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

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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.*

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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; Widiastuti *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.

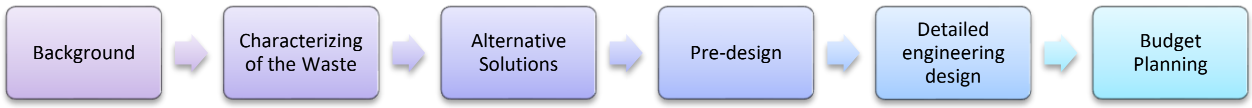


Figure 1 Wastewater treatment design methods

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 BOD_5, COD, TDS, TSS, pH, $NO\text{-}_3$ 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 BOD_5 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; $NO\text{-}_3$ testing as N refers to the *Standard Method* 4500- NO_3^- 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, td 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).

$$V = HRT \times Q \quad (1)$$

$$\%removal = \frac{m_{in} - m_{out}}{m_{in}} x100 \quad (2)$$

$$\frac{dm}{dt} = m_{in} - m_{out} - m_{reaction} \quad (3)$$

A BOD_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_5 and Total Coliform parameters. Each concentration at high and low discharge conditions, 21.67 mg/l, and 19.33 mg/l for BOD_5 parameters and 27.333 mg/l and 72.666 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 1 Average water quality of the sewerage system at Universitas Pertamina

Parameter	Unit	Quality standard Class 4	Average
TDS	mg/l	2 000	252.83
TSS	mg/l	400	44.50
Turbidity	NTU	-	17
pH	-	-	7
BOD_5	mg/l	12	20.50
COD	mg/l	100	80.50
Total phosphate	mg/l	5	1.67
Nitrate	mg/l	20	<0.1
Surfactant	mg/l	-	0.39
Total Coliform	MPN/100ml	10 000	50 000

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 2 The average of wastewater discharge from the plumbing unit load at Universitas Pertamina

Name of Plumbing Tool	Total	Unit	Fixture Unit	Total
Urinoar	94	units	4	376
Sink	168	units	2	336
Dishwasher	54	units	2	108
Dishwasher	1	units	2	2
Shower	123	units	2	246
Ablution	82	units	2	164
Clothes	2	units	2	4
	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

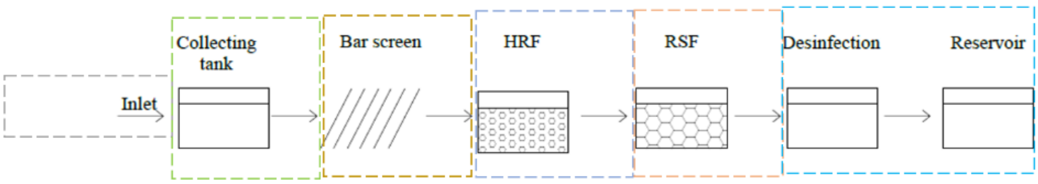
To determine the WWTP waste treatment design's effectiveness required pre-design comprising the step of mass balance calculations and preliminary sizing. The mass balance is calculated based on the wastewater quality's examination results in the largest load conditions. The largest concentration of each 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

Parameters		Influent	*Bar Screen*		HRF		RSF		Disinfection		Government Law No. 22 of 2021
			%	Effluent	%	Effluent	%	Effluent	%	Effluent	
TDS	mg/L	278	0%[1]	278	-	278	-	278	-	278 000	2 000
TSS	mg/L	56	0%[1]	56	33.2% [2]	37.968	96.57%[6]	1.302	-	1.302	400
Turbidity	NTU	22	0%[1]	22	85% [3]	3.3	95% [7]	0.165	-	0.165	-
BOD_5	mg/L	25	0%[1]	25	54% [4]	11.5	94.50% [7]	0.633	-	0.633	12
COD	mg/L	91	0%[1]	91	68.41% [5]	30.576	80% [7]	6.115	-	6.115	100
Total phosphate	mg/L	3	0%[1]	3	26% [5]	2.154	55,91%[7]	0.950	-	0.950	5
Nitrate	mg/L	0.1	0%[1]	0.1	34% [5]	0.066	-	0.066	-	0.066	20
Detergent	mg/L	0.7	0%[1]	0.7	-	0.7	-	0.7	-	0.7	-
Total Coliform	MPN/100 mL	92 000	0%[1]	92 000	-	92,000	90-96% [7]	4 600	Max. 100 % [8]	100 000	10 000

