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Evaluation and Planning of Domestic Wastewater Management in Simokerto District

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ABSTRACT: Simokerto District has 45 communal wastewater treatment plants (WWTPs), but they face several issues such as effluent not meeting quality standards, poorly maintained physical conditions, unsuitable designs, and residents not managing their domestic wastewater properly. Therefore, an evaluation and planning for future domestic wastewater management are needed. This study conducts evaluation and planning through the analysis of primary and secondary data. Primary data were collected through direct observation and interviews with Simokerto residents, covering the existing conditions of domestic wastewater management. The evaluation results indicate that the communal WWTP on Jalan Sidoyoso Wetan can still increase its service capacity by 238 people but requires a redesign with the addition of an equalization tank, pumps, and a disinfection unit. Meanwhile, the communal WWTP on Jalan Granting needs repairs for leakage, the construction of a dedicated domestic wastewater channel, and a redesign to enlarge the overall dimensions of the WWTP, including the addition of an equalization tank, pumps, and a disinfection unit.

KEYWORDS: communal WWTP, domestic wastewater, evaluation, planning, Simokerto District

I. INTRODUCTION

Surabaya is the second-largest city in Indonesia, with a population of 2.88 million (BPS, 2023). As the population of Surabaya increases, the potential for environmental pollution due to wastewater also rises. According to previous research, 76% of river pollution in Surabaya is caused by household and apartment wastewater (Nilandita et al., 2019). Domestic wastewater consists of greywater and blackwater. Greywater originates from activities such as bathing, laundry, and washing. Greywater typically accounts for 70-75% of domestic wastewater (Khotimah et al., 2021). In contrast, blackwater comes from urine and feces. Urine and feces generally contain chemical residues and other toxic substances that the body does not need. These residues come from the consumption of chemicals in various forms, such as medicines or supplements. The more residues produced by the body and disposed of in urine and feces, the more hazardous the blackwater becomes (Suparno, Pangesti, and Ariesmayana, 2021).

Everyone is required to manage domestic wastewater in accordance with environmental quality standards and must obtain permission from the authorities (Law of the Republic of Indonesia No. 32 of 2009). Domestic wastewater management can be carried out using the On-site Domestic Wastewater Management System or Centralized Domestic Wastewater Management System. Centralized Domestic Wastewater Management System is considered more suitable for application in developing countries with high population density (Afandi, 2013). Therefore, Centralized Domestic Wastewater Management System is more appropriate for Simokerto District, as it currently has the highest population density in Surabaya (BPS, 2022).

According to previous studies, sanitation in 4 out of the 5 sub-districts in Simokerto District is categorized as very high-risk, with the remainder being medium-risk areas. Data from the Tambakrejo and Simolawang Health Centers in 2015 also showed that 1,186 households still discharge domestic wastewater directly into water bodies without prior treatment (Surabaya City Health Office, 2022).

Simokerto District has made efforts to address sanitation issues, but some communal WWTPs are still not operating optimally. For instance, the communal WWTP in RT 1 and RT 4 RW 1 of Simokerto Sub-district faces technical problems such as detergent and toxic substance interference, cloudy and odorous effluent, prone-to-leakage buildings, and low treatment efficiency (Purwatiningrum, 2018). Communal WWTPs in Indonesia generally use Anaerobic Baffled Reactor (ABR) or Upflow

Anaerobic Filter (UAF) units as the main treatment units (Hastuti, Nuraeni, and Darwati, 2017). The evaluation is based on the design criteria of these units. The main design parameters for ABR units are Hydraulic Retention Time (HRT) > 8 hours, upflow velocity < 2 m/h, and organic loading of 3 kg COD/m^3/day. With these design parameters, ABR can achieve COD removal efficiency of 65-90% and BOD removal efficiency of 70-95% (Sasse, 1998). Despite its advantages, ABR has drawbacks, such as requiring a constant water flow, necessitating a collection tank and pump before the wastewater enters the ABR unit. Moreover, ABR is less effective in removing nutrients and pathogens and has a long acclimatization period (Tanaka, 2015). In contrast, UAF treatment with coagulation as pre-treatment can achieve removal rates of TSS, BOD, COD, Total N, and Ammonia of 98%, 86%, 88%, 85%, and 98%, respectively (Lestari, 2017). UAF has advantages such as minimal sludge production, short HRT (under 5 days), the ability to treat high-organic-load wastewater, and higher methane gas production (Karadag et al., 2015).

