



# Planning Advanced Treatment of Tap Water Consumption in Universitas Pertamina

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## ABSTRAK

Instalasi Pengolahan Air Limbah (IPAL) di kawasan Universitas Pertamina beroperasi sudah sangat baik. Adanya program *green campus* dengan indikator daur ulang air limbah menjadi salah satu tantangan dalam meningkatkan kualitas *effluent WWTP* tersebut dengan menambahkan unit *advanced treatment*. Tujuan dari studi ini adalah untuk merancang unit-unit pengolahan *advanced* dan perkiraan hasil *effluent* dan biaya yang dibutuhkan. Studi ini dilakukan dengan melakukan survey lapangan, pengambilan data kualitas air, dan studi literatur. Dengan debit ( $Q_{peak}$ ) perencanaan 8,45 m<sup>3</sup>/jam, luas lahan yang dibutuhkan untuk penambahan *advanced treatment* adalah 105,85 m<sup>2</sup>. *Advanced treatment* terdiri dari 1 unit bak ekualisasi, 2 unit saringan pasir lambat, 1 unit bak pencuci pasir, 2 unit membran mikrofiltrasi, 1 unit proses desinfeksi, dan 2 unit *reservoir*. Dengan adanya unit-unit tersebut diharapkan kualitas *effluent* memenuhi standard kualitas air minum dengan nilai TSS 0 mg/L, Amonia (NH<sub>3</sub>-N) 0,35 mg/L, Zat Organik (KmnO<sub>4</sub>) 0,513 mg/L, Zat Terlarut (TDS) 23 mg/L, dan Total Koliform 0/100 ml sampel. Total biaya yang dibutuhkan untuk membangun *advance treatment* untuk konsumsi air keran adalah Rp 374.727.334.

**Kata kunci:** Air keran, IPAL, kampus, pengolahan lanjut

## ABSTRACT

The wastewater treatment plant (WWTP) in Universitas Pertamina's area is operating very well. The existence of a green campus program with a wastewater recycling indicator has become one of the challenges. Improving the WWTP effluent quality by adding an advanced treatment unit. This study aims to design advanced processing units and estimate the effluent yields and required costs. This study was conducted by conducting a field survey, collecting water quality data, and literature study. With planning discharge ( $Q_{peak}$ ) of 8.45 m<sup>3</sup>/hour, the land area required for the addition of advanced treatment is 105.85 m<sup>2</sup>. Advanced treatment consists of 1 unit of Equalization Tank, 2 units of slow sand filter, 1 unit of sand washer, 2 units of microfiltration membrane, 1 disinfection body, and 2 reservoir units. These units it is expected to make effluent quality meets the drinking water quality standards with a TSS value of 0 mg/L, Ammonia (NH<sub>3</sub>-N) 0.35 mg/L, Organic Substances (KmnO<sub>4</sub>) 0.513 mg/L, Total Dissolved Solids (TDS) 23 mg/L, and Total Coliform 0 Total/100 ml of sample. The total cost needed to build an advance treatment for tap water consumption is Rp 374,727,334.

**Keywords:** Advanced treatment, campus, tap water, WWTP.

## 1. INTRODUCTION

The Wastewater Treatment Plant (WWTP) of the Universitas Pertamina's area functions to treat properly the domestic wastewater produced by Universitas Pertamina's area. The quality of wastewater effluents will negatively impact the receiving water bodies [1, 2]. WWTP effluent discharged to the sanitary sewer. However, these efforts are

still limited to the end of the pipe, while currently, proactive efforts are needed to create sustainable innovation. One of the proactive efforts in managing WWTP in the Universitas Pertamina's area is the wastewater reuse opportunity to become tap water for the Universitas Pertamina's community. A sustainable campus is an environmental system of environmental



issues, innovation, and research and involves campus residents [3].

System's ability to recycle wastewater to reduce waste contamination to the environment, where the water can be reused, minimizes the use of water underground, which means maintenance the use of the water sources that are increasingly limited water resource and water quality in Jakarta time by times [4, 5]. With the addition of an advanced treatment unit at the end of WWTP, it has the potential to be used as tap water.

