Redesign of Communal Wastewater Treatment Plant (WWTP) at RW 02 Duri Utara, Tambora District, West Jakarta

Imroatus Sholikhah[1], Betanti Ridhosari[2], Evi Siti Sofiyah[3]

{sholikhahiimo15@gmail.com[1], betanti.ridhosari@universitaspertamina.ac.id[2], es.sofiyah@universitaspertamina.ac.id[3]}

Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jakarta 1220, Indonesia

Abstract. The Duri Utara Communal Wastewater Treatment Plant (WWTP) is one of the community-led total sanitation programs carried out at RW 02, Duri Utara, Tambora District, West Jakarta. This Communal WWTP has been operating for 4 years, but the quality of its effluent does not meet the domestic wastewater quality standards as standardized in the Regulation of the Minister of the Environment Number 68 of 2016. Therefore, it is necessary to evaluate the performance of the Communal WWTP in which the obtained data will be used in redesigning the new Communal WWTP. The approach used to choose the most suitable alternative is the Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) method. Based on the consideration of environmental, operational and maintenance, as well as economic aspects, the chosen alternative design is an anaerobic-aerobic biofilter with an effective land area of 4.44 m^2 and a capacity of 15.39 m^3/s.

Keywords: Domestic wastewater, Quality standard, Communal WWTP, TOPSIS, Biofilter.

1 Introduction

Data from Badan Pusat Statistik (BPS) of West Jakarta in 2015 stated that Duri Utara had a population of 20,603 people and it increased by 23,711 people in 2016 [1]. Indonesia's health profile data in 2016 states that nationally, the percentage of villages that have open defecation free (ODF) is 26% [2]. In 2020, the percentage of villages that have open defecation free (ODF) is 36.2%. The percentage of open defecation free in DKI Jakarta in 2020 only reached 10.9% of the 2020 strategic plan target of 40% [3]. Previously, most residents in Duri Utara did not have a septic tank and defecation from the toilet was directly channeled into the sewer. This causes groundwater or wells to be polluted and causes disease to the community. Based on data from Dinas Kesehatan of West Jakarta, diarrhea cases in Tambora District in 2014 were the 3rd highest diarrhea cases after Kalideres and Cengkareng Districts [4]. Data from the Tambora District Health Center in 2015 also stated that there were about 50 cases of diarrhea every month that occurred in Duri Utara and the most cases happened to residents of RW 02 Duri Utara [5].

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Overall, West Jakarta is the administrative city with the largest number of diarrhea cases in DKI Jakarta in 2015, which is 32% [6] .

The community-led total sanitation (CLTS) programs carried out in Tambora District from October 2016 to July 2017 which aims to improve sanitation and hygiene of the city, one of which is by building the Duri Utara Communal Wastewater Treatment Plant (WWTP). The success of the CLTS programs in Duri Utara can be seen after the program has been running in 2 or 3 years [7]. The CLTS technical implementation guideline also states that measuring or monitoring the CLTS program achievement indicators can be done after the program impact could be seen, which is a minimum of 3-5 years from the initial intervention [8]. In 2022, the Communal WWTP Duri Utara has been operating for 4 years. In this regard, it is necessary to evaluate the operational and maintenance aspects at the Duri Utara Communal WWTP. This is to determine the effectiveness of the Duri Utara Communal WWTP so that the sustainability of this facility can be carried out. Evaluation of effluent quality also needs to be carried out due to changes in domestic wastewater quality standards in 2016, namely the Regulation of Minister of Environment and Forestry Number 68 of 2016 concerning Domestic Wastewater Quality Standards. The effluent produced from the processing of the Duri Utara Communal WWTP using a mixed system (black water and gray water) must be ensured to meet the latest quality standards. Therefore, a redesign of the Duri Utara Communal WWTP needs to be done so that the effluent can meet the applicable quality standards. The data needed to evaluate the performance of the Duri Utara Communal WWTPS is data on quality of the WWTP effluent wastewater.

2 Methodology

Existing Communal WWTP data and wastewater effluent quality will be used in the analysis and evaluation of Communal WWTP performance based on operational and maintenance, environmental, and community aspects. The analysis used is descriptive qualitative analysis. The effluent produced must meet several parameters in the domestic wastewater quality standards in accordance with the Regulation of the Minister of Environment and Forestry Number 68 of 2016 [9]. There are: 1) pH, 2) BOD_5, 3) COD, 4) TSS, 5) oil and grease, 6) ammonia, 7) total coliform, and 8) discharge. When the effluent does not meet the domestic wastewater quality standards, it is necessary to redesign the communal wastewater treatment plant unit. Data on the number of users, initial design, design criteria, available land area will be used for the Communal WWTP redesign with an on-site system processing unit.