The performance of communal WWTPs is measured by analyzing the effluent results and comparing them to domestic wastewater quality standards. The quality standards for domestic wastewater for BOD, COD, TSS, Oil and Grease, Ammonia, and Total Coliform are 30 mg/L, 100 mg/L, 30 mg/L, 5 mg/L, 10 mg/L, and 3000 counts/100mL, respectively (Minister of Environment and Forestry Regulation No: P.68/Menlhk-Setjen/2016).

II. MATERIALS AND METHOD

This research was conducted by evaluating and planning based on the analysis of primary and secondary data. Primary data were collected through field observations and direct interviews with residents of Simokerto District. Meanwhile, secondary data were obtained through the review of journals, books, regulations, and previous studies. The collected data were then analyzed quantitatively and compared with design criteria to assess their suitability.

Table 1: Primary Data Requirements and Methods

No.	Data Requriements	Methods
1	Existing communal WWTPs conditions in Simokerto District	Fiel observation
2	Existing communal WWTPs capacity in Simokerto District	Field observation
3	Effluent quality existing communal WWTPs in Simokerto District	Effluent sample collection from existing communal WWTPs and testing in the laboratory

Notes:

- The existing communal WWTPs are located on Jalan Sidoyoso Wetan and Jalan Granting, Simokerto Sub-district, Simokerto District.
- Observations of the existing communal WWTPs were conducted from March to May 2024, from morning to noon.
- Effluent quality observations of the existing communal WWTPs were carried out by collecting samples and testing for parameters such as pH, BOD, COD, TSS, oil & grease, ammonia, and total coliform at the Sucofindo Laboratory.

Table 2: Secondary Data Requirements and Method

No.	Data Requirements	Source
1	Communal WWTPs' distrtribution in Simokerto District	Data of Communal WWTPs' distrtribution in Surabaya from Dinas PUPR Kota Surabaya by doing some interview
2	Population and Number of Households in Simokerto District	Badan pusat statistik Kota Surabaya
3	Domestic wastewater flow rate and characteristics	Calculation and previous studies
4	WWTPs design criteria	Previous studies
5	Domestic wastewater quality standard	PermenLHK No: P.68/ Menlhk-Setjen/2016 dan PERDA Kota Surabaya tentang Pengelolaan Kualitas Air dan Pengendalian Pencemar Air tahun 2004

III. RESULTS AND DISCUSSION

The initial step in this research is to assess the distribution of communal WWTPs in Simokerto District. The distribution of communal WWTPs in Simokerto District can be seen in table 3.

Table 3: Communal WWTPs' distrtribution in Simokerto District

Sub-District	Type of Treatment	Location	Ammount	Number of Services			Capacity (m^3)
				HC	People	HH	
Tambakrejo	Communal WWTP (PemKot Surabaya)	Jl. Tambak Segaran GG 2	1	35	140	35	45,09
		RT 1 RW 1	8	33	228	57	37,06
		Jl. Tambak Madu GG.6 RT 04 RW 09	7	46	184	46	32,43
		Jl. Tambak Laban RT 08 RW 03	7	35	140	35	32,43
		Jl Tambak Arum RW.02 Jl. Tambak Arum Tengah RW.02 Jl. Tambak Bening RW.07	7	39	150	39	27,80
Simokerto	Communal WWTP (PT Pembangkit Jawa Bali (PT PJB))	Jl. Granting RT 1 dan RT 4 RW 1	1	35	140	35	1,80
	Communal WWTP (PemKot Surabaya)	Jl. Sidoyoso Wetan, RT.01 RW.13 Jl. Sidoyoso Wetan, RT.04 RW.13 Jl. Sidoyoso Wetan, RT.05 RW.13	14	88	352	88	80,36 6 units ($4,78 m^3$) 8 units ($6,46 m^3$)

Evaluation and planning were conducted at 2 WWTP locations as research samples. The first WWTP is located on Jalan Sidoyoso Wetan and represents WWTP donated by the Surabaya City Government. The second WWTP is on Jalan Granting and represents WWTP donated by PT PJB. The WWTP on Jalan Sidoyoso Wetan was chosen as a sample because, in addition to technical aspects, this WWTP was selected due to its largest number of building units and service connections compared to other WWTPs in different areas.

