

# Redesign of Anaerobic-Aerobic Biofilter for Domestic Wastewater Treatment Plant In Textile Industry

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**Abstract.** One of the textile industries in Pasuruan already has a Domestic Wastewater Treatment Plant (WWTP) with a capacity of 35 m<sup>3</sup>/day. The treatment process combined physical, chemical, and biological processes using an anaerobic-aerobic biofilter. The domestic WWTP consists of a collection tank, equalization tank, anaerobic-aerobic biofilter tank, a filtration tank, and a chlorination tank. Existing conditions indicate that the domestic wastewater generated exceeds the capacity of the WWTP. Additional employees become one of the factors causing the increase in domestic wastewater discharge. Inadequate capacity has forced the company to bypass domestic waste into rivers. This biofilter was chosen because it could reduce high BOD values, have low operating costs, and operate efficiently. The anaerobic-aerobic biofilter reactor consists of a pre-settling tank, anaerobic tank, aerobic tank, and final settling tank. The evaluation results denoted that detention time in pre-settling, anaerobic, and settling units did not meet the design criteria. Thus, changing the design according to the design criteria. The redesign result of the anaerobic biofilter includes the pre-settling tank with a diameter of 2,5 m and a length of 3 m, an anaerobic tank with a diameter of 2,5 m and a length of 15 m, so that the total volume in the anaerobic reactor is 88.3 m<sup>3</sup>. Then anaerobic bath with a diameter of 2,5 m and a length of 6 m and a final settling tank with a diameter of 2,5 m and a length of 1,5 m so that the total volume in the aerobic biofilter reactor is 36,7 m<sup>3</sup>.

**Keywords:** domestic wastewater, anaerobic-aerobic biofilter, domestic WWTP redesign

**Article history:** Received: xxx; Revised: xxxx; Accepted: xxx; Available online: xxx (6 pt)

**How to cite this article:** Family name, A.B., Family Name, C.D., and Family name, E. (year) Title of Manuscript. Journal of Civil Engineering, Planning, and Design, x(x), xxx-xxx. (6 pt)

<https://doi.org/10.19907/jcepd.x.x.xxx-xxx>

## 1. Introduction

Domestic wastewater is wastewater generated from daily human activities related to water use. Domestic wastewater is wastewater generated from household or industrial activities that have the potential to pollute water bodies and the environment [1]. This pollution is caused by the content of organic compounds, chemical compounds and pathogenic organisms in domestic wastewater [2]. The content of organic matter and fat can be a place for the growth of microorganisms, causing odor [3]. Domestic wastewater is grouped into two types: water and gray water. Blackwater comes from human waste, including waste from toilets or septic tanks. Meanwhile, gray water is produced from kitchen water waste containing oil and food residue and water from bathing and washing with soap and detergent [4]. Domestic wastewater must be treated to not pollute the environment and endanger the health of living things [5].

PT. X is a textile company with 1.755 employees. With a large number of employees, the higher the domestic wastewater produced so that PT. X has to require domestic WWTP so that in 2020 the construction of a domestic WWTP with a capacity of 35 m<sup>3</sup>/day. A domestic WWTP or domestic sewage treatment plant is a facility to treat wastewater generated from household activities or daily human activities [6]. However, WWTP development planning was carried out improperly. The addition of employees caused the amount of wastewater produced to exceed the installed domestic WWTP capacity, so wastewater treatment could be carried out non-optimally. It is evidenced by the high value of Total Coliform from treated wastewater. The coliform bacteria in waters allow for entering pathogenic and taxi genetic microorganisms that can affect the health of aquatic biota and even humans [7]. Coliform bacteria can cause digestive disorders and various diseases such as diarrhea, acute kidney failure, and meningitis in humans [8]. Therefore, it is necessary to make improvements to prevent environmental pollution by evaluating and redesigning Domestic WWTP following the amount of wastewater produced.