Commonly used wastewater recycling technology is membrane filtration [6, 7]. Membranes for treating water and wastewater usually classified according to the pore size sequence are microfiltration (MF), ultrafiltration (UF), Nanofiltration (NF), and reverse osmosis (RO). Generally, MF is suitable for separating solids suspended, including microorganisms with a sufficiently large size, such as protozoa and bacteria. UF is needed to separate viruses and organic macromolecules with a size of around 20 nm. NF and RO could separate the smaller organic components and ion multivalent; it is even suitable for separate all dissolved species.

Conventional wastewater still contains various contaminants from suspended solids to very small inorganic [8, 9]. It has been proven that microbial pollutants have been successfully removed by MF, due to the size of the bacteria which is larger than the pore size of the membrane. However, since the plant was built for design and wastewater processing, UF could not isolate the bacteria perfectly. The positive coliform outcome is obtained when processing with an operated membrane.

Nutrient in wastewater also becomes a problem in an environment [10]. Therefore, a pretreatment such as slow sand filter (SSF) is needed before the membrane unit [11, 12]. This slower speed is caused by the smaller size of sand media (effective size = 0.15 -0.35 mm). SSF is used to remove organic, nutrients, and pathogenic organism's

contents from raw water. SSF is effectively used with relatively low turbidity, which is below 50 NTU [13]. With the SSF before the MF unit, the membrane's load will be lower, thus, the membrane fouling time will be longer.

The reappearance of these bacteria should be treated through the disinfection process. Thus, the purpose of this study is to design an advanced treatment unit to process the WWTP effluent of Universitas Pertamina's area consisting of SSF, MF units, and disinfection. Advanced wastewater treatment can provide wastewater quality to meet the standard of the Minister of Health decree number 492 of 2010 Republic Indonesia.

## **2. METHOD**

### **2.1. FIELD SURVEY**

Field surveys are used to support the design by knowing the existing conditions of the existing location. By conducting a field survey, it is expected that the design idea's implementation can be easier conducted. Field surveys can be carried out by coming directly to the research location or by asking about related matters to the WWTP officer. In this case, the field survey carried out included the existing conditions of WWTP in the Universitas Pertamina's area and the land availability for the processing unit's placement.

### **2.2. DATA COLLECTION**

Primary data is data obtained directly, from measurement or direct test. In this case, the primary data used are WWTP effluent discharge data of Universitas Pertamina's area and WWTP effluent characteristics which include pH, Total Dissolve Solid (TDS), organic substances (KMnO<sub>4</sub>), ammonia (NH<sub>3</sub>), and total coliform. Discharge data is used to determine the processing capacity, while effluent characteristic data is needed to determine the type of unit and technology to be used in the treatment system.

Sampling was carried out using a long handle scoop that has been rinsed in advance with

WWTP effluent. The containers used for the parameter test vary. Water samples for the residual parameter testing of chlorine, Total Dissolve Solid (TDS), organic substances ( $KmnO_4$ ), and ammonia ( $NH_3$ ) are taken using a 2-liter capacity plastic container, while water samples for the total coliform test are handled using a dark-colored glass bottle which been sterilized by heating with temperature  $105^{\circ}C$ . Unlike the other parameters, the pH parameters are tested in-situ using a pH meter. Then, the sample is tested in the laboratory to determine the effluent characteristics. All parameters are tested with Indonesian national standards. Suspended solid and total dissolved solid with SNI 06-6989.3-2004 by the gravimetric method, Ammonia ( $NH_3-N$ ) by SNI 06-6989.30-2005, oil and fat by SNI 06-6989.10-2011,  $BOD_5$  by SNI 06-6989.14-2004, COD by SNI 6989.2:2009, organic substance ( $KMNO_4$ ) by SNI 06-6989.22-2004, total coliform by SNI 06-4158-1996, and chlorine's residue by SNI 6989.57-2008.