A. Evaluation and Planning of Communal WWTP in Jalan Sidoyoso Wetan

On Jalan Sidoyoso Wetan RW 13, Simokerto Sub-district, there are 14 communal WWTPs spread along the road. These 14 WWTPs consist of 4 units in RT 1, 5 units in RT 4, and 5 units in RT 5. The total capacity of all WWTP units on Jalan Sidoyoso is 80.36 m^3, with 6 units (Type A WWTP) having a capacity of 4.78 m^3 each and 8 units (Type B WWTP) having a capacity of 6.46 m^3 each. The treated wastewater from these WWTPs is discharged into the river located directly in front of the residents' homes. The WWTPs on Jalan Sidoyoso Wetan are divided into 2 zones: ABR and UAF, each with 2 compartments. The design criteria for ABR and UAF are as follows:

- ABR Design Criteria:
  - Organic Loading Rate (OLR): < 3 kg COD/m^3/day
  - Hydraulic Retention Time (HRT): > 8 hours
  - Upflow Velocity (Vup): < 2 m/h
  - Compartment Length: 50% - 60% of ABR depth
  - COD Removal: 65-90%
  - BOD Removal: 70-95%
- TSS Removal: 40-70%
- UAF Design Criteria:
  - HRT: 24-48 hours
  - Organic Loading Rate (OLR): < 4-5 kg COD/m^3/day
  - Upflow Velocity (Vup): < 2 m/h
  - COD Removal: 88%
  - BOD Removal: 86%
  - TSS Removal: 98%

Based on these design criteria, the suitability of the WWTP dimensions for the planned service can be evaluated.

- Wastewater Flow Rate that Can Be Served (HRT = 24 – 48 hours):
  Q = Volume / HRT (24 hours)
  Q = 4.74 m^3/day
- Check Vup:
  - ABR Vup:
    Vup = Q / Area per compartment
    Vup = 0.18 m/h **(meets criteria)**
  - UAF Vup:
    Vup = Q / Area per compartment
    Vup = 0.29 m/h **(meets criteria)**

The communal WWTPs on Jalan Sidoyoso Wetan still has the potential for additional service capacity when considering the produced wastewater flow rate compared to the capacity of each WWTP unit. The potential for increasing the number of services for the WWTP on Jalan Sidoyoso Wetan can be seen in Table 4.

Table 4: Additional Services Potention of Communal WWTP on Jalan Sidoyoso Wetan

WWTP Point	Ammount of Services (KK)	Q (m^3/day)	Type of WWTP	Remaining Wastewater Flow Rate that Can Still Be Accommodated (m^3/day)	Additonal Services Potention (Orang)
Communal WWTP 1	7	3,36	Type A	1,42	11
Communal WWTP 2	7	3,36	Type A	1,42	11
Communal WWTP 3	5	2,40	Type A	2,38	19
Communal WWTP 4	6	2,88	Type A	1,90	15
Communal WWTP 5	7	3,36	Type B	3,10	25
Communal WWTP 6	9	4,32	Type B	2,14	17
Communal WWTP 7	11	5,28	Type B	1,18	9
Communal WWTP 8	8	3,84	Type B	2,62	21
Communal WWTP 9	9	4,32	Type B	2,14	17
Communal WWTP 10	8	3,84	Type B	2,62	21
Communal WWTP 11	7	3,36	Type A	1,42	11
Communal WWTP 12	9	4,32	Type B	2,14	17
Communal WWTP 13	5	2,40	Type A	2,38	19
Communal WWTP 14	10	4,80	Type B	1,66	13

In performance perspective, the communal WWTP on Jalan Sidoyoso Wetan is still not operating optimally. The effluent quality from the WWTP exceeds the domestic wastewater quality standards for BOD, COD, and Total Coliform parameters. The effluent quality measurement was conducted by sampling from WWTP 7, which is the the largest service capacity on Jalan Sidoyoso Wetan. The results of the effluent quality tests for WWTP 7 on Jalan Sidoyoso Wetan can be found in Table 5.