Notes: 1: Hasnaningrum *et al*., 2021; 2: Khezri *et al*., 2017; 3: Wegelin, 1996; 4: Daee *et al*., 2019; 5: Khezi *et al*., 2016; 6: Sisynreswari *et al.*, 2014; 7: Reyes *et al*., 1997; 8: Triastiani and Hazilmi, 2018.



Inlet		Collection tank	Bar Screen	HRF	RSF	Disinfection + Reservoir
Q	9,850 m³/day	9,850 m³/day	9,850 m³/day	9,844 m³/day	9,843.8 m³/day	9,843.8 m³/day
TDS	2,738 kg/day	2,738 kg/day	2,738 kg/day	2,738 kg/day	2,738 kg/day	2,738 kg/day
TSS	551.6 kg/day	551.6 kg/day	551.6 kg/day	368.5 kg/day	13.5 kg/day	13.5 kg/day
Turbidity	22 NTU	22 NTU	22 NTU	3.3 NTU	0.2 NTU	0.2 NTU
BOD_5	246 kg/day	246 kg/day	246 kg/day	113 kg/day	6 kg/day	6 kg/day
COD	896 kg/day	896 kg/day	896 kg/day	283 kg/day	57 kg/day	57 kg/day
Total Phosphate (PO_4)	29.5 kg/day	29.5 kg/day	29.5 kg/day	21.8 kg/day	9.6 kg/day	9.6 kg/day
Nitrate (NO_3^-N)	0.9 kg/day	0.9 kg/day	0.9 kg/day	0.6 kg/day	0.6 kg/day	0.6 kg/day
Detergent (MBAS)	6.8 kg/day	6.8 kg/day	6.8 kg/day	7 kg/day	7 kg/day	7 kg/day
Total Coliform	92.000 MPN/100mL	92.000 MPN/100mL	92.000 MPN/100mL	92.000 MPN/100mL	4.600 MPN/100mL	100 MPN/100mL

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 used 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

Unit	Width (m)	Area (m^2)
Collection tank	2	21
Bar Screen	0.6	1.6
HRF	5	1155
RSF	2	85.75
Total		1 263.35

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).

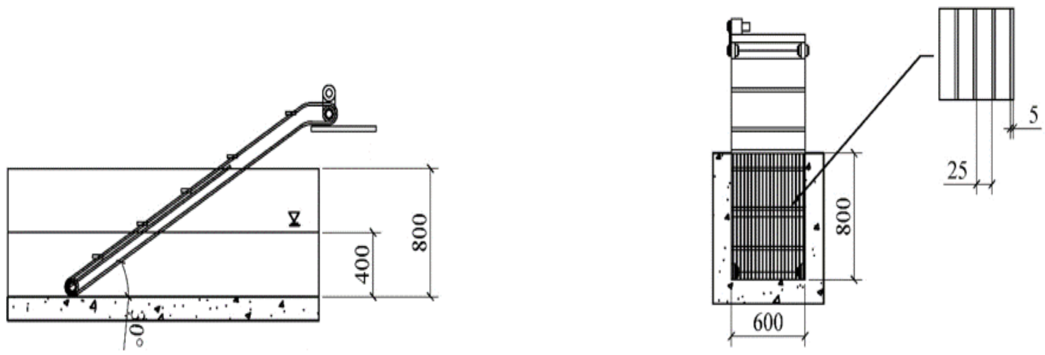


Figure 3 The detailed figure of the to be used unit bar screen (without scale)

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.