The alternative design used consists of three alternative on-site system designs that have been determined based on user capacity and processing concepts (mixed system or separate system). The method of selecting alternative design using the technique for order of preference by similarity to ideal solution (TOPSIS) method. This method is one of the approaches in fuzzy multiple attribute decision making (FMADM) which is used to find the optimal solution from several selected alternatives by evaluating these alternatives according to each design criteria. The principle is that the chosen alternative has the closest distance from the positive ideal solution (Di^+) and the farthest distance from the negative ideal solution (Di^-) [10].

The positive ideal solution is the sum of all the best values for each attribute while the negative ideal solution consists of all the worst values for each attribute [11]. The TOPSIS method is used in the selection of design alternatives because it can rank the selected alternatives, it is simple, easy to understand, and the calculations are efficient [12]. The six steps of calculation used in determining the selected alternative using TOPSIS method are listed in equation 1—7 as follows [10]:

Step 1: Construct the normalized decision matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \ i = 1, ..., m \text{ and } j = 1, ..., r. \quad (1)$$

Step 2: Construct the weighted normalized matrix.

$$v_{ij} = r_{ij} \times w_j. \quad (2)$$

Step 3: Determine ideal solution.

The positive ideal solution:

$$V^+ = \{v_1^+, \dots, v_n^+\} = \{(max_i v_{ij} | j \in \Omega_b), (min_i v_{ij} | j \in \Omega_c)\}. \quad (3)$$

The negative ideal solution:

$$V^- = \{v_1^-, \dots, v_n^-\} = \{(min_i v_{ij} | j \in \Omega_b), (max_i v_{ij} | j \in \Omega_c)\}. \quad (4)$$

Step 4: Compute the distance between each alternative and the ideal solutions.

The distance to the positive ideal solution:

$$Di^+ = \left(\sum_{i=1}^{n} \left(v_{ij} - v_j^+\right)^2\right)^{\frac{1}{2}}, \ i = 1, ..., n. \quad (5)$$

The distance to the negative ideal solution:

$$Di^- = \left(\sum_{i=1}^{n} \left(v_{ij} - v_j^-\right)^2\right)^{\frac{1}{2}}, \ i = 1, ..., n. \quad (6)$$

Step 5: Calculate the relative closeness to the ideal solutions:

Determination of preference value or relative closeness (*CCi*) is used to express the alternative distance to the positive and negative ideal solution. If the value of preference is getting bigger, the smaller the distance to the positive ideal solution and the farther the distance to the negative ideal solution.

$$CCi = \frac{Di^-}{Di^- + Di^+}, \ i = 1, ..., n. \quad (7)$$

Step 6: Rank according to *CCi* values.

The closer *CCi* is to 1, the higher the alternative should be ranked.

3 Result and Discussion

3.1 Evaluation of Duri Utara Communal WWTP

The Duri Utara Communal WWTP facilitates 18 house connections (HC) with a total of 140 people as shown in Figure 1. The Communal WWTP design used is biofilter which consists of six compartments and is equipped with a blower. Each compartment has a different function, such as to accommodate, compact, and decompose feces. The biofilter media used is fiber and coconut shell. The treated water from the Communal WWTP is channeled through the effluent pipe to the sewer. Meanwhile, the fecal sludge is periodically transported by a dung truck belonging to PD PAL Jaya [13]. Many of the residents' sewers carry small trash such as shampoo and detergent packages, or hair is the most common.