Table 5: Water quality of Communal WWTP 7 Jalan Sidoyoso Wetan Effluent

Parameters	Concentration	Standards	Unit
BOD	33,6	30	mg/L
COD	120	100	mg/L
TSS	25,8	30	mg/L
Oil and Grease	0,82	5	mg/L
Ammonia	3	10	mg/L
Total Coliform	570000	3000	colony/100mL

Source: *Result of Laboraturium Test, 2024*

This situation occurs because a communal WWTP using a filtration method should include equalization tanks and pumps to ensure that the flow rate and quality of wastewater entering the WWTP are homogeneous. Additionally, to reduce total coliform levels, the WWTP should have a disinfection unit. Given these issues, it is clear that the WWTP on Jalan Sidoyoso Wetan needs a redesign to incorporate these units. Here is an example of the redesign calculations for WWTP 1 on Jalan Sidoyoso Wetan:

Equalization Tank Requirements:

Q_{waste} = q water consumption x number of services x 80%
= 150 L/people.day x 7 HH x 4 people/HH x 80%
= 3,36 m^3/day

Vol = 3,36 m^3

H = (planned 1 m with 0,25 m *free board*)

W = 1,3 m

L = 2,6 m

Actual vol = 2,6 m x 1,3 m x 1,25 m
= 4,23 m^3

Desinfection Tank Requirements:

Vol = Q_{waste} x td (planned 4,5 hours)

Planned to use 2 compartments

Vol per compartment = 0,32 m^3

As per compartment = Vol / H (planned 1 m)
= 0,32 m^2

W = 0,40 m

L = 0,80 m

Based on the redesign calculations, the planned design for the communal WWTP on Jalan Sidoyoso Wetan can be seen in Figures 1 and 2.

