Detail Engineering Design (DED) Domestic Wastewater Distribution and Treatment System in Sampangan, Bendan Ngisor, Petompon, Gajahmungkur District

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Abstract. Environmental sanitation is one of the programs in the International Sustainable Development Goals (SDGs) 2030. Semarang Mayor Regulation No. 42 of 2013 on Semarang City Wastewater Masterplan has classified the domestic wastewater management system into two types, off-site and on-site operations. Gajahmungkur district is included in the off-site system. Sampangan, Bendan Ngisor, and Petompon are part of Gajahmungkur district that directly bordered by Kaligarang river. Most residents dispose of greywater into water bodies. This paper aims to present the results of the Detail Engineering Design (DED) domestic wastewater distribution and treatment system. The method of sampling wastewater used SNI 6989: 59: 2008. Based on the results, TSS values 236 mg/L, COD 331 mg/L, and BOD 116 mg/L. This result shows that the domestic wastewater produced is still above the Minister of Environment & Forestry Regulation No. 68 of 2016. The installation of wastewater used for the Gajahmungkur district consists of Grit Chamber, Collecting Wells, Anaerobic Baffled Reactor, Settling Tank, and Chlorination Tank. The type of domestic wastewater distribution system is a shallow sewer. This plan is divided into 11 blocks and serves a population of 20,097 people. The planned budget for the costs required to make this plan is IDR35.016.315.000,00.

1. Introduction

Environmental sanitation is one of the programs contained in the International Sustainable Development Goals (SDGs) 2030. Semarang Mayor Regulation No. 42 of 2013 on Semarang City Wastewater Masterplan has classified the domestic wastewater management system into two types, off-site and on-site operations. Gajahmungkur district is included in the off-site system. Sampangan, Bendan Ngisor, and Petompon are part of Gajahmungkur district that directly bordered by Kaligarang river. Most residents dispose of greywater into water bodies. This paper aims to present the results of the Detail Engineering Design (DED) domestic wastewater distribution and treatment system. The method of sampling wastewater used SNI 6989: 59: 2008. Based on the results, TSS values 236 mg/L, COD 331 mg/L, and BOD 116 mg/L. This result shows that the domestic wastewater produced is still above the Minister of Environment & Forestry Regulation No. 68 of 2016. The installation of wastewater used for the Gajahmungkur district consists of Grit Chamber, Collecting Wells, Anaerobic Baffled Reactor, Settling Tank, and Chlorination Tank. The type of domestic wastewater distribution system is a shallow sewer. This plan is divided into 11 blocks and serves a population of 20,097 people. The planned budget for the costs required to make this plan is IDR35.016.315.000,00.
strategies in the 100% proper sanitation program is to improve facilities and infrastructure for domestic wastewater management through the development of a centralized system of municipal, regional and communal scale domestic wastewater systems.

Semarang Mayor Regulation No. 42 of 2013 concerning about Wastewater Master Plan in Semarang city has planned a domestic wastewater management system divided into two types. There are centralized (off-site) domestic wastewater management and on-site domestic wastewater management. Gajahmungkur district is one of the sub-districts that include the category of centralized system management (off-site). Sampangan, Bendan Ngisor, and Petompon are part of the villages located in Gajahmungkur District. Those villages have a total area of 203.49 hectares and 25,531 population people [1]. Currently, disposal of domestic wastewater in those villages is carried out in two ways, using personal septic tanks and Communal Sewage Treatment Plant of the Semarang City Government through the USRI (Urban Sanitation Rural Infrastructure) community-based settlement sanitation program. There are two USRI communal WWTPs in Sampangan, but only serve 115 households, and there is only one in Bendan Ngisor Village that serves 48 homes. Personal septic tanks in the community generally have a translucent construction that caused contaminate groundwater, construction that not keep to groundwater level, and disposal of faeces or other domestic wastewater directly into the river. Meanwhile, those villages are directly adjacent to the Kaligarang River and Kali Kembang River.

Domestic waste pollution will increase levels of Biochemical Oxygen Demand (BOD), Dissolve Oxygen (DO), Chemical Oxygen Demand (COD), Nitrogen (N) and Kalium (K) in the rivers, increasing the number of Escherichia coli in wells and other residents' water sources that can stimulate the growth of water weeds [2]. This activity causes the oxygen used by all animals or aquatic plants reduced. Wastewater from laundry, bathroom, and kitchen, bathroom wastewater and kitchen wastewater are categorized as waste containing soap and microorganisms. Excreta waste, which is human faeces and urine, is dangerous because it can be the primary medium of spread for water-borne diseases [3]. It is necessary to have a centralized distribution and treatment of domestic wastewater to overcome some of the problems above. Centralized domestic wastewater system can reduce pollution to groundwater and surface water (Kaligarang River) which is expected to improve environmental quality functions and improve environmental quality sanitation facilities in the region.