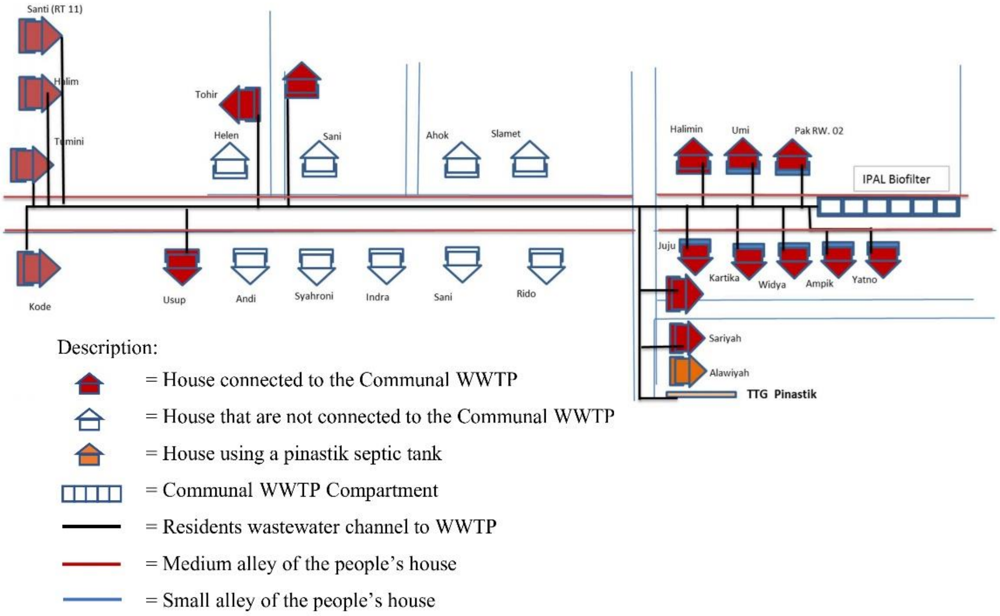

Fig. 1. Pipe network for Duri Utara Communal WWTP.

In addition, many residents do not pay the applicable fee, which is Rp20,000 per house. Some residents often delay paying their dues for months, so the WWTP management team must hammer out the residents' fees until they pay them off. Since the beginning of the Covid-19 pandemic, the neighborhood unit head began to stop the WWTP maintenance fee due to the declining economy of the residents. Therefore, there are no funds to carry out the maintenance of the Communal WWTP, such as refilling electricity tokens for blowers, draining the compartment tub, desludging sewage, repairing drainpipes, etc. Other problems such as damage to sewer pipes that cause wastewater from residents' homes cannot flow properly. As a result, a lot of wastewater starts to be thrown back into the sewers.

3.2 Wastewater Effluent Quality

The wastewater sampling method refers to SNI 6989.59:2008 concerning the Water and Wastewater Sampling Method [14]. The wastewater effluent of the Duri Utara Communal WWTP must be able to meet the domestic wastewater quality standards listed in the Regulation of the Minister of Environment and Forestry Number 68 of 2016 to be directly discharged into water bodies. Based on the report on the results of the wastewater sample test, there are three parameters that do not meet the quality standards, such as the parameters of ammonia, COD, and coliform as listed in Table 1.

Table 1. Laboratory test results of wastewater effluent at Duri Utara Communal WWTP [15]

Parameters	Results	Quality standards	Units	Method
Ammonia	10.85*	10	mg/L	SNI 06-6989.30-2005
BOD	10.55	30	mg/L	SNI 6989.72:2009
COD	106.21*	100	mg/L	SNI 6989.2:2009
Oil & Grease	3.80	5	mg/L	APHA 5520 D 2017
TSS	9.00	30	mg/L	SNI 06-6989.3:2004
Coliform	110,000*	3,000	No./100 mL	APHA 9221 B 2017

*) Exceeding the quality standard of the Minister of Environment and Forestry of the Republic of Indonesia Number P.68/Menlhk/Setjen/Kum.1/8/2016

The difference between the test results of ammonia and COD parameters with quality standards is not too large. The COD value that exceeds the quality standard is higher than the BOD value because there are more compounds that require chemical oxidation than biological oxidation [16]. A high coliform value indicates that the resulting effluent has been contaminated with fecal [17]. This could be due to the absence of desludging the fecal sludge that settles in the Communal WWTP. During the Covid-19 pandemic, the Duri Utara Communal WWTP has not carried out desludging of the produced fecal sludge because there are no adequate funds to carry out desludging of the fecal sludge.

3.3 Treatment Unit Redesign of Communal WWTP

The redesign alternative consists of several on-site system processing units listed in the Regulation of the Minister of Public Works and Public Housing Number 4 of 2017, such as septic tanks, anaerobic baffled reactors (ABR), anaerobic filters, biogas reactors, constructed wetlands, and anaerobic-aerobic biofilters. The selection of design alternatives needs to be done early selection on the on-site system processing unit. Based on existing data, the number of Communal WWTP users consist of 18 house connections (HC) with a total of 140 people. In addition, the influent wastewater that flows into the Communal WWTP consists of black water and gray water. The chosen alternative design must be able to accommodate a capacity of 140 people, be able to treat wastewater with a mixed system, on an area of 7.15 m^2. The on-site system processing units that meet these three criteria are anaerobic filters and anaerobic-aerobic biofilters.

