collection tank. This redundancy also functions to accommodate additional discharge caused by the addition of the academic community or facilities. The collection tank is designed with a detention time of 6 minutes. Thus, additional discharge can be maximized by reducing the detention time with a fixed condition within the design criteria range. Next, the sluice is added to the collection tanks to regulate the wastewater discharge. The next unit is the bar screen, which is cleaned mechanically. There are two bar screen functions (Figure 3), one bar screen as a redundancy. Therefore, an additional carrier duct with a dividing plate at the end and at the beginning of the duct can be used if the duct is not used. The duct's length before the unit is 4 m or 10 times from the depth of the duct. Addition of dividing plates and duct spacing before the bar screen is designed based on Davis (2010).

![Figure 3 The detailed figure of the to be used unit bar screen (without scale)](image)

The number of HRF bodies needed is inversely proportional to the body dimensions. Thus, the smallest and largest design criteria design will produce the same total land requirements. Adjusting with the aesthetics and land area, 16 tanks are placed in a row and forming three columns. There are two ducts carrying water from the bar screen to the column. The first duct serves 1 column with 5 HRF tanks, while the second duct serves two columns with 11 HRF tanks. According to Ahsan (1995), backwashing was not feasible for HRF because it requires a high flow velocity. Thus, manual washing is carried out media maintenance (WHO, 1984) with a washing period of 0.5-1 year (Hadi, 2012). In addition, a weir and inlet chamber was designed in the HRF body.

Moreover, to standardize the flow (WHO, 1984), a perforated baffle is added as barrier between media and inlet and an outlet chamber. The design of HRF unit can be seen in Figure 4. According to literature, producing removal requires good operation and maintenance, especially for the operation of the filtration unit.
Therefore, operational planning and operating procedures need to be done properly. The use of redundancy is also an effort to keep the results of removal from the wastewater treatment planning system going well.

Figure 4 The detailed figure of the to be used HRF unit (without scale)

The dimension of the Rapid Sand Filter (RSF) unit can be seen in Figure 5. RSF unit washing is carried out by backwashing the media conducted once per 48 hours, with two tanks per backwash. Processed water is pumped from the reservoir with a discharge of 633.6 m³/hour and head 7.5 m for backwash. The wastewater will be stored a maximum of three days, considering holidays, and then the 3rd party will treat it. The HRF media washing room is also placed above the storage tank so that the washing water can be directly stored through a hole in the storage tank. The pump used in the storage tank is the same as the backwash pump. HRF is a box-shaped unit consisting of 3-4 compartments and contains granules that are getting smaller in every compartment.

Figure 5 The detailed figure of the to be used RSF unit

Raw water that falls over the dam will enter through the inlet duct, where the flow will be distributed evenly through the vertical filter cross-section. The growth process of biofilm and acclimatization was carried out for 30 days. The research conducted by Fauziah and Hadi (2013), showed that the length of the acclimatization/seeding process would affect the biofilm layer formation efficiency. The biofilm growing process will form a biofilm layer (biological zone) that will be formed on the filter media, which is later expected to degrade the organic substances and coliform microorganisms levels to be used following their designation. During the biofilm and acclimation growth process, an aerator is added to the roughing filter.
reactor to increase oxygen supply so that aerobic microorganisms can live and develop in the roughing filter reactor.

The WWTP processed water will be used as a water sprinkling and water backwash. It is known that the volume of the chlorine contact tank is 205.2 m$^3$. Thus, the reservoir volume, which also functions as a chlorine contact tank, must fulfill that volume. The reservoir volume is planned to be 400 m$^3$. This volume determination is based on SNI 7509: 2011. The minimum effective reservoir volume is 15% of the maximum daily requirement. RSF observation room on the 2$^{nd}$ floor of WWTP is provided during the backwash. On the 2$^{nd}$ floor, room to set the sluice and the bulkhead on the HRF and bar screen also provided to close the duct when not in use. Trash held by the bar screen is also carried mechanically to the 2$^{nd}$ floor. The iron frame on the floor that can be opened is designed to facilitate access to the control unit and HRF media washing without reducing the floor area. The result of the dimensions of each unit (Table 5).

<table>
<thead>
<tr>
<th>Unit</th>
<th>HRT (min)</th>
<th>Number of Units</th>
<th>Redundancy</th>
<th>Dimension (m)</th>
<th>Additional Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection tank</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3.5 2 3 0.5</td>
<td>Sluice L= 0.4 m</td>
</tr>
<tr>
<td>Bar Screen</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1.4 0.6 0.4 0.4</td>
<td>P Duct= 8.65 m Slope= 30˚</td>
</tr>
<tr>
<td>HRF</td>
<td>224</td>
<td>14</td>
<td>2</td>
<td>11.2 5 1.5 0.5</td>
<td>Inlet and outlet Chamber P= 0.3 m</td>
</tr>
<tr>
<td>RSF</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>4 2 2.8 0.45</td>
<td>H zeolite media= 0.5 m</td>
</tr>
<tr>
<td>Reservoir</td>
<td>-</td>
<td>1</td>
<td>0</td>
<td>30 3.5 3.8 0.5</td>
<td>H buffer (gravel) media= 0.32 m</td>
</tr>
</tbody>
</table>

The result of the dimensions of each unit (Table 5).

Figure 6 WWTP layout design for gardening activity in Universitas Pertamina
The overall water treatment layout can be seen in Figure 6. Hydraulic profiles are carried out to determine whether each unit's head is sufficient to drain the water in the desired direction. The total head is affecting the hydraulic profile results from the major headloss, minor headloss, speed head, and static head from the existing unit tank or duct. If the unit or duct has a negative head, the unit calculation will make adjustments. These adjustments can be in the form of adjusting the duct's dimensions or body with the condition that the calculation components remain in the range of design criteria. The head unit's value and duct must not be negative because a negative head indicates that water flows in the opposite direction to the planned direction (Verma et al., 2015). The hydraulic profile of this design can be seen in Figure 7.

![Figure 7 WWTP hydraulic profile for gardening activity in Universitas Pertamina](image)

**CONCLUSION**

Water conservation and potential pollution reduction in the complex building of Universitas Pertamina can be achieved by designing the wastewater recycling from the drainage duct as watering plants water. To be used again as watering water, Government Regulation (PP) Number 22 of 2021 concerning Implementation of Environmental Protection and Management (attachment VI), water to watering plants need to be in class IV water quality. WWTP unit's configuration that can treat wastewater from drainage ducts in the Complex Building of Universitas Pertamina is collection tanks, Horizontal Roughing Filters (HRF), Rapid Sand Filtration (RSF), reservoirs, and disinfection with chlorine. The most important parameter in the sewerage water treatment process at Pertamina University is total coliform which must remove more than 99%.

**REFERENCES**


