Domestic Wastewater Treatment Units Design in Coastal Area with High Groundwater Level – A Case Study in Cilincing District

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Abstract. Based on the data from the Ministry of Health (2022), there are 20,586 families in Cilincing District that are still practicing open defecation. This occurs partly because some of the families have no sanitation facilities. The provision of sanitation facilities in Cilincing District is challenging. One of the reasons is because the area is a coastal area with high groundwater levels, therefore requires a particular design of sanitation facilities. This project aims to determine a suitable sanitation facility to be applied in the area. Three alternatives communal scale on-site domestic wastewater treatment system are designed. The chosen alternative is selected using the TOPSIS method, which consists of an oil and fat separator tank, control tank, anaerobic biofilter and disinfection. The total area needed is 5.65 m2 . Based on mass balance, the wastewater treatment effluent has met the domestic wastewater quality standards set by the Ministry of Environment and Forestry.

Keywords: Cilincing, Sanitation, Coastal area, High groundwater level, Anaerobic biofilter

1 Introduction

Indonesia is one of the countries that participated in agreeing to the 2030 sustainable development goals SDGs agenda, in order to achieve the success of the program Indonesia ratified the goals and targets into the National Medium Term Development Plan (RPJMN) for 2020-2024. The program has a target of 100% access to proper drinking water and 90% access to proper sanitation, including 15% access to safe sanitation and 0% free from open defecation [1]. Based on data from the Central Statistics Agency in the National Socio-Economic Survey in 2021, Indonesia shows national achievements for access to proper sanitation of 80.29% and 7.25% for safe sanitation and the percentage of open defecation in public places open by 2.66% [2].

DKI Jakarta Province, which is one of the provinces with relatively high access to sanitation, amounted to 92.17% but is still constrained by the practice of open defecation. It was recorded that 186,229 heads of families still practice open defecation. It is known that the sub-district

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with the highest level of open defecation practice in DKI Jakarta is Cilincing District with a data of 20,586 households still practicing open defecation [3].

Cilincing District is one of the densely populated area in the City of North Jakarta with a population of 440,247 people with a population density of 11,420 people/km2 [4]. The people on average have a livelihood as fishermen because the location of the sub-district is in the northern coastal area of DKI Jakarta. These professions can be classified economically into people with lower economic groups. The majority of the population have completed primary school while many others have no education. These economic condition and level of education factors play an important role in influencing the ability of the community to procure sanitation facilities and in shaping the mindset of the community regarding their concern for sanitation [5]. These factors also cause the lack of septic tanks, latrines or facilities for defecation in many houses even though according to the data from the Ministry of Health, access for households to latrines in Cilincing District has reached 87% [3].

In addition, other factor that affect the provision of sanitation facilities in Cilincing District is the situation where the District lays. The area is categorized as a specific area where the District situated in coastal zone with high groundwater levels (< 2 mdpl). Specific areas are areas whose geographical and climatic conditions are different compare with terrestrial area so then an affordable sanitation service system is challenging to build or implement so then requires special sanitation services in order to minimize the potential for pollution that will occur [6]. Based on data from the BPS for North Jakarta City in 2021, Cilincing District is included in an area that often experiences tidal flooding and seawater intrusion. This can affect the performance of domestic wastewater treatment. On the other hand, with high groundwater levels, the depth of the groundwater table is close from the ground surface so that it has the potential to pollute groundwater quality.

The government of DKI Jakarta has established programs to meet the 2020-2024 RPJMN target. One of the programs is to develop the Jakarta sewerage system (JSS) in 15 zones that covers most part of the capital city. In the program, Cilincing District is divided into 2 zones, namely Zone 8 and Zone 9. Zone 8 or the Marunda Reservoir Area is a priority zone where the sewerage system will be constructed in 2020-2030. Currently, Zone 8 is still in the planning stage. On the hand, the program for Zone 9 will be carried out in 2030-2050 [7]. Therefore until now the domestic wastewater treatment in Cilincing District is still carried out by the community independently or directly disposed of to the nearest water body.