This paper aims to present the results of the Detail Engineering Design (DED) of the Domestic Wastewater Distribution and Treatment System in Sampangan, Bendan Ngisor, and Petompon Gajahmungkur District. The processing system is reviewed from several suitable alternatives to be applied in the region. The benefit of this plan is to reduce the negative impact of domestic wastewater pollution that percolate into the soil or rivers, which can be a major for spreading disease.

2. Methodology

2.1. Wastewater Sampling Technique

Samples were taken randomly from the drainage channel in Sampangan, Petompon, and Bendan Ngisor, Gajahmungkur District. The waste is greywater & blackwater. Wastewater sampling techniques refer to SNI 6989: 59: 2008 concerning Water and Wastewater - Part 59 Sampling Methods for Wastewater. The steps in sampling include preparing sampling tools according to the drainage channel; rinsing the devices with the sample 3 (three) times; taking the example according to the purpose of the analysis and mix it in a temporary container, then homogeneous; putting it into the box for the analysis purpose; carrying out tests immediately for some parameters: temperature, turbidity, and electrical conductivity, pH and dissolved oxygen which can change quickly and cannot be preserved; field parameter test results are recorded in a special notebook; and sampling for testing parameters in the laboratory is maintained.
3. Result and Discussion

3.1. Site Plan

![Administrative map of Gajahmungkur District](image)

Figure 1. Administrative map of Gajahmungkur District

Topography in Gajahmungkur Subdistrict, especially in Sampangan, Bendan Ngisor, and Petompon are including flat to sheer slopes and only a few steep areas. The average topography in Gajahmungkur District is 2-15% with an average height above 14 meters above sea level. Groundwater in Gajahmungkur District is 10-20 meters above sea level. This planning area is an urban scale, in determining the area that included in this system, it must observe the contours that can flow gravitationally. So, not all areas in the three villages are served. The number of served residents are shown in the Table 1.

| Village     | Number of People | Number of served people |
|-------------|------------------|-------------------------|
| Sampangan   | 10.163           | 10.163                  |
| Bendan Ngisor| 7.621            | 4.889                   |
| Petompon    | 7.749            | 5.045                   |
| **Total**   | **25.533**       | **20.097**              |
3.2. Domestic Wastewater Quantity

Table 2. Q Average, Q Peak, and Q Minimum

|        | Q Average   | Q Peak      | Q Min      |
|--------|-------------|-------------|------------|
|        | 31,67 liter/seconds | 68,51 liter/seconds | 14,63 liter/seconds |

3.3. Domestic Wastewater Quality

The average quality of domestic wastewater in Sampangan, Petompon, and Bendan Ngisor, Gajahmungkur District are:

Table 3. Quality of wastewater in the service area

| Parameters   | Effluents | Environment & Forestry Regulation No. 68 of 2016 |
|--------------|-----------|-------------------------------------------------|
| TSS          | 236 mg/l  | 30                                               |
| BOD          | 331 mg/l  | 30                                               |
| COD          | 116 mg/l  | 100                                              |
| Ammonia      | 14,8 mg/l | 10                                               |
| Total Coliform | 11.800 MPN/1000 mL | 3000 MPN/1000 mL | Not Fulfill |

3.4. Treatment Unit Calculation

3.4.1. Grit Chamber. Grit Chamber is a unit in the wastewater treatment system that functions to separate inorganic solids, especially inorganic waste (discrete particles). Removal of grits from wastewater can be achieved in a grit chamber or with the approval of a solid centrifugal. A grit chamber designed to contain grits, consisting of sand, gravel, charcoal, or other solid material that has a specific velocity or gravity
greater than organic matter in liquid waste. The main chamber is located on the screen bar and before the primary sedimentation tank. Installing a screening facility before the grit room makes operating and adjusting the grit facility easier [4]. Influent in grit chamber are as follows: COD = 331 mg/L; BOD = 116 mg/L; TSS = 236 mg/L.