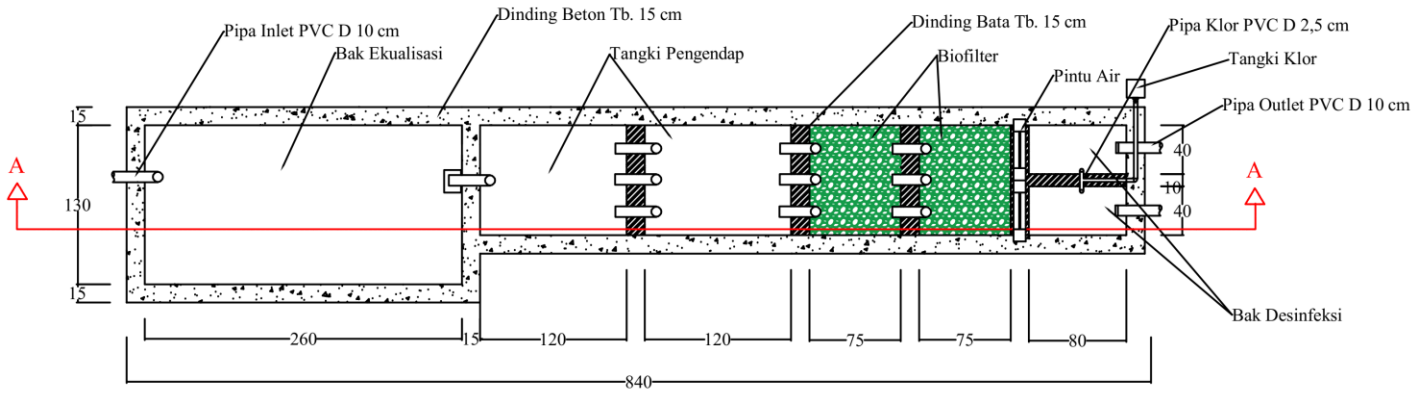

Figure 1: Layout of the Redesigned Communal WWTP 1 on Jalan Sidoyoso Wetan

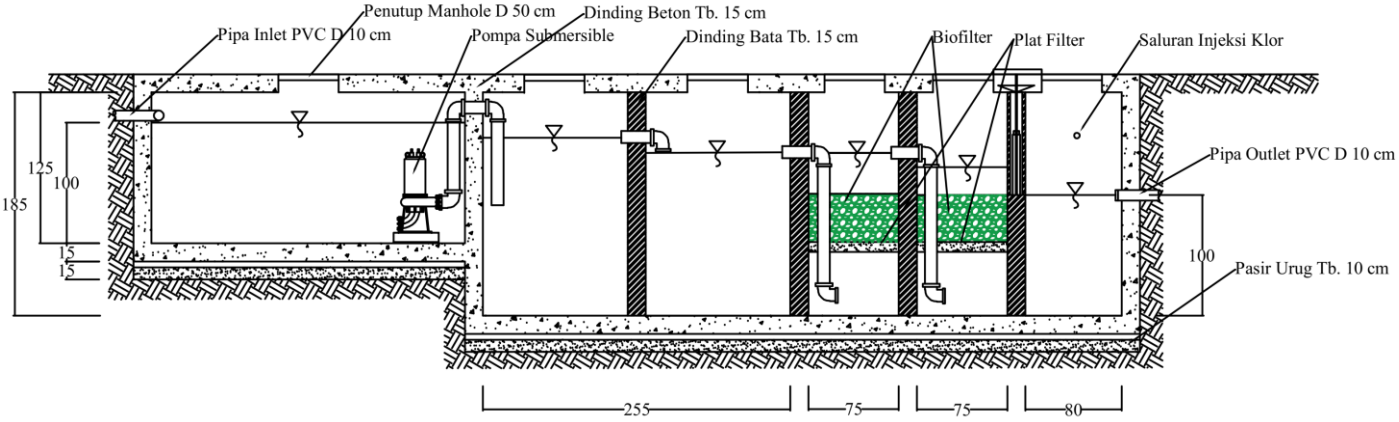

Figure 2: A-A Cut of the Redesigned Communal WWTP 1 on Jalan Sidoyoso Wetan

B. Evaluation and Planning of Communal WWTP in Jalan Granting

The communal WWTP on Jalan Granting was built by PT PJB in collaboration with ITS in 2011 to serve 30-40 households (KK) in the Kelurahan Simokerto area. This WWTP is specifically designed to treat greywater, but it faces several issues:

- Wastewater is still channeled through open ditches integrated with the drainage system, leading to overflows of wastewater into the surrounding environment before it reaches the WWTP, especially during rain.
- The physical structure of the WWTP has many leaks, and the covers used are ineffective in isolating water and air from the outside. This results in increased wastewater flow rates during rain, reducing treatment efficiency due to disruptions in the anaerobic system.
- Excessive wastewater flow can lead to pollution as untreated wastewater may exit the WWTP unit before it is properly treated.

The dimensions of the WWTP on Jalan Granting are detailed in table 6.

Table 6: Dimensions of Communal WWTP on Jalan Granting

Treatment Unit	Lenght (m)	Width (m)	Height (m)	Volume (m^3)
Monitoring Tank	0,30	0,50	0,30	0,05
Sedimentation Tank	0,45	1	1	0,45
Filtration Unit	0,35	1	1	0,35
Biofiltration Unit	1	1	1	1
Storage Tank	0,85	1	1	0,85

From the existing capacity of the WWTP, we can compare it with the current level of service provided and then evaluate its compliance with the design criteria.

