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RESEARCH PAPER

The strategy of domestic wastewater management in Kenjeran Surabaya

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Abstract. Kenjeran is one of the districts in Surabaya with high-risk sanitation based on EHRA Surabaya 2012. Kenjeran has 4 (four) sub-districts that consists of Bulak Banteng, Tanah Kali Kedinding, Sidotopo Wetan, and Tambak Wedi. Bulak Banteng, Tanah Kali Kedinding, and Tambak Wedi have been identified as the areas in which open defecation still happened. The research is descriptive study by using field survey, interview, and comparison of existing condition with standards and regulations. The technical aspect study is conducted by analyzing the needs of wastewater infrastructure facilities based on the volume of domestic wastewater. 80 (eighty) Communal Sewage Treatment Plant (STP) were designed to solve domestic wastewater handling in 4 (four) sub-districts. Each of 80 (eighty) STP was designed to cover 75 – 100 households. The domestic wastewater treatment used Anaerobic Baffled Reactor Technology. An example of STP design was conducted in Dukuh Bulak Banteng with the coverage of 100 households.

Keywords: Domestic Wastewater; Anaerobic Baffle Reactor

1. Introduction

The Government of Indonesia will enter the new National Medium Term Development Plan (*Rencana Pembangunan Jangka Menengah National*, RPJMN) 2015-2019 which sets a new target of universal access to accessible sanitation by the end of 2019 in the form of 100% fulfillment of clean water, 0% slum area and 100% sanitation access. In an effort to achieve these targets it is felt the importance of having a sustainable sanitation strategy.

Surabaya as a Metropolis which is also the capital of East Java province consists of 31 districts that have a population of 2,977,520 inhabitants (BPS, 2015). Kenjeran is one of the districts in Surabaya with high risk sanitation. Kenjeran has four sub-districts that have been identified as the areas in which open defecation still happened.

The development of wastewater infrastructure and education of sanitation for public is one of the efforts to manage the wastewater treatment in Kenjeran. These developments

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will have a good impact in public health. This research will identify suitable strategies for domestic wastewater management in Kenjeran. The analysis of domestic wastewater management strategies is assessed on the technical aspect.

2. Review of the literature

2.1. Domestic wastewater management system

The wastewater treatment system according to Tchobanoglous (1981) consists of collecting, transmission, and treatment systems. Domestic wastewater management system can be done by onsite system and offsite system. Influencing factors that affect the wastewater management are demography and technical handling.

The population density levels commonly used in wastewater systems management are high density less than 300 persons/ha, medium density of 100 -300 persons/ha, low density less than 100 persons/ha. Population density more than 300 persons/ha use the septic tanks with absorption well that potentially cause contamination of pathogenic bacteria on soil and ground water. The communal wastewater system management is more economical and efficient in the coverage of densely populated areas. In general, the strategy directions of handling wastewater management system are as follows:

- The amount of BOD parameter in wastewater must be lower
- Selection of densely populated areas that need to be applied with wastewater management system
- Determining the scale of treatment based on economic considerations and specifying the type of wastewater management system to be used for densely populated areas.

Meanwhile, the technical handling of waste water was intended for building inlet, outlet process meet the essence of health includes the distance of the septic tank infiltration field with the source of drinking water shall be maintained with a distance more than 10 meters for clay type and more than 15 meters for sand soil; the density of 100 people/ha using individual septic tank may affect contamination coli bacteria on soil and ground water. Thus, for individual sanitary users in the area of such density, the application of anaerobic filters in lieu of the infiltration field and its effluents may be discharged into open channels, or communal using off site sanitation systems.

2.2. Domestic wastewater treatment technology

Septic tank

The SNI 03-2398-2002 about the procedure of septic tank planning with recharge system is as follows. First, building materials must be strong. Second, it has to be resistant to acid and waterproof. Third, building materials that can be selected for basic building, cover and sewage pipes are stone, red brick, brick, ordinary concrete, reinforced concrete, asbestos cement, PVC, ceramic and iron plate. Fourth, length ratio (P) and width (L), (2-3: 1), with minimum width of 0.75 meters, minimum length of 1.5 meters, tank height of at least 1-5 meters including 0.3 meters threshold. Septic tanks also require sufficient land from water sources to avoid water source contamination. The distance of the catchment system to the water source is more than 10 meters.