**Table 4. Design criteria of grit chamber**

| Unit                  | Design Criteria | Design Criteria Selected | Source |
|-----------------------|-----------------|--------------------------|--------|
| Retention time (td)   | seconds         | 45-90                    | 60     | [5]    |
| Horizontal speed (vh) | m/seconds       | 0.25-0.4                 | 0.3    | [5]    |
| Sedimentation speed (vs) | m/minutes   | 1.0-1.3                  | 1.15   | [5]    |

A grit chamber is provided to (1) protect mechanical equipment moving from abrasion and normal wear that accompanies it; (2) reduce the frequency of digester cleansing caused by excessive accumulation of grits. Grit removal is very important to be installed in front of centrifuges, heat exchangers, and high-pressure diaphragm pumps [5]. In a horizontal flow type grit chamber, the flow passes through the chamber in the horizontal direction and the straight line velocity of the flow is controlled by the dimensions of the unit, the gate of the influent distribution, and the weir at the end of the effluent [5].

**Table 5. Dimension and effluent of grit chamber**

| Dimension | Effluent |
|-----------|----------|
| Length    | Width    | Height  | TSS      | COD      | BOD     |
| 4,2 m     | 0,85 m   | 1 m     | 212,4 mg/L | 314,45 mg/L | 110,2 mg/L |

**Table 6. Design criteria for collecting wells**

| Unit                  | Design Criteria | Design Criteria Selected | Source |
|-----------------------|-----------------|--------------------------|--------|
| Retention time (td)   | seconds         | ≤ 10 minutes             | 5 minutes | [7]    |
| Flow speed            | m/seconds       | 0.3 – 3 m/ seconds       | 0.3    | [7]    |

**Table 7. Dimension and effluent of collecting wells**

| Dimension | Effluent |
|-----------|----------|
| Length    | Width    | Height   | TSS      | COD      | BOD     |
| 30 m      | 15 m     | 2,6 m    | 212,4 mg/L | 314,45 mg/L | 110,2 mg/L |

3.4.2. Collecting Wells. The function of collecting wells is to collect wastewater from the bar screen and then pumped it into the next treatment units. The duration of wastewater in the collecting well must be less than 30 minutes to prevent the deposition and decomposition of wastewater [6]. The use of collecting wells in primary treatment is aimed at several things, namely, collecting wastewater from a channel whose depth is below the surface of the treatment plant before the water is pumped upwards. The collection wells can stabilize variations in discharge and concentration of wastewater that will enter the water treatment plant, so there is no shock loading during processing. Influent at collecting wells are as follows: COD = 314.45 mg/L; BOD = 110.2 mg/L; TSS = 212.4 mg/L.
3.4.3. Anaerobic Baffled Reactor. Anaerobic Baffled Reactor (ABR) is a modified sedimentation tank with the function to increasing the removal efficiency of dissolved and non-settling solids [8]. ABR is effective for removing organic material and suspended solids, but it is not effective for removing nitrogen, phosphorus, and pathogenic bacteria [9]. ABR is an anaerobic suspension treatment system, in an insulating bioreactor. ABR consists of a septic tank, and an upright bulkhead installed in a compartment and the flow of water moves up and down from one compartment to another, in this way the wastewater is reconciled with the remaining sludge containing microorganisms that function to decompose pollutants in anaerobic conditions. The ABR design guarantees a longer wastewater stay so that it produces high quality treatment and low levels of sludge produced [10]. The deposition zone at ABR is used to deposit large solids before passing through the next compartment. Water can flow between compartments downward caused by a wall insulation or pipe that leads downward. Prevention of the entry of scum formed in the flow-up flow is done by the outlet of each tank placed slightly below the water level [11].

Each Anaerobic Baffle Reactor compartment will produce gas. In this ABR there are three operational zones: acidification, fermentation, and buffering. The acidification zone occurs in the first compartment where the pH value will decrease due to the formation of volatile fatty acids and after that will increase again due to increased buffer capacity. Zone buffer is used to keep the process running well. Methane gas is produced in the fermentation zone. The more organic load, the higher the processing efficiency. ABR is suitable for application in small environments. In addition for maintenance purposes, the feces truck must be able to enter the location. The Influent in ABR are as follows: TSS = 212.4 mg/L = 0.212 kg/m³; BOD = 110.2 mg/L = 0.110 kg/m³; COD = 314.45 mg/L = 0.315 kg/m³.

| Table 8. Design and effluent of anaerobic baffled reactor |
|----------------------------------------------------------|
| Design | Effluent |
| Number of compartment | 4 + sedimentation tank |
| Q maks each tub m³/hour | (100 – 42,3)% x 110,2 mg/L = 63,59 mg/L |
| Detention time (td) hour | (100 – 68)% x 212,4 mg/L = 67,97 mg/L |
| Up Flow Velocity m³/hour | (100 – 39,9)% x 314,45 mg/L = 188,98 mg/L |

Figure 3. Design of anaerobic baffled reactor
3.4.4. Settling Tank. The shape of the settling tank is a pyramid.