Based on previous research discussing sanitation problems in coastal settlements, according to Wahyuni & Qomariyah in 2018, the technology Tripikon-S is applied to people whose homes are close to the shoreline. Communal septic tanks for areas far from the beach and most of them have their own latrines. Anaerobic Baffled Reactor (ABR) for areas that do not have MCK infrastructure, the distance between people's residences that are close together, and the area of land that is relatively very small [8].Also according Sembiring & Safithri in 2021 with the physical conditions of irregular house buildings, the technology used Anaerobic Baffle Reactor (ABR) for communal scale and site treatment for Tripikon-S [9]. The selection of the right technology to properly manage domestic waste is influenced by various factors that must be considered.

For those reasons above, the purpose of this study is to design an alternative sanitation system for domestic wastewater treatment in Cilincing District that is suitable for a coastal area with a high groundwater level based. The design is carried out based on the Regulation of the Minister of Public Works and Public Housing Number 04/PRT/ M/2017 of 2017 concerning the implementation of a domestic wastewater management system.

2 Method and Material

The method used in this design is secondary data collection (literature study) and site survey. Secondary data is obtained from publications in the form of books, journals, regulations, articles and other valid sources. Secondary data collected includes the quantity and quality of domestic wastewater in Indonesia, related regulations such as Regulation of the Minister of Public Works and Public Housing Number 04 of 2017 concerning the implementation of domestic wastewater management systems for the selection of sanitation systems and design criteria for processing technology, processing technology and design criteria in the Guidelines for Detailed Engineering Planning for a Centralized Domestic Wastewater Management System or SPALD-T Book A, and quality standards based on Minister of Environment and Forestry Regulation Number 68 of 2016 concerning domestic wastewater quality standards.

After that, the data obtained is processed and analyzed to determine several alternative design solutions. In the early stages, there were three alternative system designs that were selected based on the conditions of the area (coastal areas and areas with high water levels). Then, the three design alternatives will be compared and analyzed using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The working principle of the TOPSIS method is that the chosen alternative has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. A positive solution here means that the solution achieved maximizes the profit aspect (benefit) and minimizes the loss aspect (cost). In the TOPSIS method, calculations will be carried out using the existing formula and require criteria that can be indicators of analysis. The criteria that will be used in the selection of this design alternative are the number of quality parameters that meet quality standards, investment costs, land area used and ease of operation and maintenance. The assessment of each criterion is based on the weight (number) of the priority level (category), the higher the priority level, the greater the weight. Each criteria with their weight, the number of quality parameters that meet quality standards (3 as benefit), investment costs (2 as cost), land area used (2 as cost), and ease of operation and maintenance (3 as benefit).

The results of the TOPSIS method will produce the most appropriate design solution. Then, from the selected alternative solutions design calculations can be carried out, after that calculated the mass balance to identify whether the output produced from the system meets the applicable quality standards, make the budget plan, then make a 2-dimensional design and design drawings as the final design results.

3 Results and Discussion

3.1 Domestic Wastewate Quality and Quantity Data

In this design, the wastewater to be treated is blackwater originating from the toilet in the form of feces and flushing water. Based on the literature study, there is no data that specifically discusses blackwater in Cilincing District. Thus, for the data on the quality of the blackwater used in the design, the data on the quality of the blackwater in Indonesia, according to Widyarani [10]. The characteristics of the wastewater are then compared with the Regulation of the Minister of Environment and Forestry Number 68 of 2016 concerning the quality standards of domestic wastewater [11], which can be seen in Table 1.