Anaerobic baffled reactor

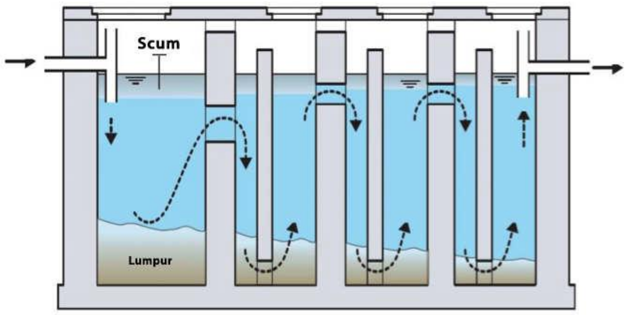
Anaerobic baffled reactor (ABR) is a modified septic tank technology by adding several compartments to generate up flow through anaerobic sludge and increase the contact time between active biomass and wastewater. The advantages using ABR are it is able to treat high organic load wastewater, it has easy operation and maintenance and also produces biogas that can be utilized as an energy source.

The design of ABR based on the following design criteria and technical requirements are available land for ABR where it is easy to construction, operate and maintain, can be used on communal scale and ABR used as preliminary treatment if the concentration of BOD more than 300 mg/liters.

Table 1. Design Criteria ABR

Parameter	Criteria
Velocity	< 2 m/hour
Removal COD	65 – 90 %
Removal BOD	70 – 95 %
Organic Loading	< 3 kg COD/m^2.day
Hydraulic Retention Time	6 – 20 hours
Organic Loading Rate	0,1 – 8 kg COD/m^2.day

Figure 1. Typical ABR Reactor



Sewerage system

Based on sewerage design criteria (MPUPR, 2017), there are 3 types of sewerage, i.e. small bore sewer, shallow bore sewer, and conventional sewer.

Small bore sewer

Small Bore Sewer is suitable for areas with medium to high density (more than 200 person/ha), especially for the areas that have been using septic tank but the surrounding soil is no longer able to absorb the effluent from septic tank. The components of small bore sewer consists of household, septic tank, sewer, manhole, and pumping (if needed). The standard criteria of small bore sewer are minimum pipe diameter is of 100 mm, maximum velocity in pipe is of 3 m/sec, and only receives effluent from septic tank and grey water, the existence of septic tank should be maintained.

Shallow bore sewer

Shallow Bore Sewer is considered for the areas with high density and large populations that already have water supply. These system covers domestic wastewater that served by lateral pipe, service pipe and sewage treatment plant. The criteria of shallow bore sewer are used for high density population (more than 200 person/ha) in order to have sufficient volume of water for self-cleansing, suitable serve in low income areas, already have wastewater connections and should not have septic tank, the pipe diameter is of minimum 150 mm, minimum velocity is of 0.5 m/second and maximum velocity is of 3 m/second and the minimum depth pipeline is of 0.4 meter.

Conventional sewer

A conventional gravity sewer system is used to collect wastewater from multiple sources and covey by gravity the wastewater to a treatment plant or other authorized point of discharge. The sewer pipelines are designed so that the slope and size of the pipe is adequate to maintain flow without surcharging manholes or pressurizing the pipe. The collection sewer pipelines are typically eight-inch or larger in diameter Pipes are installed with sufficient slope to keep the suspended solids moving through the system. If gravity flow is not possible throughout the system, lift stations are installed at lower elevations of the network in order to pump the sewage up to another gravity pipeline. Manholes are installed at regular intervals to provide maintenance access.

Proper maintenance includes periodic line repairs and inspection, cleaning out blockages, and repairing areas where significant infiltration is occurring. Gravity sewers in cluster or small community systems do not include septic tanks for primary treatment on each lot. Thus, the central treatment facility must provide primary treatment.

3. Result and discussion

Most of the land used in Kenjeran sub-district based on regulations Regional Regulation of Surabaya Spatial Plan in 2014-2034 is a settlement land. The available land is now limited due to the already built residential area and trade and services building.