### 2.3. DATA PROCESSING

The design phase and design calculations are carried out to clarify the processed data. At this stage, one processing unit selected in the pre-design step will be detailed in both technical and expense terms. The following are aspects that will be examined in the

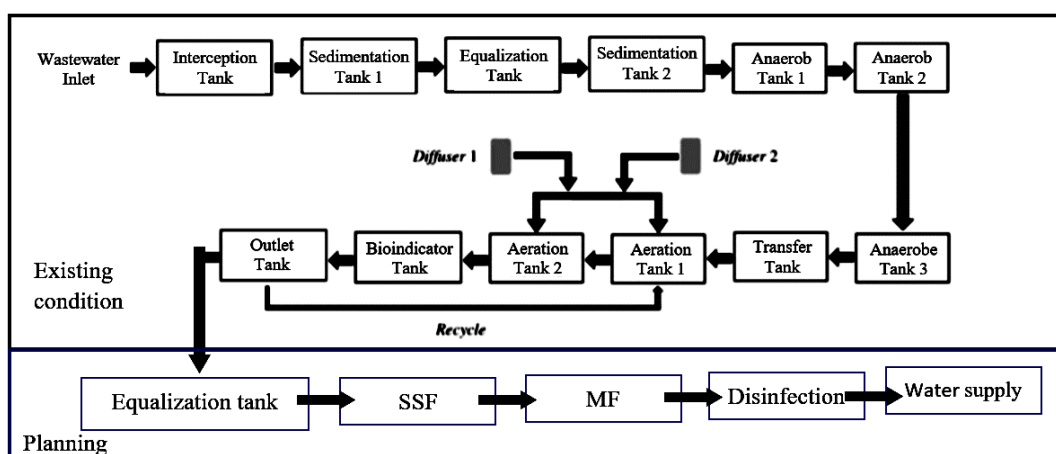
design and design calculation stages: calculating the dimensions of the processing unit and other supporting needs by referring to the literature and design criteria, visualizing the processing unit in detail, and making a draft budget of each unit.

## 3. RESULTS AND DISCUSSION

### 3.1. WWTP EXISTING CONDITION

The area of Universitas Pertamina is an area that consists of 5 institutes, Pertamina Learning Center, Pertamina Simprug Residence, the Pertamina Foundation, Patra Women's Association, and Universitas Pertamina. Before being treated at the WWTP, domestic wastewater generated by all institutes will be collected first in collection tanks that are spread around Universitas Pertamina.

Waste collected in the collection tanks consists of septic tank runoff water and domestic waste from institutes' operational activities such as kitchen, bathroom, and sink. After collected in the collection tanks, the wastewater will be flowed to the WWTP by using an automatic pump installed in the tanks. The diagram process of domestic wastewater treatment processes in the Universitas Pertamina's area can be seen in Figure 1.



**Figure 1.** The Diagram Process of Domestic Wastewater Treatment in the Universitas Pertamina's Area (Existing and Planning)

Wastewater that has arrived at the WWTP, will then enter sedimentation tank 1 to precipitate sludge and other solids that are still carried from the settling tanks. The wastewater will overflow towards the equalization tank to homogenize its characteristics and the wastewater discharge. This is important because the other WWTP units will not work optimally if the wastewater discharge and the characteristics entering the WWTP are not standardized. The equalization tanks also function as a solid precipitant that is still carried away from the settling tanks. Therefore, it is necessary to conduct periodic checking to remove solids settled in the equalization tanks. Moreover, the equalization tanks also function as a decomposition container for organic compounds in solids, sludge decomposers, and mud collectors. The last stage before being discharged into the water body is that the waste will enter the bioindicator tank through the aeration tank. A bioindicator is a living creature representing the condition of an ecosystem and the

environment [14]. The bioindicators used in the WWTP at the Universitas Pertamina are goldfish. In this tank also, the disinfection was carried out manually by the WWTP operator. The type of disinfectant used is chlorine. Disinfecting is intended to kill pathogenic bacteria in treated water. After that, the effluent that has been processed will be flowed to the outlet tank and discharged into the water bodies. However, not all effluents will be released into water bodies, and some will be used again (recycle) to make a fall in the aeration tank 1.