## 2. Research Method

This study was conducted at PT. X, which is located in Pasuruan Regency. The evaluation was carried out by testing the quality of domestic wastewater at the Graha Mutu Persada Laboratory with a sampling method that refers to SNI 6989.59:2008 method grab sampling at 4 points including the inlet, equalization tank, aerobic-anaerobic biofilter reactor and outlet. The wastewater quality test includes pollutant parameters such as pH, BOD, COD, TSS, Ammonia, Oil fat, and total coliform. After the wastewater quality test was carried out, an evaluation was carried out by calculating the removal efficiency of each unit compared to the design criteria of each Domestic WWTP unit for further calculations. Detailed Engineering Design for the aerobic anaerobic biofilter unit

## 3. Result

Domestic wastewater discharge was carried out by recording the value flowmeter installed at the inlet, and the outlet of the domestic WWTP value flowmeter was recorded by the officer at 07.00 A.M. every day. Based on the recording results, the average domestic wastewater discharge at PT. X is 62,7 m<sup>3</sup>.

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### Results of Analysis of the Wastewater Quality

Results of analysis of the quality of domestic wastewater at PT. X can be denoted in the following table :

**Table 1.** Results of Domestic Wastewater Quality Analysis at PT. X

Parameter	Quality Standard	Unit	Average	Remark
pH	6 - 9	-	7,6	Comply
BOD	30	mg/L	16,2	Comply
COD	100	mg/L	46,1	Comply
TSS	30	mg/L	1,8	Comply
Ammonia	5	mg/L	2,1	Comply
Oil and Grease	10	mg/L	1,7	Comply
Total Coliform	3000	Amount/100mL	8.440	Not Comply

(Source: Primary Data, 2021)

Based on the table, it can be analyzed that all parameters have met the quality standards based on Minister of Environment and Forestry Regulation No. P. 68 of 2016, except for the total coliform parameter

### WTP Unit Performance

An evaluation was carried out by calculating the Eligibility Efficiency of each WWTP unit with the following results:

**Table 2.** Provisioning Efficiency Results

No	Unit	Removal Efficiency (%)		
		BOD	COD	TSS
1	Equalization tank	62 %	64 %	45 %
2	Aerobic anaerobic biofilter	40,5 %	16 %	23 %
3	Filtration and disinfection	26 %	32 %	82 %

(Source: Primary Data, 2021)

Based on the calculation results, it can be analyzed that the efficiency of removing organic pollutants in the collector and equalization tanks is quite high because the residence time in the collection tank is quite long. While the efficiency of the anaerobic-aerobic tub based on the calculation results is less effective than research conducted by Nasution (2008), the anaerobic-aerobic tub has an efficiency of 75-95% BOD removal, 80-85% COD, and 50-65% TSS [9]. Due to the short residence time, the process of decomposition of organic matter by microorganisms does not take place optimally. It is in line with the research conducted by Said (2006) [10]. Another influential factor is the absence of maintenance/cleaning in the aerobic-anaerobic reactor. Although the removal efficiency is insufficient, the results of the analysis of the quality of domestic wastewater for parameters BOD, COD, and TSS meet the government's quality standards. It is related to the content of organic matter in wastewater which is not too high. The cause of the low organic pollutants in domestic wastewater at PT. X includes a lot of wastewater that overflows and does not enter the treatment system, as well as the habit of employees in using excessive clean water

### Redesign of Anaerobic

An anaerobic-aerobic biofilter is a biological treatment process with an inherent growth in which microorganisms were developed in a medium. This unit consists of several compartments, including an pre-settling tank to precipitate wastewater particles, an anaerobic tank to decompose wastewater with microorganisms, anaerobic tank to decompose wastewater with microorganisms with the help of aeration, and a final settling tank. The following is the result of the calculation of the performance analysis of the aerobic-anaerobic biofilter reactor in each compartment

#### Pre-settling Tank

Existing volume = 1,3 m<sup>3</sup>.

Diameter = 2,5 m

Water level = 2 m

Reactor length = 0,3 m

Check Td = Volume/Qave

= 1,3 m<sup>3</sup>/ 2,6 m<sup>3</sup> /hour

= 0,5 hours

Based on the calculation of the volume of the initial settling basin not following the design criteria, namely 3 -5 hours. In short, the residence time in the settling basin causes the TSS value to be greater than the equalization tank, so it is necessary to redesign it with the following calculations:

$$\begin{aligned}\text{Volume} &= Q \times t_d \\ &= 2,6 \text{ m}^3/\text{hour} \times 4,5 \text{ hour} \\ &= 11,7 \text{ m}^3 \\ \text{Planned that D} &= 2,5 \text{ m with } 0,5 \text{ m freeboard so that} \\ V_{(\text{freeboard})} &= 0,2 \times V_{\text{total tub}} \\ &= 0,2 \times 11,7 = 2,34 \text{ m}^3 \\ V_{\text{total body}} &= V_{\text{total}} + V_{\text{freeboard}} \\ &= 11,7 \text{ m}^3 + 2,34 \text{ m}^3 \\ &= 14,04 \text{ m}^3 \\ V &= r^2 t = 3,14 \times (1,25 \text{ m})^2 \\ 14,04 \text{ m} &= 4,9 \text{ t} \\ T &= 2,8 \text{ m}\end{aligned}$$