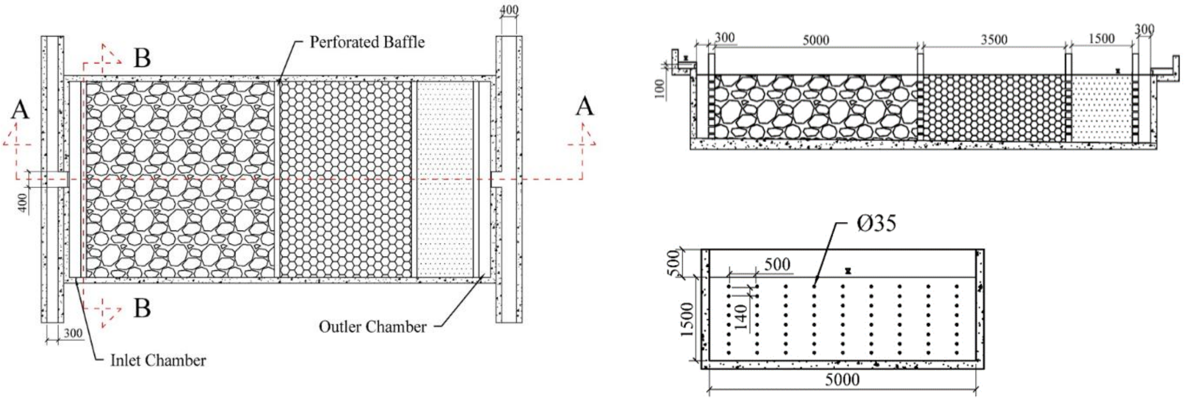


Figure 4 The detailed figure of the to be used HRF unit (without scale)

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 m^3/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.

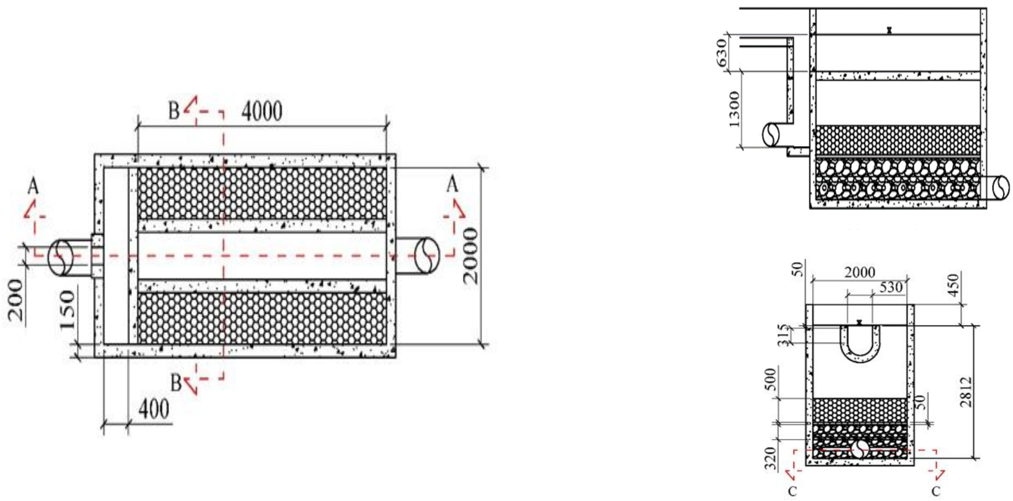


Figure 5 The detailed figure of the to be used RSF unit

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 5 The designed dimensions of each unit

Unit	HRT (min)	Number of Units	Redun-dancy	Dimension (m)				Additional Specifications
				Length	Width	Depth	fb	
Collection tank	5	2	1	3.5	2	3	0.5	Sluice L= 0.4 m
Bar Screen	-	1	1	1.4	0.6	0.4	0.4	P_{Duct}= 8.65 m Slope= 30°
HRF	224	14	2	11.2	5	1.5	0.5	Inlet and outlet Chamber P= 0.3 m
RSF	15	5	1	4	2	2.8	0.45	H zeolite media= 0.5 m H buffer (gravel) media= 0.32 m H geotextile= 0.05 m
Reservoir	-	1	0	30	3.5	3.8	0.5	-

