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PLANNING OF WASTEWATER TREATMENT PLANTS IN THE TAPIOCA FLOUR INDUSTRY USING ANAEROBIC FILTER UPFLOW SYSTEM (UAF) (Case Study of Mojoagung Village, Trangkil District, Pati Regency)

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Abstract

Mojoagung Village, Trangkil District, Pati Regency, is one of the major tapioca flour production areas in Central Java, Indonesia. The wastewater generated from tapioca processing is commonly discharged directly into nearby rivers without adequate treatment, causing unpleasant odors, low pH levels, and environmental pollution that may disturb the aquatic ecosystem. This study aimed to design a Wastewater Treatment Plant (WWTP) for the tapioca flour industry using an Upflow Anaerobic Filter (UAF) system combined with biofilter media consisting of bioballs, honeycomb media, and pumice stone.

The research employed a quantitative analytical method based on wastewater quality testing and hydraulic design calculations. The parameters analyzed included Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), cyanide (CN), and pH. The laboratory results indicated that the BOD, COD, and TSS concentrations met the wastewater quality standards, while the CN and pH parameters did not comply with the applicable standards due to acidic conditions and noticeable discoloration. Based on the design calculations, the proposed WWTP requires a land area of 29.28 m³ with dimensions of 18.3 m in length, 1.6 m in width, and 2.5 m in depth. The estimated construction cost of the WWTP was Rp 69,959,471.109. The proposed UAF-based treatment system is expected to reduce environmental pollution and improve the management of wastewater generated from tapioca flour production.

Keywords: wastewater, tapioca flour, WWTP, anaerobic, biofilter

INTRODUCTION

Waste disposal at this time is one of the problems that is often faced by an industry. Improper waste disposal and causing pollution to the environment will be sanctioned based on the rules or laws that have been set by the government (Rizani et al., 2023).

Mojoagung Village, Trangkil District, Pati Regency is one mainstay in tapioca flour production among 3 other sub-districts. This tapioca industrial wastewater has a content of organic matter glucose of 21.067%, carbohydrates of 18.900%, and vitamin C of 51.040% (Sensih & Prayitno, 2023).

According to the Semarang Industrial Research and Development Institute, the quality of untreated tapioca wastewater is as follows: BOD5 = 2000-5000 mg/L; COD = 4000-30,000 mg/L; Total Suspended Solids = 1500-5000 mg/L; CN (Cyanide) = 0-15 mg/L; and pH = 4.0-6.5. Meanwhile, the wastewater quality standard for tapioca industry businesses and/or activities (Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards), the highest level is BOD5 = 150 mg/L; COD = 300 mg/L; Total Suspended Solids = 100 mg/L; CN (cyanide) = 0.3 mg/L; and pH = 6.0-9 (Aina, n.d.).

Therefore, tapioca flour industries that dispose of their waste directly without any waste treatment must first have an adequate Wastewater Treatment Plant (WWTP). WWTP has various types, including aerobic and anaerobic.

Currently, the most widely used types of anaerobic reactors by industry, especially in Central Java, are *lagooning* (septic tank) and *UAF*. *UAF* was first discovered by Young and M.C. Carty in 1962. The process takes place in a sealed reactor filled with a material filter. Filter materials that can be used include: stone, PVC, ceramic or plastic media with various configurations (Suwarnarat dan Weyrauch, 1978 dalam Djarwanti, 2015).

Based on the context that has been described, the problem is formulated as follows:

a. What is the quality and quantity of wastewater produced by the tapioca flour factory in Mojoagung Village, Trangkil District, Pati Regency?
b. How is the construction planning and budget plan for wastewater treatment plant costs using *the UAF (Upflow Anaerobic Filter)* system?

Limitations of the problem include:

a. The place of the research case study is at the Tapioca Flour Factory in Mojoagung Village, Trangkil District, Pati Regency.
b. Aspects assessed include parameter allowance and WWTP construction using *the Upflow Anaerobic Filter* system and cost budget plan
c. The RAB method uses an analysis of the regulations of the Public Works Office of Highways and Cipta Karya of Central Java Province, 2024.