### 3.2. WWTP EFFLUENT QUALITY

In this design, the results of laboratory tests are needed, which refers to 2 different quality standards, which are the quality standard of the Ministerial Decree of Environment and Forestry number 68 of 2016 [15] and Minister of Health Decree number 492 of 2010 [16] concerning the requirements for drinking water quality. However, one parameter does not meet the criteria yet, and it is total coliform (Table 1).

**Table 1.** The Analysis Results of WWTP Effluent Laboratory of Complex Building of Universitas Pertamina

Parameter	Unit	Quality Standard*	Quality Standard**	Result
pH	-	6-9	6.5-8.5	6.66
Suspended Substances	mg/L	30		29
Total Dissolved Solid (TDS)	mg/L	-	500	298
Ammonia (NH <sub>3</sub> -N)	mg/L	10	1.5	1.82
Oil and Fat	Ug/L	5	10	<5
COD	mg/L	100	500	63.36
BOD <sub>5</sub>	mg/L	30	5	5.06
Organic Substances (KMnO <sub>4</sub> number)	mg/L	-	10	8.84
Total Coliform	Total/100 ml of sample	3000	0	13000-160000
Chlorine's Residue	mg/L	-	5	0

\* Ministerial Decree of Environment and Forestry number 68 of 2016

\*\* Minister of Health Decree number 492 of 2010', - No standard

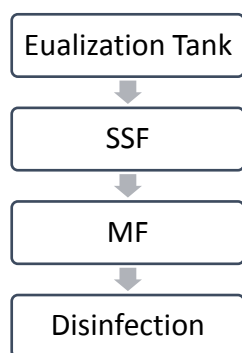
The quality standard stated that the maximum allowable level for the total coliform

parameters is 3000/100 ml of the sample, while from the laboratory test results, the

results for the total coliform obtained are 13,000/100 ml of the sample. Therefore, total coliform will be the reference parameter in determining the processing unit.

### 3.3. ADVANCED TREATMENT UNIT ADDITION

The equalization tank is used to generalize the to be treated water discharge. The effluent discharge generated by WWTP tends to fluctuate and is not sustainable every hour. Besides, the equalization tank will also increase the operating effectiveness of the to-be-used sand filter unit. Advanced processing unit design can be seen in Figure 2.



**Figure 2.** Flow chart of WWTP advanced treatment processing design at Complex Building of Universitas Pertamina

The slow SSF is used as a pretreatment before the water is treated in the filter membrane. A slow sand filter can reduce particulate matter in water; thus, it helps the performance of the membrane unit. As a result, the possibility of the membrane filtering to clog is even lower. Moreover, the use of a slow sand filter in this advanced processing unit also aims to save costs and operations which tend to be easier when compared to the rapid sand filter.

In the SSF treatment, this unit has a schmutzdecke layer consisting of organic waste, bacteria, algae, and other biological compounds that grow on the surface of the filter media. [17]. The formation of a ripe schmutzdecke layer takes 2-3 weeks and depends on temperature and biological content (bacteria and organic matter) in raw

water. In this schmutzdecke layer there is biomass [17]. The main function of biofilm in an SSF is to remove pathogenic microorganisms and degrade organic substances, nutrients, suspended solid, and dissolved solid.

Apart from the parameters mentioned in Table 2, the microfiltration membrane can remove metals such as nickel [18]. Microfiltration membranes generally have pore sizes between 0.05  $\mu\text{m}$  and 10  $\mu\text{m}$ , with a pressure range of a.1 bar to 2.0 bar [19]. Sustainable water resources management and conservation is the biggest challenge for every civilization, especially for areas experiencing water scarcity due to population growth, industry, tourism, etc. [20]. Designing a water reuse system in a safe campus through maximizing water recycling with membrane technology can minimize the discharge of domestic wastewater into water bodies is the final goal of sustainable water management. Several campuses have carried out projections and plans regarding water purification to get the nickname as a green campus [21, 3, 22, 23].