Table 1. Quality of Domestic Toilet Wastewater in Indonesia [10]

No.	Parameter	Unit	Value of Blackwater	Maximum Rate	Explanation
1.	Total Suspended Solids (TSS)	mg/1	184	30	Does not meet
2.	*Biological Oxygen Demand (BOD)*	mg/1	206	30	Does not meet
3.	Chemical Oxygen Demand (COD)	mg/1	509	100	Does not meet
4.	Oil and fat	mg/1	14	5	Does not meet
5.	pH	-	6,8	6 – 9	Meet
6.	Ammonia	mg/1	112	10	Does not meet
7.	Total Coliform	MPN/100 ml	$9{,}8 \times 10^5$	3000	Does not meet

The quantity of domestic wastewater is obtained through a population approach to the consumption of drinking water which becomes domestic waste in each service area. The percentage of domestic wastewater generation is 60-80% of drinking water use [12]. The national average of drinking water consumption for the 2010-2020 period for the DKI Jakarta area reaches 150 liters/person/day while the blackwater percentage factor used is 20% [10]. Based on SNI 2398:2017, the communal scale processing system consists of 2-10 families in each family consisting of 5 people [13]. In this design, it is assumed to serve 5 families consisting of 25 people. The following is the calculation of the waste water discharge of the toilet water that will be used.

Waste water discharge = 70% x water usage in DKI Jakarta x 20% x 25 person
= 70% x 150 L/person/day x 20% x 25 person
= 525 L/day
= 0,525 m3 /day

3.2 Selection of Sanitation System

The selection of a sanitation system or domestic wastewater treatment system is guided by the provisions of the Regulation of the Minister of Public Works and Public Housing Number 04 of 2017 concerning the implementation of a domestic wastewater management system [14]. Based on recommendations from the Cilincing District office and field surveys conducted, the design location is in the Marunda Kepu area RT 09/RW 07, Marunda Village, Cilincing District. The area was chosen because the area is in coastal zone, has high groundwater levels, inadequate domestic wastewater treatment facilities, and open defecation practices are still in high number. The available land area has an area of 15 m2 with dimensions of 3 x 5 m. The land is the land of residents who are willing to donate their land for the design of the sanitation system in the area.

The system selection can use the flow chart in **Figure 1**. Based on the flow chart, Marunda Village with a population density of 4,292 people/km2 does not exceed the stipulation limit of 15,000 people/km^2, so choose the option no and the recommended system is on-site system. On the other hand, if it is adjusted to the DKI Jakarta Provincial Government's program for waste water management, it is holding a 15 zone Jakarta Sewerage System (JSS) development activity with 5 priority zones that act as a Centralized Domestic Wastewater Management System in DKI Jakarta. It can be seen in **Figure 2**. Cilincing District is divided into 2 zones, namely Zone 8 and Zone 9. Zone 8 or the Marunda Reservoir Area (coastal area) is a priority zone, however, it is different from the other 4 priority zones which have entered the Zone 8 development stage at this time. still in the planning stage [7]. Therefore, the centralized system option has not been implemented, so for now the system that can be used is the on-site system.

The scale that will be used in this system is the communal scale. The thing to consider is that based on the results of the survey it can be seen in **Figure 3** and **Figure 4**, the distance between houses is very close, there is little available land that can be utilized because in addition to population density, the location also has limitations on the depth of the soil with excavations as deep as 1.5-2 meters already inundated. Another factor is that transportation access for stool cars cannot reach all areas because there are several areas that do not allow cars to enter.