So the dimensions of the settling basin are planned with a diameter of 2,5 m, a length 3 m with 2 m depth and 0,5 m freeboard.

### Anaerobic Tank

Known :

$$\begin{aligned}\text{Existing volume} &= 1,47 \text{ m}^3 \\ \text{Diameter} &= 2,5 \text{ m} \\ \text{Water level} &= 2 \text{ m}\end{aligned}$$

$$\text{Check } t_d = \frac{1,47}{62,6} \times 24 = 0,55 \text{ m}^3/\text{hour} .$$

Based on the check results, the  $T_d$  does not match the design criteria, namely 24-48 hours. So it is necessary to redesign with the following calculations:

$$\begin{aligned}\text{BOD load} &= Q \times \text{BOD in} \\ &= 62,2 \text{ m}^3/\text{day} \times 0,37 \text{ kg} / \text{m}^3 \\ &= 23 \text{ kg/day}\end{aligned}$$

In this plan, the BOD load used is 0,6 kg BOD/ $\text{m}^3 \cdot \text{hr}$ .

$$\text{Media Volume} = 23 \text{ kg}/\text{m}^3 / 0,6 \text{ kg BOD}/\text{m}^3 \cdot \text{hr} = 38,3 \text{ m}^3$$

It is determined that the media volume is 60% of the total reactor volume so that the reactor volume is

$$\begin{aligned}\text{Reactor volume} &= 100/60 \times 38,3 \text{ m}^3 \\ &= 64 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Check } T_d &= V/Q \\ &= 64 \text{ m}^3 / 2,6 \text{ m}^3/\text{hour} = 25 \text{ hours}\end{aligned}$$

(Design criteria 24 - 48 hours)

Planned :

$$D = 2,5 \text{ m with } 0,5 \text{ freeboard so}$$

$$\begin{aligned}V_{\text{freeboard}} &= 0,2 \times V_{\text{total body}} \\ &= 0,2 \times 64 = 12,8 \text{ m}^3\end{aligned}$$

$$\begin{aligned}V_{\text{total body}} &= V_{\text{bak}} + V_{\text{freeboard}} \\ &= 64 \text{ m}^3 + 12,8 \text{ m}^3 = 76,8 \text{ m}^3\end{aligned}$$

$$\begin{aligned}V &= \pi r^2 L = 3,14 \times (1,25 \text{ m})^2 \times L \\ 76,8 \text{ m}^3 &= 4,9 L\end{aligned}$$

$$L = 15 \text{ m}$$

### Load per volume of media

$$\begin{aligned}\text{Load/vol} &= \text{Load BOD} / V_{\text{media}} \\ &= 23 \text{ kg/day} / 38 \text{ m}^3 \\ &= 0,6 \text{ kg.BOD}/\text{m}^2 \cdot \text{day (OK)}\end{aligned}$$

(Standard load of BOD per volume of media = 0,4 - 4,7 kg.BOD/ $\text{m}^3 \cdot \text{day}$ , [10])

So the dimensions of the tub are planned anaerobic with a diameter of 2,5 m, a length of 15 m with a depth of 2 m and a freeboard of 0,5 m.

### Aerobic Tank

Known :

$$\begin{aligned}\text{BOD in} &= 367,8 \text{ mg/l} \\ \text{Volume ex} &= 17 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Check Td} &= \text{Volume}/Q \\ &= 17 \text{ m}^3 / 2,6 \text{ m}^3/\text{hour} \\ &= 6,5 \text{ hours}\end{aligned}$$

Based on the results of the calculation of the volume of the aerobic tub, it is following the design criteria, which is 6-8 hours

$$\begin{aligned}\text{BOD Load} &= Q \times \text{BOD in} \\ &= 62,4 \text{ m}^3/\text{day} \times 0,7 \text{ kg}/\text{m}^3 \\ &= 23 \text{ kg}/\text{day}\end{aligned}$$

In this plan, the BOD load used is 2 kg BOD/m<sup>3</sup>.hour.