The microfiltration membrane in the advanced processing unit aims to eliminate organic and inorganic materials and bacteria left in the treated water. Disinfection in wastewater processing unit's aims to remove pathogenic bacteria left in treated water. The disinfection unit in the design of further processing is quite important because, as stated in the quality standard of Minister of Health Decree number 492 of 2010 [16], water can be suitable for drinking if it has a total coliform level of 0/100 ml of the sample. Besides, according to the World Health Organization (WHO), there must be residual chlorine of 0.2 mg/l in processed water until reached by the customer so that the water remains safe from pathogenic bacteria after the distribution process [24]. The type of

disinfectant that will be used in this design is sodium hypochlorite (NaOCl). The use of

NaOCl as a disinfectant is cheap, affordable, and easy to use by the public [25].

**Table 2.** The Estimated Effluent Quality in SSF and MF Units based on Literature Study

Parameter	Value	Unit	Slow Sand Filter			Microfiltration		
			Removal Efficiency (%)	Effluent	Source	Removal Efficiency (%)	Effluent	Source
pH	6.66	-	-	-	-	-	-	-
TSS	29	mg/L	91.2	2.552	[26]	100	0	[27]
Ammonia (NH3-N)	1.82	mg/L	75	0.455	[28]	10	0.35	[29]
Organic Substances (KmnO4)	8.848	mg/L	60	3.539	[30]	81.3	0.513	[31]
TDS	298	mg/L	86.1	41.422	[26]	44.65	23	[27]
Total Coliform	160,000	Total/100 ml of sample	99	1,600	[32]	100	0	[27]

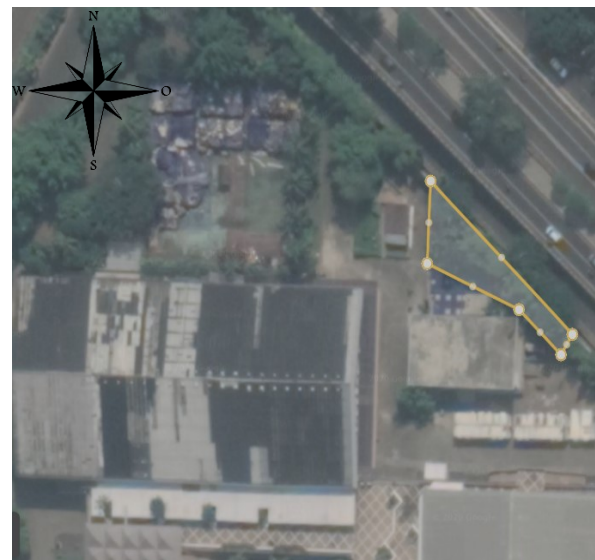
### 3.4 PROFILE HYDRAULIC AND LAYOUT

The advanced processing unit's design includes the calculation of the dimensions and the accessories used. This calculation is carried out to determine the amount of land needed for each unit and detailed accessories. The amount of required land must be following land availability. Design calculation and additions use based on existing design criteria so that later the unit can operate properly.

The discharge used in this design is peak hour discharge ( $Q_{peak}$ ) with a value of 8.45 m<sup>3</sup>/hour. Based on calculations, the land area required to build this further treatment plant is 105.85 m<sup>2</sup>. Land availability is one of the factors so that the design can be implemented (Figure 3). This is because each planned processing unit will use a certain amount of land at Universitas Pertamina. Overall land area needed and the amount of land available to build advanced WWTP treatment at Universitas Pertamina is sufficient.

The available land area of about 320 m<sup>2</sup> (Figure 4). The dimension of equalization tank and SSF are 3.5m x 3m x 2.6m and 5m x 5m x 2.7m. The diameter of MF is 39 mm.

Details for each unit in the WWTP advanced treatment can be seen in Table 3.