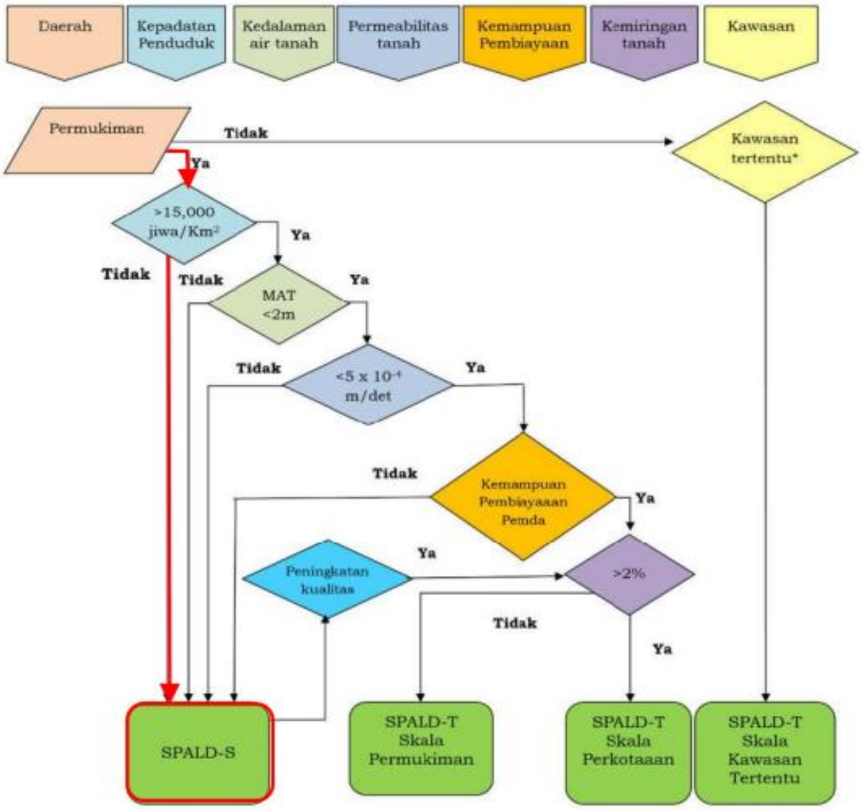

Fig. 1. Flowchart of Selection of Sanitation System [14]

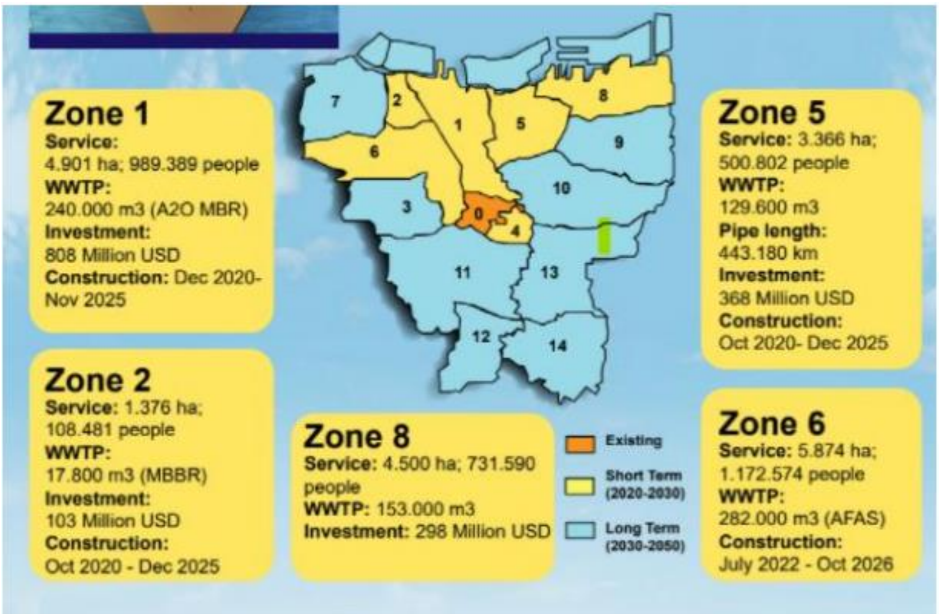

Fig. 2. Location of Jakarta Sewerage System or JSS Program Service [7]

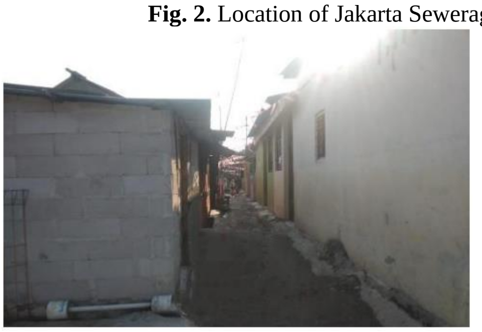

Fig. 3. Condition of House in Location

Fig. 4. Design Location

3.3 Alternative Design of Domestic Wastewater Treatment Unit

The treatment unit that will be used as an alternative design refers to the provisions of the Regulation of the Minister of Public Works and Public Housing Number 04 of 2017 concerning the implementation of a domestic wastewater management system. At the beginning of the design, three alternative sanitation systems were determined which were then selected the most suitable using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. The criteria used in the selection are processing performance, investment costs, land area, ease of operation and maintenance also consider coastal areas with high groundwater levels. The chosen alternative from the TOPSIS method has a configuration that can be seen in **Figure 5**.