**Media Volume** = BOD load/Load per media Volume

$$\begin{aligned}&= 23 \text{ kg}/\text{day} / 2 \text{ kg}/\text{m}^3.\text{day} \\ &= 11,5 \text{ m}^3\end{aligned}$$

It is determined that the media volume is 50% of the total reactor volume so that the reactor volume is equal to the reactor

$$\text{Volume} = 100/50 \times 11,5 \text{ m}^3 = 23 \text{ m}^3$$

$$\begin{aligned}\text{Check Td} &= V/Q \\ &= 23 \text{ m}^3 / 2,6 \text{ m}^3/\text{hour} \\ &= 8 \text{ hours}\end{aligned}$$

(Design criteria 6 - 8 hours Vtotal meet)

$$V_{\text{freeboard tub}} = 0,2 \times 23 = 4,6 \text{ m}^3$$

$$\begin{aligned}V_{\text{total body}} &= V_{\text{total}} + V_{\text{freeboard}} \\ &= 23 \text{ m}^3 + 4,6 \text{ m}^3 = 27,6 \text{ m}^3\end{aligned}$$

Planned :

$$D = 2,5 \text{ m with } 0,5 \text{ freeboard so that}$$

$$V = \pi r^2 L = 3,14 \times (1,25 \text{ m})^2 \times L$$

$$27,6 \text{ m}^3 = 5,6 L$$

$$L = 5,6 \text{ m}$$

**Load per media volume**

$$\begin{aligned}\text{Load/ volume} &= \text{BOD load} / \text{Media volume} \\ &= 23 \text{ kg}/\text{day} / 14,4 \text{ m}^2 \\ &= 1,6 \text{ kg.BOD}/\text{m}^2.\text{day} \text{ (OK)}\end{aligned}$$

(Standard Load BOD per volume of media = 0,4 - 4,7 kg.BOD/m<sup>3</sup>.day, [10])

**Hydraulic Loading Rate**

$$\begin{aligned}\text{Area Area (A)} &= 2 \pi r (r + t) \\ &= 2 \times 3,14 \times 1,25 \text{ m} (1,25 + 6) \\ &= 7,85 \text{ m} \times 9,1 \text{ m} = 71,45 \text{ m}^2\end{aligned}$$

$$\begin{aligned}\text{HLR} &= Q / A \\ &= 62,6 \text{ m}^3/\text{day} / 71,45 \text{ m}^2 \\ &= 0,87 \text{ m}^3/\text{m}^2.\text{day} \\ &= 0,04 \text{ m}^3/\text{m}^2.\text{hour} \text{ (Meet)}\end{aligned}$$

$$\text{Design Criteria} = < 2 \text{ m}^3/\text{m}^2.\text{hour}$$

So it is planned that the dimensions of the aerobic tub with a diameter of 2,5 m, a Length 6 m with a depth of 2 m and 0,5 m freeboard. Aerobic systems use aeration with the help of a blower and diffuser.

**Oxygen Demand**

Known

$$Y = 0,5$$

$$Q = 62,6 \text{ m}^3/\text{day} = 2,6 \text{ m}^3/\text{hour}$$

$$[\text{BODin}] = 367,8 \text{ mg}/1 = 0,37 \text{ kg}/\text{m}^3$$

$$[\text{BODout}] = 218,8 \text{ mg}/1 = 0,22 \text{ kg}/\text{m}^3$$

$$F = 0,68$$

### Mud Calculation

$$P_x = \frac{Y \times Q(S_o - S_e)}{1000}$$

$$P_x = \frac{0,5 \times 62,6 \text{ m}^3/\text{day} (0,37 - 0,22) \text{ kg}/\text{m}^3}{1000}$$

$$P_x = 0,004 \text{ kg}/\text{day}$$

### Theoretical Oxygen Demand

$$N = \frac{Q \times (S_o - S_e)}{1000 \times f} - 1,42 P_x$$

$$N = \frac{62,6 \text{ m}^3/\text{day} (0,37 - 0,22) \text{ kg}/\text{m}^3}{1000 \times 0,68} - 1,42 \times 0,004 \text{ kg}/\text{day}$$