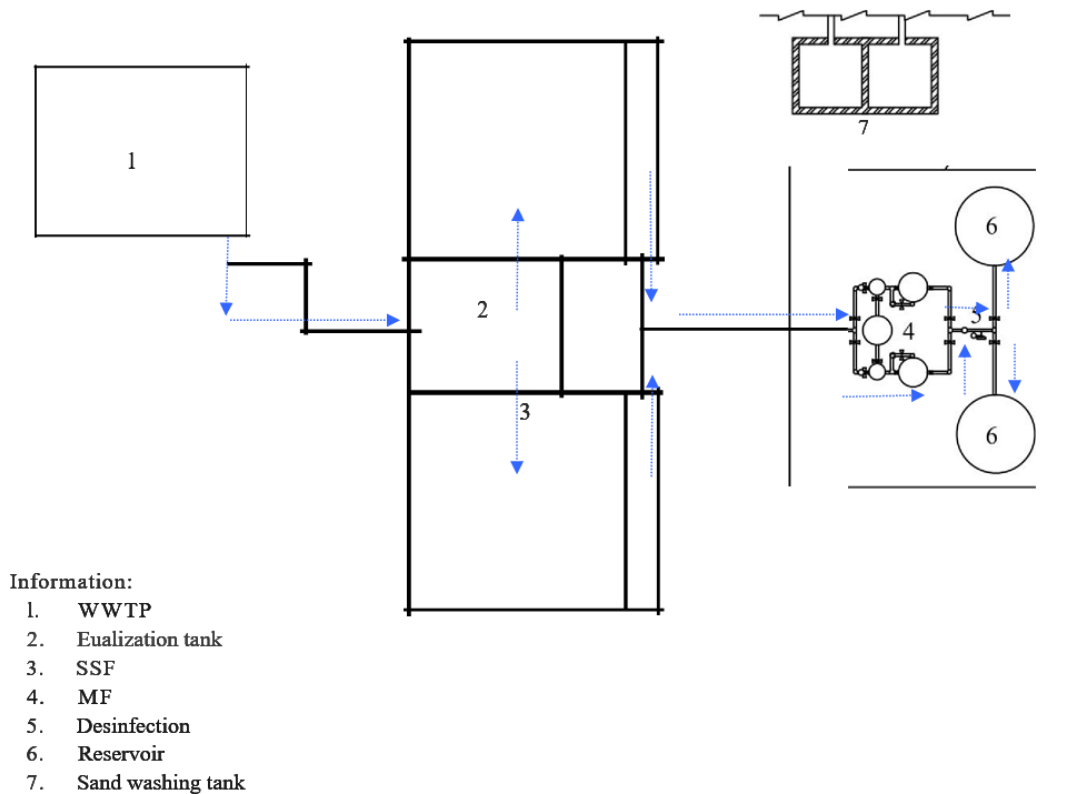
**Figure 3.** Land availability for WWTP advanced treatment planning at Universitas Pertamina (---: available land)

The hydraulic profile is used to determine the water level when the unit is operating. The hydraulic profile is calculated based on ground elevation, considering the head loss of each unit. Figure 5 shows the hydraulic profile of the WWTP advanced treatment unit design at Universitas Pertamina. The hydraulic profile is a comparison overview of

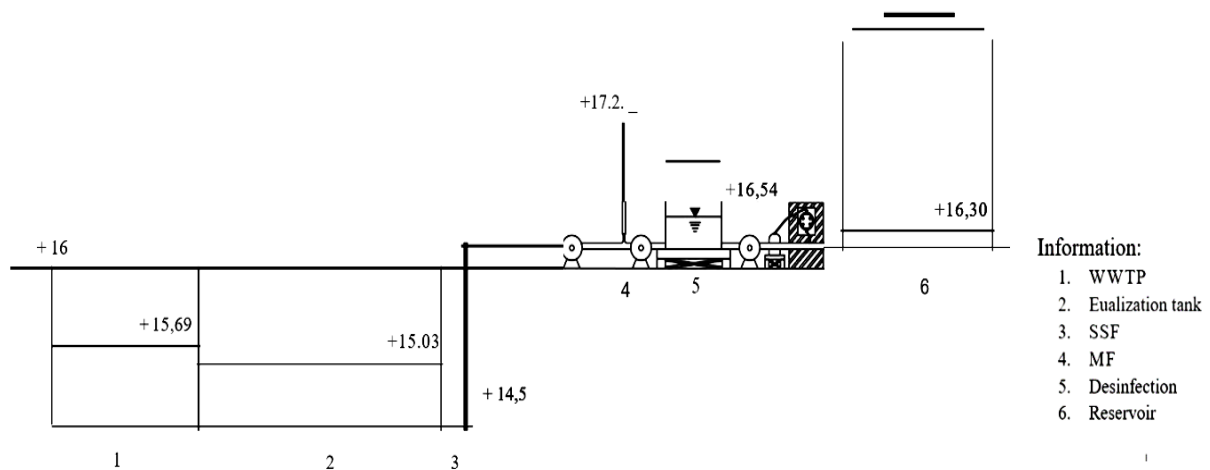


the water surface level with the land elevation. Hydraulic profile determined based on the amount of decrease in the water surface level due to several things. The

application of hybrid treatment with due observance to the hydraulic design criteria at Universitas Pertamina is expected to reclaim wastewater [33].