The grease trap is placed at the beginning of the processing in order to separate the fat and oil before going to other units to avoid clogging or clogging in the filter media or pump used so that processing efficiency is disrupted. After going through the grease trap unit, the wastewater will be collected in the control basin first before being distributed using a pump to the biological unit. The biological unit used is an anaerobic biofilter consisting of 3 compartments, namely initial settling tank, anaerobically filtering media using honeycomb media and final settling tank. However, effluent from biological treatment cannot be directly discharged into water bodies because it has the potential for biomass carried in treated water which can cause environmental problems so that a disinfection unit is added at the end of this design configuration in order to eliminate bacteria or microorganisms so that it can meet the required wastewater quality standards. safe to discharge into water bodies.

Then, the chosen design alternative is calculated with Detail Engineering Design (DED) including detailed dimension calculations to the accessories that will be used by each unit. A recapitulation of additional dimensions and accessories can be seen in Table 2 and for the Cross section of anaerobic biofilter can be sen in **Figure 6**.

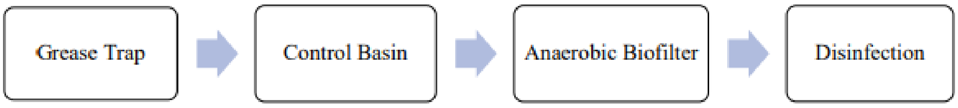

Fig. 5. Alternative Configuration of the Selected Sanitation System

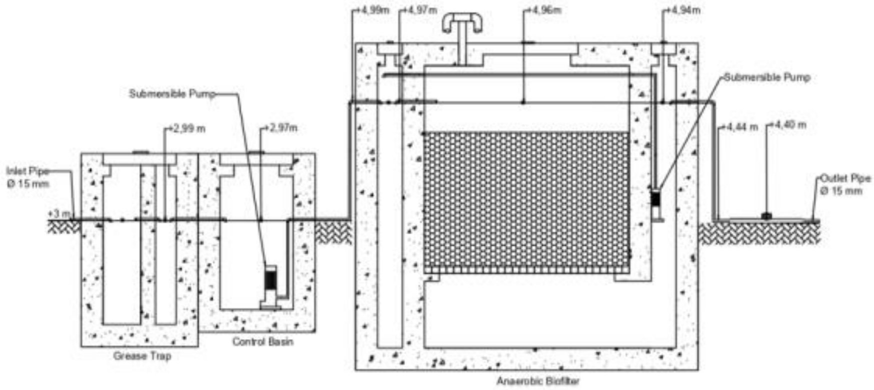

Fig. 6. Cross section of anaerobic biofilter

Table 2. Recapitulation of DED Processing Unit

Unit	Dimension (m)			Number of Units	Additional or Complementary Accessories
	Length	Width	Depth		
Grease Trap	0.5	0.2	1	1	Piping: - PVC pipe 5/8” - Elbow 90^0
Control Basin	0.5	0.5	0.9	1	Piping: - PVC pipe 5/8” - Elbow 90^0 - Gate Valve 1 piece submersible pump Yamaha pro PM794 type SRX 550

Initial Settling Tank	3	0.17	2.2	1	Piping: - PVC pipe 5/8” - Elbow 90^0
Biofilter Media Basin	3	1.4	2.2	1	Piping: - PVC pipe 5/8” - Elbow 90^0 Support plate with a thickness of 5 cm Honey Comb filter media (30 cm x 30 cm x 30 cm)
Final Settling Tank	3	0.17	2.2	1	Piping: - PVC pipe 5/8” - Elbow 90^0 1 piece submersible pump Yamaha pro PM794 type SRX 550
Disinfection	0.52	0.16	0.5	2	Piping: - PVC pipe 5/8” - Elbow 90^0 - Tees 1 piece chlorinator Disinfeeting using Chlorine