Alternative designs for anaerobic filters and anaerobic-aerobic biofilters will be considered in the TOPSIS method with several parameters. There are: 1) land area, 2) ease of operation & maintenance, 3) electrical power requirements, 4) organic removal efficiency, ammonia removal efficiency, and 5) odor potential. The first parameter has a weigh value of 1 because they do not affect effluent quality and operational costs. The second and third parameters have a weight value of 2 because they do not affect the quality of the effluent but influence operational costs. The last parameter has a weight value of 3 because it affects the quality of the wastewater effluent.

Alternative 1 has a higher odor potential than alternative 2 because the process that occurs in alternative 1 is anerobic. The anaerobic process will produce several compounds such as ammonia, H_2S gas, methane gas, and carbon dioxide which cause odors in the reactor. Alternative 2 which has a combined process between anaerobic and aerobic can oxidize ammonia to nitrite and H_2S gas to sulfate [18]. Based on the results of the selection of alternative designs for anaerobic-aerobic biofilters with the TOPSIS method as shown in Table 2, the chosen alternative design is alternative 2, anaerobic-aerobic biofilter. Alternative 2 was chosen because it has a value that is closer to the positive ideal solution and further to the negative ideal solution.

Table 2. Weighted normalized data design alternative

Parameters	Alternative 1	Alternative 2	V_1	V_2	Positive (V+)	Negative (V-)
	Anerobic Filter	Anaerobic-Aerobic Biofilter				
Land area (m^2)	0.894	0.447	0.075	0.037	0.075	0.037
Ease of operation & maintenance	0.707	0.707	0.118	0.118	0.118	0.118
Electrical power requirement (watts)	0.894	0.447	0.149	0.075	0.149	0.075
Organic removal efficiency	0.447	0.894	0.112	0.224	0.224	0.112
Ammonia removal efficiency	0.447	0.894	0.112	0.224	0.224	0.112
Odor potential	0.447	0.894	0.037	0.075	0.075	0.037
Di^+	0.162	0.083				
Di^-	0.083	0.162				
CCi	0.339	0.661				
Ranking	2	**1**				

The configuration of the selected alternative design, anaerobic-aerobic biofilter, is depicted as shown in **Figure 2**. Based on the results of the operational and maintenance aspects, that there is still trash entering the Communal WWTP, then the alternative design is equipped with oil & grease trap (OGT). The oil & grease trap serves to set aside oil & grease and some trash that enters the Communal WWTP such as plastic waste, hair, and other solids, so as not to interfere with processing in the nest processing.

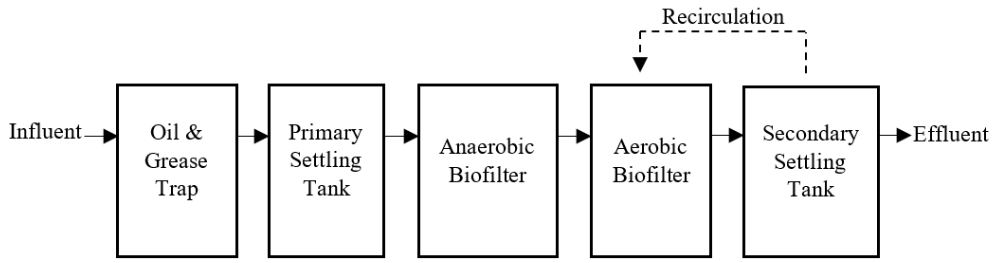

Fig. 2. Anaerobic-aerobic biofilter configuration.

The capacity of the new Communal WWTP with anaerobic-aerobic biofilter treatment is 15.39 m^3/day with a total effective land area of 4.44 m^2. This biofilter uses a biofilter media in the form of a honeycomb media. When compared with several biofilter media such as small pebbles, large gravel, mash pad, scouring pad, bio ball, and random dumped, the honeycomb media has the highest weight value and is the biofilter media that meets the best requirements. The selection is based on the weighting value of several aspects including having a large specific surface area, volume fraction high voids, large diameter free slits, can be resistant to clogging, media material is made of inert material, has low price per unit surface area, good mechanical strength, light weight media, good media flexibility, easy media maintenance, low energy consumption, and has good wettability. Honeycomb media has a specific surface area of 150-240 m^2/m^3 [19].