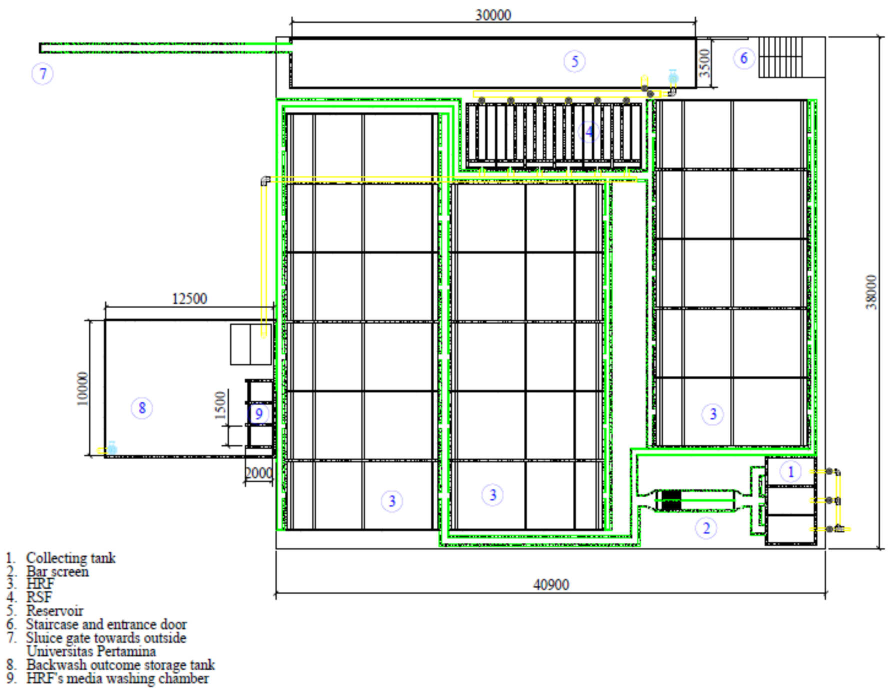


Figure 6 WWTP layout design for gardening activity in Universitas Pertamina

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.

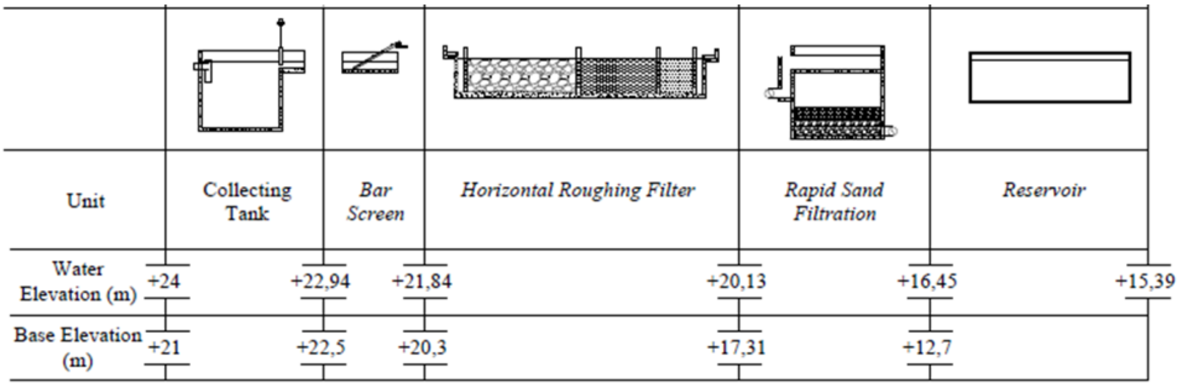


Figure 7 WWTP hydraulic profile for gardening activity in Universitas Pertamina

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%.

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