3.4 Budget Plan

In this design, the budget plan is prepared referring to the Regulation of the Minister of Public Works and Public Housing Number 01 of 2022 concerning the Analysis of Unit Price of Work for the General Sector. The calculation begins by calculating the unit price of each job, then multiplied by the quantity obtained from the DED calculation so that the budget plan is compiled. Budget plan recapitulation for each processing unit can be seen in Table 3.

Table 3. Recapitulation of Total Cost Processing Unit

No	Job Description	Total Cost
1.	Preparatory work	300,000
2.	Earthwork and Foundation	392,098
3.	Grease Trap	1,431,860
4.	Control Basin	3,608,160
5.	Anaerobic Biofilter	68,433,533
6.	Disinfection	138,500
	Total	74,304,151

3.5 Processing Unit Mass Equilibrium

Mass balance is carried out in the design of the wastewater treatment system because it aims to determine the mass changes that occur during the treatment process from the entry of wastewater to the exit of the treatment unit. Equilibrium means that the influent entering the treatment process and the effluent leaving the treatment process will be the same. The mass balance flow chart can be seen in **Figure 7** and percent allowance for each unit in Table 4.

Table 4. Precent Allowance for Each Processing Unit

Parameter	Influent	Elimination Result of Each Unit												Quality standards	Explanation
		Grease trap		Control Basin		Initial Settling Tank		Anaerobic Biofilter		Final Settling Tank		Disinfection			
		Efficiency %	Result (mg/l)	Efficiency %	Result (mg/l)	Efficiency %	Result (mg/l)	Efficiency %	Result (mg/l)	Efficiency %	Result (mg/l)	Efficiency %	Result (mg/l)		
BOD	206	0	206	0	206	43[16]	117.42	76.29[16]	27.840	39[16]	16.9826	0	16.98	30	Meet
COD	509	0	509	0	509	26.6[16]	373.606	68.12[16]	119.106	26.6[16]	87.4235	0	87.42	100	Meet
TSS	184	0	184	0	184	61[16]	71.76	70.18[16]	21.3988	61[16]	8.34554	0	8.35	30	Meet
Amonia	112	0	112	0	112	0	112	75[17]	28	0	28	87.5[18]	3.5	10	Meet
Oil & Fat	14	80[15]	2.8	0	2.8	0	2.8	0	2.8	0	2.8	0	2.8	5	Meet
pH	6.8	0	6.8	0	6.8	0	6.8	0	6.8	0	6.8	0	6.8	6 – 9	Meet
Total Coliform	980000	0	980000	0	980000	0	980000	0	980000	0	980000	99.99[19]	98	3000	Meet