Based on a theoretical approach to several literature studies [19] [20] [21] [22] [23] [24] [25] [26], the effluent produced from the domestic wastewater treatment process with the new Communal WWTP (anaerobic-aerobic biofilter) for each parameter oil and grease, BOD, COD, TSS, and ammonia is <1 mg/L, 7.43 mg/L. 8.84 mg/L, and <1 mg/L as listed in Table 3. These values have met the domestic wastewater quality standard listed in the Regulation of the Minister of Environment and Forestry Number 68 of 2016.

Table 3. The results of the removal of each unit on anaerobic-aerobic biofilter

Parameters	In	OGT		Primary Settling		Anaerobic Biofilter		Aerobic Biofilter		Secondary Settling		Out	Quality Standard
		Rem	Eff	Rem	Eff	Rem	Eff	Rem	Eff	Rem	Eff		
	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	mg/L	mg/L
BOD	110	-	110	25	82.50	70	24.75	70	7.43	-	7.43	7.4	30
COD	250	-	250	26.7	183.33	69.7	55.59	84.1	8.84	-	8.84	8.8	100
TSS	120	-	120	63.5	43.84	80	8.77	99.1	0.08	-	0.08	0.1	30
Ammonia	24	-	24	-	24	70.6	7.07	81.6	1.30	-	1.30	1.3	10
Oil & Grease	54	95	2.70	-	2.70	-	2.70	97.6	0.07	-	0.07	0.1	5

The mass balance in the selected alternative needs to be calculated to determine the balance of the incoming, outgoing, and accumulated masses in a system. **Figure 3** shows the mass balance of an anaerobic-aerobic biofilter which has been equipped with a sludge recirculation process. Sludge recirculation serves to circulate some of the sludge that settles in the final settling basin to the aerobic biofilter basin. It aims to return the sludge that still contains biomass to be able to decompose organic subtances that enter the reactor.

The construction design of a new Communal WWTP (anaerobic-aerobic biofilter) with dimensions of 6.03 m x 1 m x 3.5 m and a discharge of 15.39 m^3/s is illustrated in **Figure 4** and **Figure 5**. This new Communal WWTP is equipped with an oil & grease trap, a primary settling tank, two chambers of anaerobic biofilter, two chambers of aerobic biofilter, and a secondary settling tank.

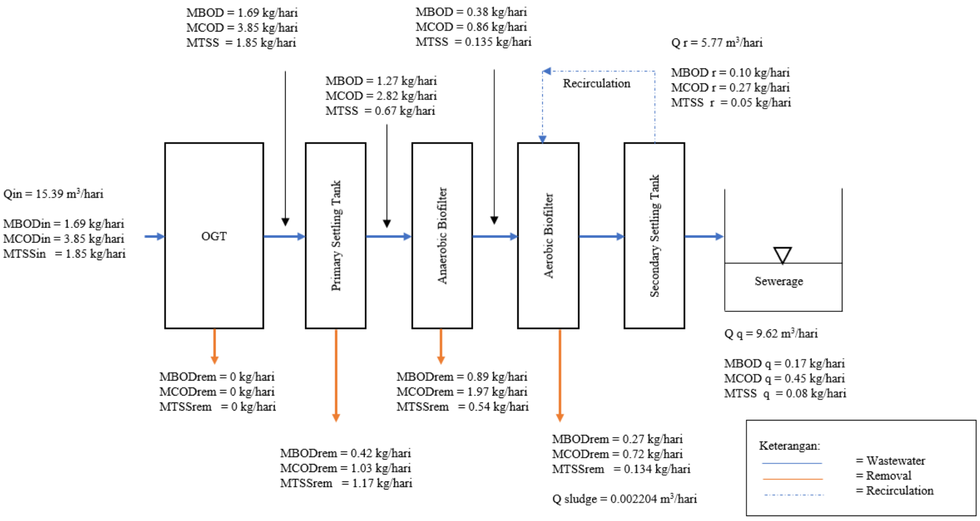

Fig. 3. Mass balance diagram of anaerobic-aerobic biofilter process.