$$N = 13,7 \text{ kg}/\text{day}$$

### Standard Oxygen Condition (SOR) in the Field

Field Temperature = 30 C

$$\alpha = 0,98$$

$$\beta = 1$$

$$C_{\text{walt}} = 7,95$$

$$C_t = 2 \text{ mg}/\text{L}$$

$$C_s = 9,08 \text{ mg}/\text{L}$$

$$F_a = 0,98$$

Source : [11]

$$SOR = \frac{N}{\left( \frac{\beta \times C_{\text{walt}} \times F_a - C_t}{C_s} \right) \times 1,024^{T-20} \times \alpha}$$

$$SOR = \frac{13,7 \text{ kg}/\text{day}}{\left( \frac{1 \times 7,95 \times 0,98 - 2 \text{ mg}/\text{l}}{9,08 \text{ mg}/\text{l}} \right) \times 1,024^{30-20} \times 0,98}$$

$$SOR = 9,4 \text{ kg}/\text{day}$$

### Requirement Blower

If the blower to transfer oxygen is 2 kg/O<sub>2</sub> Kwh, and the saturated oxygen concentration at 20 C is 7,95 mg/L, then the oxygen transfer under field conditions

$$= N_o \left( \frac{\beta \times C_{\text{watts}} - C_l}{9,17} \right) 1,024^{30-20} \times \alpha$$

$$= 2 \left( \frac{1 \times 7,95 - 2}{9,17} \right) 1,024^{30-20} \times 0,98$$

$$= 2,9 \text{ kg.O}_2/\text{kwh}$$

So the amount of oxygen that must be transferred every day is

$$= 2,9 \text{ kg O}_2/\text{kwh} \times 24 \text{ jam}$$

$$= 69,6 \text{ kg O}_2/\text{kwh .hari}$$

Power requirement

$$= \frac{0,71 \text{ kg.O}_2/\text{day}}{2,9 \text{ kg.O}_2/\text{kwh.day}} = 0,23 \text{ kwh}$$

From the calculation results, 9,4 kg/day of field oxygen is required to reduce the BOD load from 368 mg/l to 219 mg/l. Thus, a blower to supply air of 69,6 kg.O<sub>2</sub>/kW.day.

### Final Settling Tank

Known :

$$\text{Volume ex} = 3 \text{ m}^3$$

$$R = 1,25 \text{ m}$$

$$T = 0,6 \text{ m}$$

$$\text{Surface Area} = 2 \pi r (r + t)$$

$$= 2 \times 3,14 \times 1,25 (1,25 + 0,6)$$

$$= 7,85 \text{ m} \times 1,85 \text{ m} = 14,5 \text{ m}^2$$

Check Td = Volume/Q  
 =  $3 \text{ m}^3 / 2,6 \text{ m}^3/\text{hour} = 1,15 \text{ hour}$

hours. So that the redesign calculation is carried out according to the design criteria as follows

Planned:

D = 2,5 m with a freeboard of 0,5 m

Volume = Q x td  
 =  $2,6 \text{ m}^3/\text{hour} \times 2,5 \text{ hour} = 6,5 \text{ m}^3$

V<sub>freeboard</sub> = 0,2 x V<sub>total body</sub>  
 =  $0,2 \times 6,5 = 1,3 \text{ m}^3$

V total body = V<sub>total</sub> + V<sub>freeboard</sub>  
 =  $6,5 \text{ m}^3 + 1,3 \text{ m}^3 = 7,8 \text{ m}^3$

V =  $\pi r^2 L = 3,14 \times (1,25 \text{ m})^2 \times L$

7,8 m<sup>3</sup> = 4,9 L

L = 1,5 m

### Calculation of Total

TSS Sludge deposited = TSS removal x TSS effluent  
 =  $23\% \times 10 \text{ mg/l} = 2,3 \text{ mg/l}$

Amount of Sludge = TSS precipitated x Q  
 =  $2,3 \text{ mg/l} \times 62.600 \text{ l/day} = 143.980 \text{ mg/day} = 0,14 \text{ kg/day}$

Sg mud = %solid/Sgsolid + % water / Sga  
 =  $5\%/1,4 + 95\% / 0,99 = 0,07 + 0,94 = 1,01$