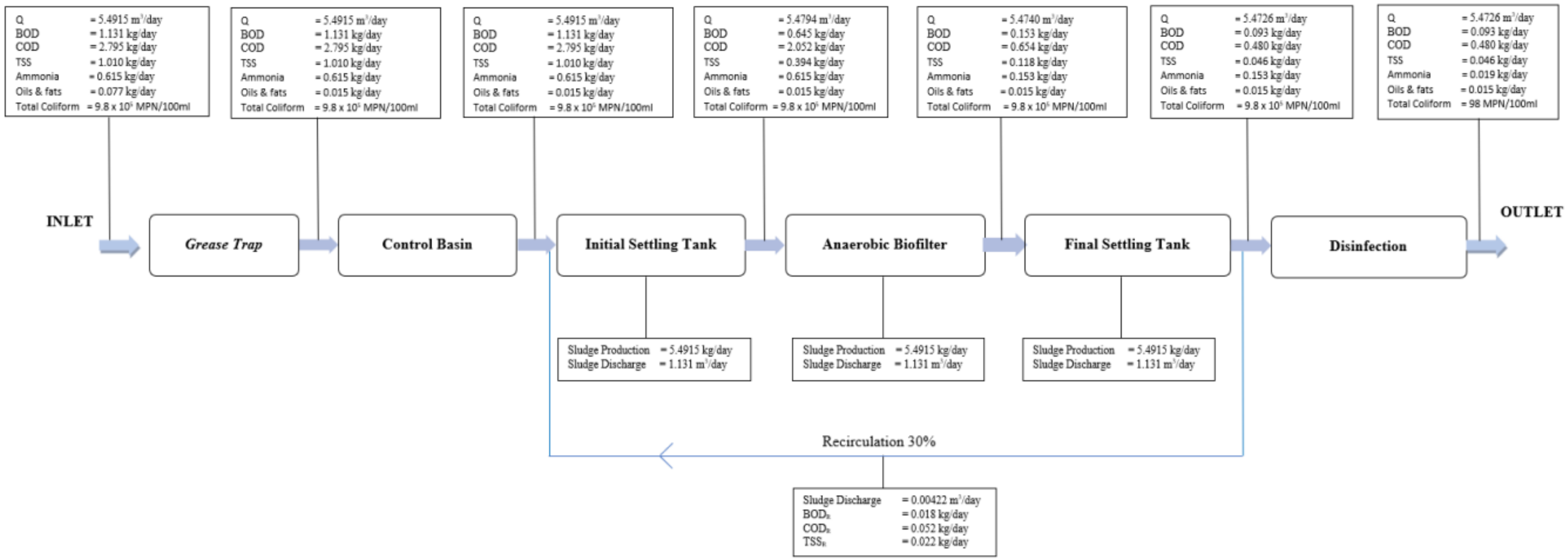

Fig. 7. Processing Unit Mass Equilibrium

4 Conclusions

The design of the sanitation system was carried out in Marunda Kepu, RT 09/RW 07, Marunda Village, Cilincing District, North Jakarta. The area is the northern coastal area of DKI Jakarta and has a high groundwater level, with a depth of 1.5–2 meters of excavation below the ground surface there is already stagnant water. Referring to the Regulation of the Minister of Public Works and Public Housing Number 04 of 2017, the sanitation system that can be used is a communal scale on-site system. In the selection of design alternatives using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method with design criteria including processing performance, investment costs, land area used, ease of operation and maintenance also consider coastal areas with high groundwater levels. The chosen alternative is an alternative that uses an anaerobic biofilter as biological unit. The processing unit in the form of an anaerobic biofilter is suitable if applied to coastal areas with high groundwater levels because it requires a small area and the processing mechanism does not occur in the infiltration process and does not produce by-products in the form of leachate that can contaminate groundwater. The selected alternative configuration consists of an grease trap, control basin, anaerobic biofilter and disinfection.

The land area used is 5.65 m2 with dimensions of 4.52 m x 2.6 m. The first unit is a grase trap unit which functions to remove oil and grease pollutants from wastewater with dimensions of 0.5 m x 0.2 m x 1 m. The second unit is the control basin that functions to collect water from the residents canal, which has dimensions of 0.5 m x 0.5 m x 0.9 m. Then for biological treatment using an anaerobic biofilter reactor with honeycomb media having dimensions of 3 m x 1.74 m x 2.2 m and the last unit disinfection using chlorine having dimensions of 0.52 m x 0.18 m x 0.5 m. This design configuration still has the remaining space from the available land. In the treatment using the selected configuration, it succeeded in eliminating the pollutant content contained in the domestic wastewater and meetsthe domestic wastewater quality standards. The processed effluents are BOD 16.98 mg/L, COD 87.42 mg/L, TSS 8.35 mg/L, ammonia 3.5 mg/L, oils and fats 2.8 mg/L and 98 MPN/100 mL for total coliforms. Waste effluent that meets quality standards is an indicator that the treatment system designhas succeeded to eliminate pollutans and the design is suitable for coastal area with high groundwater level.

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