**Figure 4.** Layout design of WWTP advanced treatment processing at Universitas Pertamina



**Figure 5.** Hydraulic profile of the advanced treatment addition at WWTP Complex Building of Universitas Pertamina

**Table 3.** Cost budget plan for the advanced treatment addition at WWTP Complex Building of Universitas Pertamina

No	Unit	Description	Total	Cost Per Unit	Subtotal
1.	Equalization tank	The flow that will enter the slow sand filter unit needs to be generalized. The dimensions (length x width x height) for equalization tanks are (3.5m x 3m x 2.6m).	1	Rp48,599,049.92	Rp48,599,049.92
2.	Slow sand filter	Silica sand media is used as a pretreatment filter membrane. The design of the slow sand filter refers to the SNI 3981: 2008 standard with the DED calculation results dimensions (5m x 5m x 2.7m). The media used in this filter are silica and gravel media as a buffer.			
	Slow sand filter tank		2	Rp104,475,119.01	Rp208,950,238.03
	Sand washer tank		1	Rp4,645,956.88	Rp4,645,956.88
3.	Microfiltration membrane	Length (1.016 m), membrane area (5.8 m <sup>2</sup> ), diameter (39 mm), and the flux plans during operation (0.034 m <sup>3</sup> /m <sup>2</sup> .h).	2	Rp22,493,914.29	Rp44,987,828.58
4.	Disinfection	Requires 0.14 kg/day chlorine. The type of disinfectant that will be used in the disinfection unit is liquid chlorine (sodium hypochlorite (NaOCl) with a daily requirement of 0.24 l/day. The disinfection process will be carried out in a reservoir tank that has a capacity of 5000 liters.			
	Contact tank/reservoir		2	Rp14,230,070.00	Rp28,460,140.00
	Affixing system		1	Rp5,018,000.00	Rp5,018,000.00
				<b>Total Cost</b>	Rp340,661,213.41
				<b>PPN 10%</b>	Rp34,066,121.34
				<b>Total Cost</b>	Rp374,727,334

### 3.5 Budget Plans

The budget plan (RAB) is the overall cost needed to build the processing unit. The RAB

calculation refers to the Harga Satuan Pokok Kegiatan (HSPK) DKI Jakarta in 2019 [34]. The budget calculation results for each



WWTP advanced treatment unit in the Complex Building of Universitas Pertamina can be seen in Table 3. The specifications and quality of the influent used are following Table 2 so that it is estimated that the effluent will have the same quality.

The budget plan for adding advanced wastewater treatment in Universitas Pertamina is cheaper than the budget plan from conventional unit planning. The planning for conventional WWTP processing at ITS Campus for MIPA Tower already costs Rp. 743,275,675.0 [35]. When compared with the advanced processing unit of constructed wetlands, it costs Rp. 412,059,022,- [36].

#### 4. CONCLUSION

The total cost required for the advanced treatment addition at WWTP Complex Building of Universitas Pertamina is Rp374,727,334.- for 1 unit of Equalization tank, 2 units of slow sand filter, 1 unit of sand washer tank, 2 units of microfiltration membrane, 1 unit of disinfection, and 2 units reservoir. The land area required is 105.85 m<sup>2</sup> with the quality effluent expected TSS 0 mg/L, Ammonia (NH<sub>3</sub>-N) 0.35 mg/L, Organic Substances (KMnO<sub>4</sub>) 0.513 mg/L, Total Dissolved Solids (TDS) 23 mg/L, and Total Coliform 0 Total/100 ml of sample.

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