Vol Sludge = TSS/(%solid x Sgl x Sga)  
 =  $0,14 \text{ kg/day} / (92,6) = 0,0015 \text{ m}^3/\text{day}$

Mud Tank Volume

Length = 3,5 m

Width = 1,3 m

Height = 1,5 m

Volume = W x W x H =  $3,5 \text{ m} \times 1,3 \text{ m} \times 1,5 \text{ m} = 6,8 \text{ m}^3$

Thus, the draining time can be known as follows:

Draining Time = Tub Vol/Mud Volume  
 =  $6,8 \text{ m}^3 / 0,0015 \text{ m}^3/\text{day} = 4.533 \text{ day}$

So the dimensions of the final settling tank are planned with a diameter of 2,5 m, length 1,5 m with a depth of 2 m and 0,5 m freeboard. Based on the calculations, the dimensions of the redesigned reactor are obtained as follows:

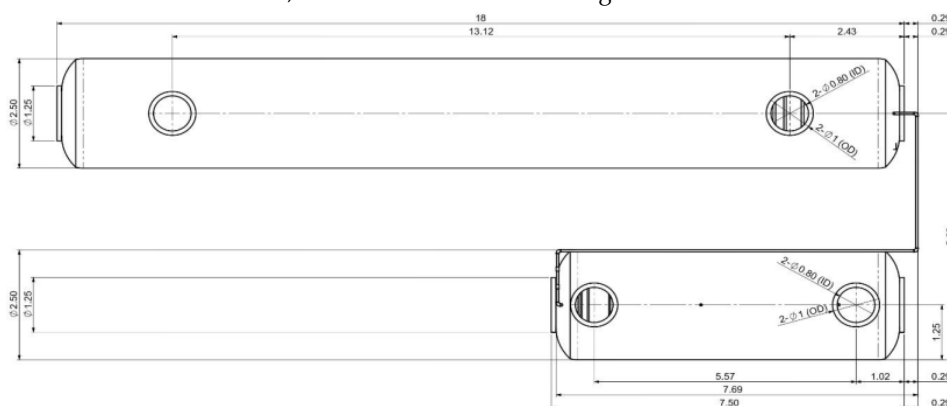


Figure 1: Anaerobic- aerobic Biofilter Top View

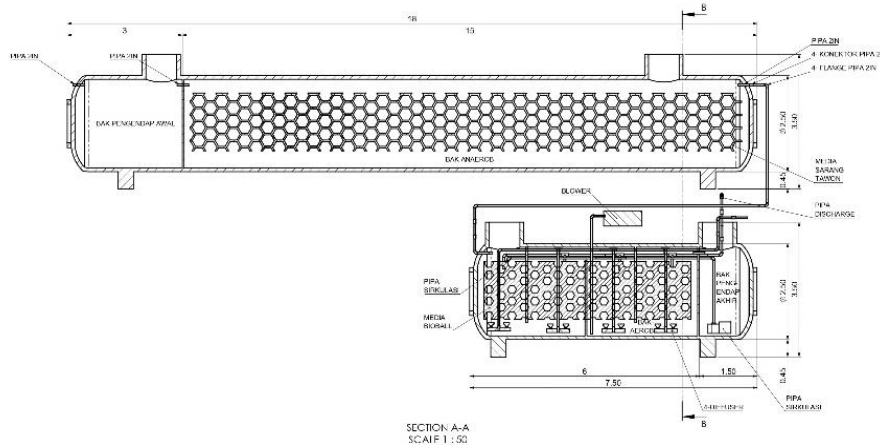


Figure 2: Anaerobic-aerobic Biofilter Section A-A .

#### 4. Conclusion

Based on the evaluation results, the efficiency of removing organic loads in wastewater in aerobic-anaerobic biofilter reactors is less than optimal. The wastewater discharge exceeds the capacity of the existing WWTP, so it needs to be redesigned. The redesign of the anaerobic biofilter includes pre-settling tank with a diameter of 2,5 m and a length of 3 m, an anaerobic tank with a diameter of 2,5 m, and a length of 15 m so that the total volume in the anaerobic reactor is 88.3 m<sup>3</sup>. Then an aerobic tank with a diameter of 2,5 m and a length of 6 m and a final settling tank with a diameter of 2,5 m and a length of 1,5 m so that the total volume in the aerobic biofilter reactor is 36,7 m<sup>3</sup>

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