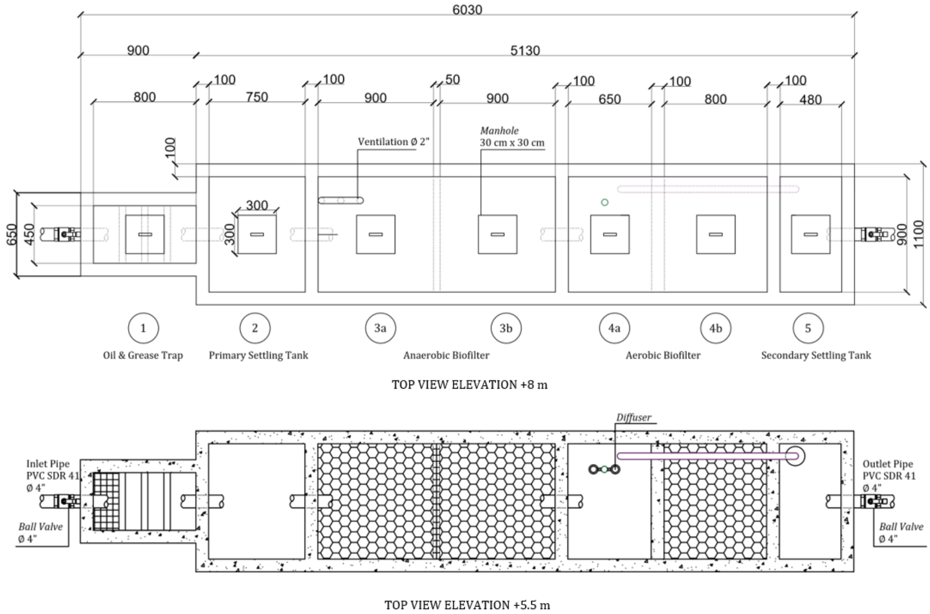

Fig. 4. Top view of anaerobic-aerobic biofilter.

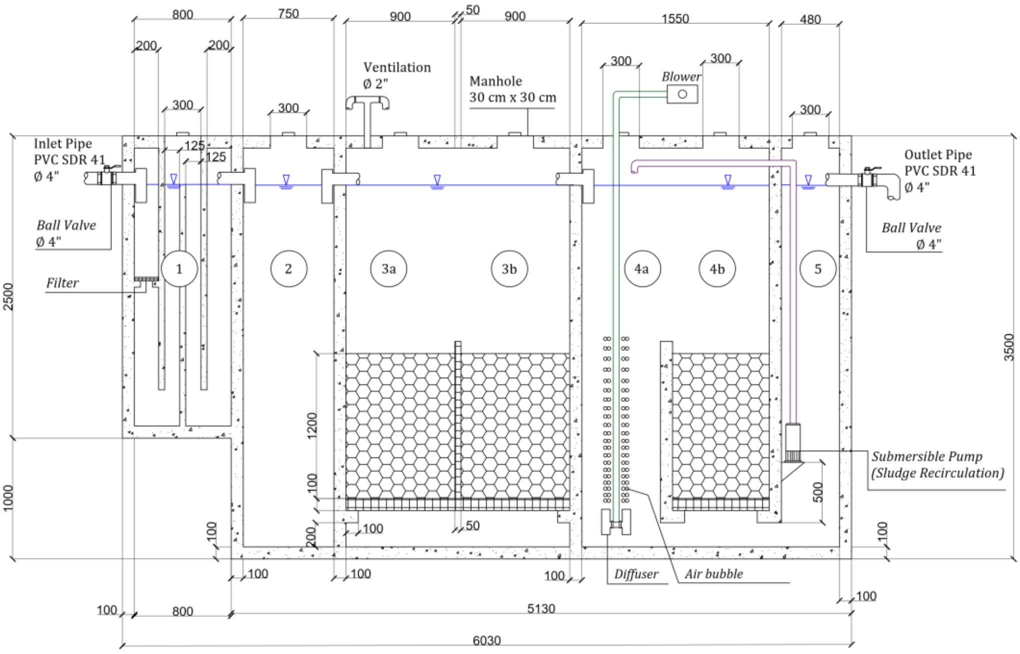

Fig. 5. Cross section of anaerobic-aerobic biofilter.

4 Conclusion

The Duri Utara Communal WWTP has been established since 2017, but the quality of the effluent has not met the domestic wastewater quality standards. Therefore, we did research and redesign the WWTP so that the wastewater can be treated properly, and the effluent can meet domestic wastewater quality standards—the Regulation of Minister of Environment and Forestry Number 68 of 2016. We used the TOPSIS method to select a new set of wastewater treatment units (on-site system) for the new Communal WWTP. Through a theoretical approach, the selected alternative on-site treatment that can meet domestic wastewater quality standards for a new Communal WWTP is an anaerobic-aerobic biofilter with a capacity of 15.39 m^3/s. The anaerobic-aerobic biofilter consists of an oil & grease trap, a primary settling tank, two chambers of anaerobic biofilter, two chambers of aerobic biofilter, and a secondary settling tank. The effective land requirement used is 4.44 m^2.

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