Table 2. Population density based on building density in Kenjeran Surabaya

Sub-district	Area (km^2)	Population	Population density (people/ha)
Tanah Kali Kedinding	2.41	52,678	219
Sidotopo Wetan	1.66	56,325	340
Bulak Banteng	2.67	30,660	115
Tambak Wedi	0.98	14,328	147

Table 3. Population of Kenjeran, Surabaya residents in 2013-2016 (BPS, 2015; 2016)

Year	Population
2016	153,991
2015	147,692
2014	158,554
2013	151.,933

The source of domestic wastewater

Fecal sludge

Based on standard criteria of the Ministry of Public Work (DPU, 2006), the range of fecal sludge amount from Water Closet into septic tank are between five to forty liters/person/day. The amount of mix black water and grey water range is 45 – 150 liters/person/day. The calculation of fecal sludge is:

$$Q = \textit{Population people of Kenjeran in 2017} \times \textit{the amount of fecal sludge} \qquad (1)$$

Volume of fecal sludge and total mass of fecal sludge in each sub-district of Kenjeran are shown in Table 4.

Table 4. The volume and mass of fecal sludge

Sub district	Population (capita)	Volume Fecal Sludge (m3/day)	Total Amount of fecal sludge (ton/day)
Tanah Kali Kedinding	52,678	263,390	9
Sidotopo Wetan	56,325	281,625	10
Bulak Banteng	30,660	153,300	5
Tambak Wedi	14,328	71,640	3
Total	153,991	769,955	28

Grey water

The population of Kenjeran was multiplied by the consumption of fresh water, i.e. 150 liters/person/day. The wastewater discharge was 70% of the water consumption. The calculation of volume of grey water in Kenjeran is following the equation (2) and the results are shown in Table 5.

$$\textit{Debit Domestic Wastewater} = \textit{the population} \times \textit{consumption water} \times 70\% \qquad (2)$$

Table 5. Domestic wastewater debit

Sub-district	Population (capita)	Water Consumption (150 liters/capita/day)	Debit wastewater, (m3/day)
Tanah Kali Kedinding	52,678	7,902	5,531
Sidotopo Wetan	56,325	8,449	5,914
Bulak Banteng	30,660	4,599	3,219
Tambak Wedi	14,328	2,149	1,504
Total	153,991	23,098	16,169

The coverage of communal sewage treatment plant

Based on technical criteria in regulation Ministry of Public Work number 47 year 2015, the range of offsite system of domestic wastewater management could be served between 50 persons until 1000 persons. The location that can be built for Communal STP is considered technical criteria that consist of the coverage Communal STP to serve minimum 50 households, the available land to build Communal STP, the availability of water bodies to receive effluent Communal STP, easy to operation and maintain communal STP and the resident that has risk sanitation domestic wastewater to prevent water pollution.

Eighty communal STP were designed to solve domestic wastewater handling in 4 (four) sub district. Each of 80 (eighty) STP designed to cover 75–100 households. The total of communal STP were planned in Kenjeran consists of 21 point locations STP in Tambak Wedi, 19 point locations STP in Bulak Banteng, 20 point locations STP in Sidotopo Wetan, 20 point locations in Tanah Kali Kedinding. Each of coverage service of STP was planned to serve one block of residential that considered build STP by underground street, high density population and easy to maintenance STP.

The selection of communal sewage treatment technology

Alternative IPAL technology will be done with the comparison of advantages and disadvantages and provide scores on each criterion are required. The highest score will indicate that the description can be applied shown in Table 6. Scoring in technology selection are score 3 (applicable), score 2 (can be applicable with conditions), and score 1 (can't be applied).

Based on the highest score of STP technology options in Table 7, the selected technology is anaerobic baffle reactor (ABR) with land considerations, low maintenance cost requirements, easy operation, and good effluent.