Current Service Capacity (30-40 households):

- Wastewater Flow Rate:
  Q_{waste} = q water consumption x number of services x 80%
  = 150 L/person.day x 30 HH x 4 people/HH x 80%
  = 14,40 m^3/day
- Check HRT:
  HRT = 1,80 m^3/ 0,60 m^3/hour
  = 3 hours (**doesn't meet criteria**)
- Check Vup:
  - Filtration unit Vup:
    Vup = Q / Area per compartment
    Vup = 1,70 m/h **(meets criteria)**
  - Biofiltration unit Vup:
    Vup = Q / Area per compartment
    Vup = 0,60 m/h **(meets criteria)**

From the calculations, it is evident that the communal WWTP on Jalan Granting is servicing too many households relative to its building capacity, resulting in a Hydraulic Retention Time (HRT) that does not meet the design criteria. According to the design criteria, the WWTP on Jalan Granting should ideally serve a maximum of 1.80 m^3/day or 3-4 households.

Thus, there are two options to address this issue:

1. **Add More WWTP Units:**
   An additional 10 WWTPs units would be required to meet the current service demand.
2. **Increase Existing WWTP Capacity:**
   This option involves redesigning the WWTP to expand its capacity. In addition, the WWTP would need extra units such as equalization tanks and pumps due to its filtration processes, and a disinfection unit to reduce total coliform levels in the wastewater.

The treatment results from the communal WWTP on Jalan Granting can be seen in table 7.

Table 7: Water quality of Communal WWTP on Jalan Granting Effluent

Parameters	Concentration	Standards	Unit
BOD	5,40	30	mg/L
COD	19,90	100	mg/L
TSS	5	30	mg/L
Oil and Grease	0,20	5	mg/L
Ammonia	0,24	10	mg/L
Total Coliform	19000	3000	colony/100mL

Source: Result of Laboraturium Test, 2024

Calculation of redesign communal WWTP on Jalan Granting:

Equalization Tank Requirements:

Q_{limbah} = 150 L/person.day x 30 KK x 4 people/HH x 80%
= 14,40 m^3/day ~ 0,60 m^3/hour

Vol = Q_{waste} x HRT (planned 1 day)
= 14,40 m^3

As = Vol / H (planned 2 m with fb = 0,25 m)
= 7,20 m^2

W = 2 m

L = 4 m

Actual vol = 2 m x 4 m x 2,25 m
= 18 m^3

WWTP dimensions redesign:

- Sedimentation tank dimension (td = 3 hours)
  Vol = 1,80 m^3
  Vol = A x h (planned 2 m)
  As = 0,90 m^2
  L = 0,95 m ~ 1 m
  W = 0,95 m ~ 1m
  Check v:
  Vs = Q / A
  = 0,00017 m/s
  Vh = Q / (W x H)
  = 0,000083 m/s

  In the design criteria, the condition Vs>Vh:
  0,00017 m/s > 0,000083 m/s **(meets the criteria)**
  Planned
  H *freeboard* = 0,25 m
  Actual H = 2,25 m
  Actual vol = 2,25 m^3

- Filtration Unit Dimension
  Vol = 14,40 m^3
  (planned using 2 compartments)
  Vol per compartment = 7,20 m^3
  Dimension of each compartment:
  Vol = A x h (planned 2 m with fb = 0,35 m)
  As = 3,60 m^2
  (Direncanakan L:W = 2:1)

L = 1,35 m
W = 2,70 m
Actual vol = 2,70 m x 1,35 m x 2,35 m
= 8,57 m^3
Total vol = 17,13 m^3
Check vup:
vup = Q / As per compartment
= 0,17 m/hour (**meets the criteria**)

- Desinfection Unit Dimension

Vol = Q_{waste} x td (planned 3 hours)
= 1,8 m^3
Planned using 2 compartments
Vol per compartment = 0,90 m^3
As per compartment = Vol / h (planned 1 m with 0,4 m *free board*)
= 0,90 m^2
W = 0,70 m
L = 1,40 m

From the redesign calculations that have been done, the planned design for the communal WWTP on Jalan Granting can be seen in Figures 3 and 4.