Table 9. Dimension and effluent of settling tank

| Dimension | BOD Ef  | TSS  | COD  |
|-----------|--------|------|------|
| Top Length| 13,5 m | 35,099x35% = 12,28 mg/L | 67,97x65% = 44,18 mg/L | 109,1x32,9% = 35,9 mg/L |
| Width     | 2,38 m | 35,099-12,28mg/L = 22,8 mg/L | 67,97 mg/L - 44,18 mg/L = 23,8 mg/L | 109,1 mg/L - 35,9 mg/L = 73,2 mg/L |
| Height    | 2,2 m  | 149.571 mg / sec |
| Bottom    | 3,38   | 14.8 x 30% = 4,808 | 149.571 mg / sec |
| Length    | 10,5 m | 14.8-4,808 = 9,9 mg/L |

3.4.5. Chlorination Tank. Chlorination by injection is using a dosing pump/infusion chlorinator. The material is chlorine because it has economic advantages and effectively kills microorganisms [12]. Chlorination is a satisfactory way to disinfect water with less severe contamination [13]. Besides being able to eradicate bacteria and microorganisms such as amoeba, algae and others, chlorine can oxidize metal ions such as Fe^{2+}, Mn^{2+} to Fe^{3+} and Mn^{4+}, and break down organic molecules. During the process, the chlorine itself is reduced to chloride ions (Cl-) which have no disinfection power. Chlorine compounds commonly used in drinking water treatment companies are chlorine (Cl₂), Ca (OCl)₂ NaOCl and ClO₂. NaOCl and Ca(OCl)₂ are chlorine compounds that are most often used in water treatment companies [6].

Table 10. Dimension and effluent of chlorination tank

| Dimension | Effluent |
|-----------|----------|
| Length 10.5 m | Width 2 m and depth 3 m with three baffles |
| Height 3 m | = 14.8 x 30% = 4,808 |
| Ammonia remaining after chlorination | = 14.8-4,808 = 9,9 mg/L |
| Need for Chlorine | 149.571 mg / sec |

Figure 4. Site plan of treatment unit
Table 11. Final effluent

| Parameters     | Effluents | Environment & Forestry Regulation No. 68 of 2016 |
|----------------|-----------|-----------------------------------------------|
| TSS            | 23.8 mg/l | 30                                   | Fulfil |
| BOD            | 22.8 mg/l | 30                                 | Fulfil |
| COD            | 73.2 mg/l | 100                                 | Fulfil |
| Ammonia        | 9.9 mg/l  | 10                                  | Fulfil |
| Total Coli     | 0         | 3000                                | Fulfil |

3.4.6. Budget Planning

Table 12. Budget planning

| Work                                      | Cost         |
|-------------------------------------------|--------------|
| Preparation                               | IDR 45.680.250,00 |
| Land excavation                           | IDR 4.608.212,190,00 |
| Dismantles and Pairs                      | IDR 3.444.501,113,00 |
| Processing and Installation of Pipes      | IDR 1.075.272,039,00 |
| Making Manhole                            | IDR 565.469,932,00 |
| Making Carrier Channels                   | IDR 1.861.266,00 |
| Making Bar Screen & Grit Chamber          | IDR 56.671.206,00 |
| Making Anaerobic Baffled Reactor          | IDR 1.371.254,402,00 |
| Making Sedimentation Tank                 | IDR 591.654,473,00 |
| Making Chlorination Tank                  | IDR 178.088,690,00 |
| Making Wet Well and Pump House            | IDR 1.662.691,807,00 |
| Making Grease Trap and Control Board      | IDR 9.825.788,930,00 |
| Making Home Connection Pipe               | IDR 8.254.050,752,00 |
| Making Security Pos                       | IDR 92.027,948,00 |
| Making Rail and Road                      | IDR 59.788,577,00 |
| Total                                     | IDR 31.833.013.558,00 |
| Tax 10%                                   | IDR 3.183.301,355,00 |
| Total + Tax 10%                           | IDR 35.016.314,914,00 |

4. Conclusion

The results of this plan detail engineering design of wastewater distribution system and wastewater treatment plant (WWTP). The system implemented in the distribution of wastewater is the shallow sewer system. The service area is 201 hectares, and this system will serve 20,097 people or 79% of the population in the Sampangan, Bendan Ngisor, and Petompon. Units in wastewater treatment plants are grit chamber, collection well, anaerobic baffled reactor, settling tank and chlorination tank. The final effluent of TSS is 23.8 mg/l, BOD 22.8 mg/l, COD 73.2 mg/l, Ammonia 9.9 mg/l, and Total Coli is 0. The cost required for the construction of domestic sewage and wastewater treatment system is IDR 35,016,315,000.
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