Table 6. Alternative Selection STP Technology

Description	Alternative 1		Alternative 2		Alternative 3	
	Bio filter	Score	Anaerobic baffle reactor	Score	Wetland	score
Land	Can be build underground	2	Can be build underground	3	Need a large enough land	1
Operational & Maintenance	Need routine to clean filter. Low cost of maintenance	2	Easy to operate , low cost of maintenance	3	Easy to operate , low cost of maintenance	3
Construction	Material Plant from concrete, material is easy to get	2	Material Plant from concrete, material is easy to get	3	Material Plant from concrete, material is easy to get	3
The need of Operator	No need professional	2	No need professional	3	No need professional	3
Community Participate	Can participate fully	2	Can participate fully	3	Can participate fully	3
The Effluent STP	Good	2	Good	3	Good	3
Total		17		18		16

Planning sewage treatment plant in Bulak Banteng, Kenjeran

Dukuh Bulak Banteng settlement which is located near to Kali Tebu is one of the areas that open defecation still happened. Based on survey result that there are 100 (one hundred) houses where only have a latrines but the pipeline directly into Kali Tebu Bulak Banteng. These location has topography relatively flat with elevation between 3 masl and 4.5 masl. The land for construction STP was in an underground street next to drainage channel. The location STP planned could be shown in Figure 2.

Notes: location STP

service coverage

Figure 2. Planning location of STP in Dukuh Bulak Banteng

ABR designed into several compartments where each compartment has the same length as one another. It aims to make stable flow and prevent the existence of excessive turbulence in each compartment. The calculation of mass balance is required to show result of effluent STP. The result STP can be shown in Table 7.

Table 7. Treatment process in ABR

Parameter	Efficiency ABR (%)	Influence ABR (mg/L)	Effluent ABR (mg/L)	Standards of Domestic Wastewater * (mg/L)
BOD	93	142	10	30
COD	91	235	23.5	50
TSS	80	140	4.2	50

Noted *: Regulation in East Java Governor Regulation Number 72 Year 2013

Table 7 describes that concentration of BOD, COD and TSS after treatment through ABR and the effluent ABR was allowed to be discharged into river.

Determination of sewerage

The sewerage considers the current conditions at the site of planning, especially the characteristic of the ground elevation. The sewerage in settlements strength Kali Tebu using a small piping connected to the wastewater treatment plant. Sewerage through the collecting pipe to the next carrier pipe will go to the STP then the effluent of STP flowed into the river. The dimension of the collecting pipe is 4 inches (10 cm) in diameter and the carrier pipe is 6 inches (15 cm) in diameter. While the slope (Slope) used is 0.6 %. The result calculation of sewerage in Dukuh Bulak Banteng could be shown in Table 8.

Table 8. The result calculation diameter pipe domestic wastewater

Pipe	Coefficient	d/D	Qpeak/ Qfull	Qfull (m^3/sec)	Slope	Diameter (cm)	Diameter used	
							inch	Cm
A- B	0.013	0.8	0.85	0.00077	0.006	5.59	6	15.24
B-C	0.013	0.8	0.85	0.00143	0.006	7.04	6	15.24
C-D	0.013	0.8	0.85	0.00220	0.006	8.27	6	15.24
D-IPAL	0.013	0.8	0.85	0.00281	0.006	9.07	6	15.24

Determination of design ABR

Designed STP with coverage of 100 home connections serving a population of 480 people. Based on the data of PDAM Kota Surabaya (2016), the average consumption of Surabaya residents' water reaches 150 – 190 liters/person/day. The volume of domestic waste water generated is 70% of water consumption. The following is the calculation of wastewater treatment buildings:

Household = 100 HH
Population = 100 KK x 4 capita/HH = 400 HH
Water consumption = 150 liter/capita/day
Wastewater Percentage = 70 %
Wastewater flows = 150 liter/capita/day x 400 capita x 0.7
= 42 m^3/day
= 1.75 m^3/hour

Design Compartment

Design Criteria ABR (Sasse, 2009)
Velocity = < 2 m/hour, Used 1.8 m/hour
Detention time (Td) = ≥ 6 hours, Used 10 hours
Depth of compartment = 2.5 meters
Length of compartment = 50% until 60% depth, used 50%
Area of each compartment = 1 m^2
Length of compartment = 1.25 meter
Width of compartment = 1.5 meter