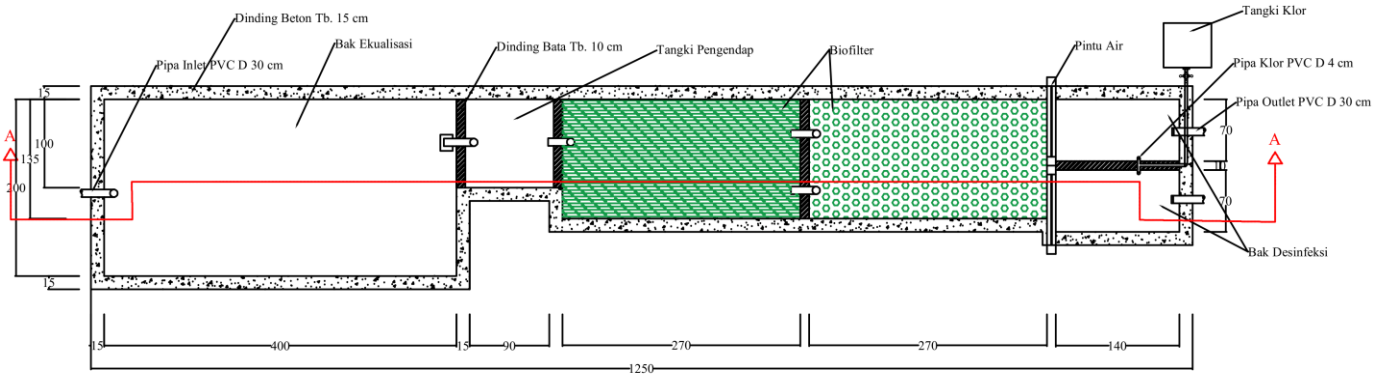

Figure 3: Layout of the Redesigned Communal WWTP on Jalan Granting

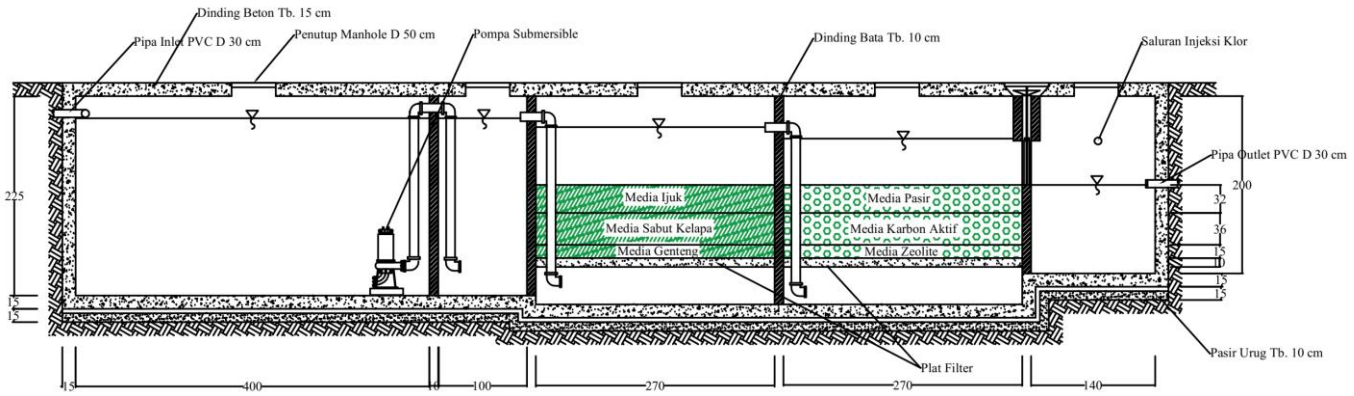

Figure 4: A-A Cut of the Redesigned Communal WWTP on Jalan Granting

IV. CONCLUSION

The communal WWTP on Jalan Sidoyoso Wetan still has the potential to add service for 238 more people. However, it requires redesigning the WWTP by adding equalization tanks, pumps, and a disinfection unit to reduce BOD, COD, and total coliform levels in the wastewater to below domestic wastewater quality standards.

The WWTP on Jalan Granting currently needs repairs for leakage, the creation of a dedicated channel for domestic wastewater, and a redesign to increase the overall dimensions of the WWTP. It also requires the addition of equalization tanks, pumps, and a disinfection unit to ensure optimal operation of the treatment process.

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