The calculation compartment

Freeboard	= 0.3 m
Volume each compartment	= 5.3 meter
Total volume ABR	= 23.25 m^3
The amount of compartment	= 4 compartments
Check organic loading rate	= 0.28 kg COD/m^3 day-

Total dimension anaerobic baffled reactor

Length = 1.25 m x 4 compartments = 6 meter
Width = 1.5 meter
Depth = 2.5 m + 0.3 m = 2.8 m

Dimension settler anaerobic baffle reactor

Depth	= 2.5 m
Width	= 1.5 m
Detention time at settler	= 3 jam
Sludge volume	= 4 m^3
Wastewater volume	= 10.5 m^3
Total volume	= 14.5 m^3
Length	= 4 m

Calculation collection chamber

Design criteria collection chamber

Detention time	= 10 minutes
Amount	= 1 (one) unit
Flow	= 3.5 m^3/hour = 0.06 m^3/minute
Depth	= 1 m
Area of compartment	= 0.6 m^2
Length: width ratio	= 1: 1
	= 0.8 m
Volume	= 0.6 m^3

Calculation Pump

- Debit (Q) : 1 l/seconds
- Pipe : 1 unit
- Velocity : 1.25 m/Sec
- Elevation : 3.8 m
- Pump : Submersible Pump
- Length of pipe : 3.7 m
- C pipe PVC : 120

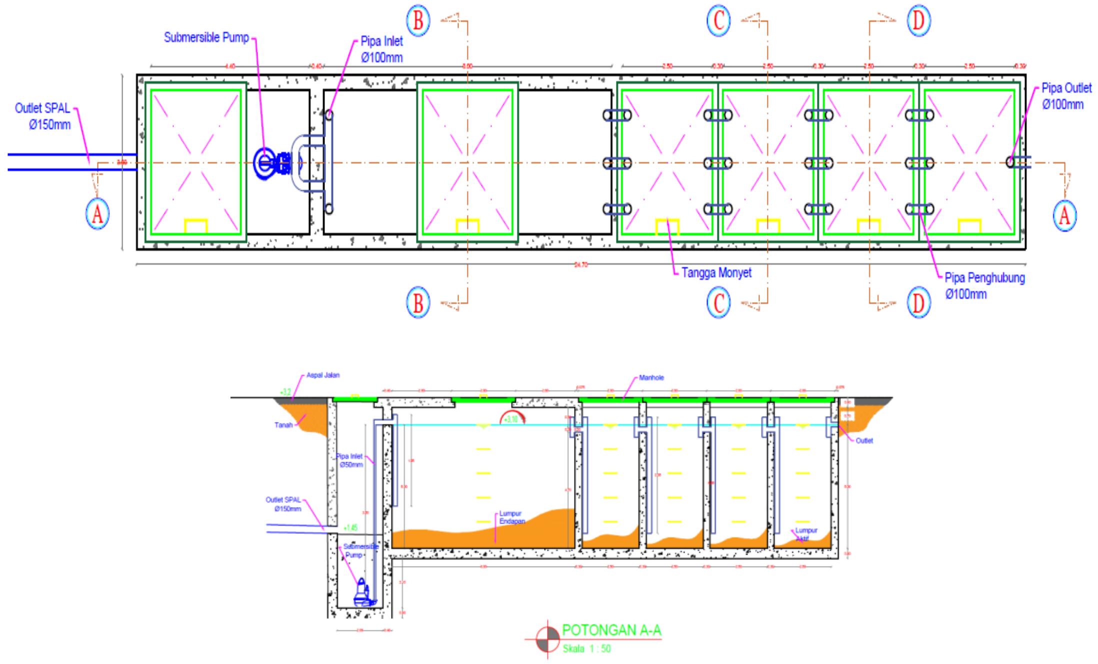


Figure 3. Layout anaerobic baffle reactor

4. Conclusion

After analyzing the data, the researchers conclude that 80 (eighty) Communal Sewage Treatment Plant (STP) were designed to solve domestic wastewater handling in 4 (four) sub district. Each of 80 (eighty) STP was designed to cover 75 – 100 households. The domestic wastewater treatment plant was designed using Anaerobic Baffled Reactor Technology.

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