LITERATURE REVIEW

The characteristics of tapioca flour industrial liquid waste are as follows:

1. Chemical Oxygen Demand (COD)
   The amount of oxygen needed by oxidizers in oxidizing organic and inorganic materials (Metcalf, dkk, 2003).
2. Biochemical Oxygen Demand (BOD)
   Parameters for assessing the amount of dissolved organic substances (Metcalf, dan Eddy, 2003).
3. Total Suspended Solid (TSS)
   solids that cause water turbidity, and cannot settle directly (Effendi Hefni, 2003).

4. Degree of Acidity (pH)
   Tapioca flour industrial wastewater tends to be acidic, so it is very easy to release volatile substances, and emit a bad odor (Adibroto, T. 1997).
5. Sianida (CN)
   a highly toxic substance and is the main cause of pollution cases by tapioca flour industrial waste (Soelaeman et al., 2010).

In the Regulation of the Minister of Environment No. 5 of 2014, it replaces many regulations regarding wastewater quality standards. This Ministerial Regulation comes into effect on the date of promulgation, which is starting on October 25, 2014, while the standard for the quality of tapioca industrial waste is only liquid waste, with the characteristics presented including:

Table 1. Tapioca Flour Wastewater Quality Standards

Parameter	Highest Levels (mg/L)	Highest Pollution Load (kg/ton)
BOD5	150	4,5
COD	300	9
TSS	100	3
CN	0,3	0,009
pH	6,0 – 9,0	
Q Highest	30 m3 per ton of tapioca products	

Source: Regulation of the Minister of Environment Number 5 of 2014

Industrial WWTP Planning includes:

a. Equalization Tub

To determine the equalization tub, first determine the required volume with the formula:

V = Q x td

Keterangan:

Q_{limbah} = Waste discharge (m3/hour)

td = Stay time (hours)

Average Stay Time (TD) is required 3-5 hours (kementrian Kesehatan 2011).

Dimension calculation:

$$\text{Length} = \frac{Volume}{lebar\ x\ kedalaman}$$

The width and depth have been determined.

Dimension = Length x Width x Depth

b. Early and Final Sedimentation Tubs

The calculation of the dimensions of the initial and final settler tanks can be calculated with the formula (Fathoni et al., 2023):

$$\text{Tub Volume} = \frac{rt}{24\ jam} x\ Q$$

Description :
rt = Waiting Time
Q = Wastewater discharge
Dimension calculation:

Length $= \frac{Volume}{lebar\ x\ kedalaman}$

The width and depth have been determined.
Dimension = Length x Width x Depth

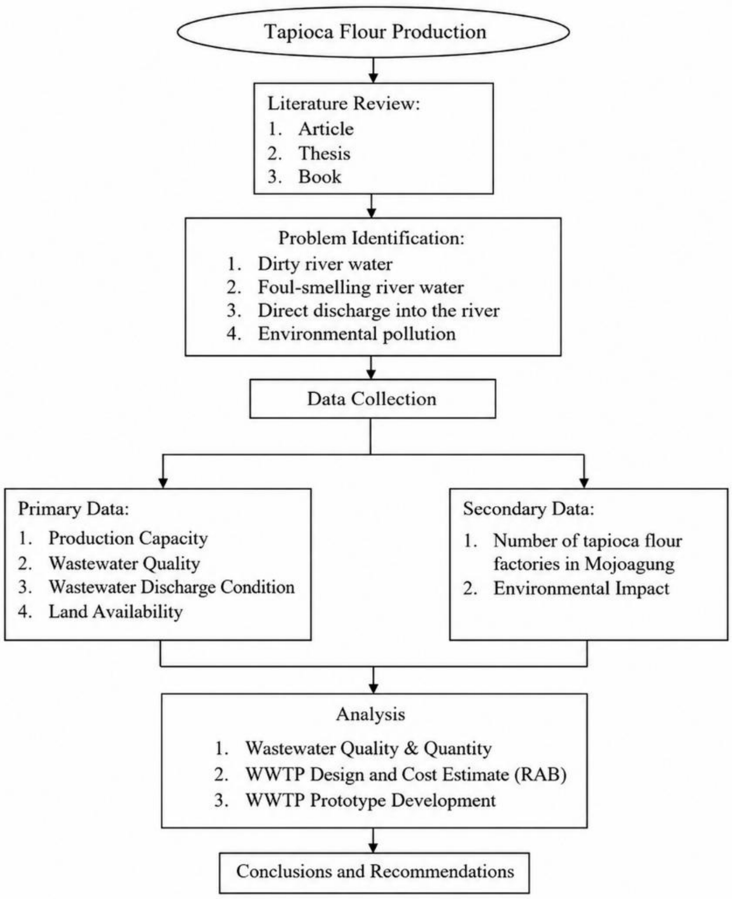
c. Behind the biofilter
The calculation of the dimensions *of the anaerobic filter* tank can be calculated by the formula:

Volume media biofilter $= \frac{BODmasuk}{BODstandar}$

Stay time $= \frac{Volume\ reaktor}{Q}$

RESEARCH METHODS

This type of research is a planning research that will be carried out by the planning of a Wastewater Treatment Plant to process liquid limb at the tapioca flour factory. The parameters to be tested are BOD, COD, TSS, CN, and pH to determine the characteristics of tapioca flour liquid waste.



Sumber: Penulis, 2024

RESULTS AND DISCUSSION

Wastewater quality testing was carried out at the Central Java Provincial Health and Medical Device Testing Laboratory. The wastewater taken is 5 liters.
The sample was taken on Tuesday, May 21, 2024 at 08.00 WIB at the tapioca flour factory in Mojoagung Village, Trangkil District, Pati Regency. Then the sample was tested to the laboratory on that day. The results of the inlet test still meet the standard of wastewater quality while CN, and the pH has not met and the characteristics of the wastewater become acidic and change color to cloudy.

Table 2. Inlet Wastewater Quality

No	Parameter	Quality Standards	Results	Units	Method
1	BOD	150	26	mg/L	SNI 6989.72.2009
2	COD	300	77,4	mg/L	SNI 6989.73.2009
3	TSS	100	9	mg/L	SNI 06.6989.3.2004
4	CN	0,3	≤ 0,006	mg/L	SNI 6989.8.2009
5	pH	6,0- 9,0	4,97	-	SNI 6989.11.2019

Source: Central Java Health Laboratory and Medical Device Testing, 2024

The testing of wastewater samples taken from the river flow (*outlet*):

Table 3. Outlet Wastewater Quality

No	Parameter	Quality Standards	Results	Units	Method
1	BOD	150	17	mg/L	SNI 6989.72.2009
2	COD	300	50,27	mg/L	SNI 6989.73.2009
3	TSS	100	3	mg/L	SNI 06.6989.3.2004
4	CN	0,3	≤ 0,006	mg/L	SNI 6989.8.2009
5	pH	6,0- 9,0	8,25	-	SNI 6989.11.2019

Source: Central Java Health Laboratory and Medical Device Testing, 2024

With the difference in test sampling locations, it can be seen that the levels of BOD, COD, TSS are lower and still meet quality standards. CN showed no change in the quality standard while the pH changed to a higher number so that it became alkaline. So that the pH change affects the color of the wastewater to blackish ash and a very strong odor. And the environment becomes polluted and disrupts the aesthetics of the environment around the factory. Outlet wastewater is drained into the tributaries and used by residents as rice field irrigation, so that the rice field environment is polluted in terms of odor and. As a result of the factory manager's interview, every day the tapioca flour factory processes an average of 12 rits (± 60 tons) of cassava. With 9-hour working hours per day starting from 07:00 to 16:00 and holidays on Sundays. Estimated wastewater discharge can be seen in the following table:

The following is the calculation of the discharge of the wastewater plan:

a. Daily discharge (Qab) : 480 m3

b. Infiltration discharge

The amount of infiltration discharge is 10% - 20% of the amount of wastewater discharge (Moduto, 2000)

Qinf = 20% x Qab
= 20% x 480 m3 = 96 m3/day

c. Maximum daily discharge (Qmd)

Maximum daily discharge is wastewater discharge under maximum usage conditions. Factor Peak (fp) based on the Planning Criteria of the Directorate General of Cipta Karya of the Public Works Office 1996 in the urban category is 1.75 – 2.0. Then the calculation of the maximum daily discharge (Qmd) is as follows:

Qmd = fp x Qab
= 2.0 x 480 m3 = 960 m3/day

1. The dimensions of the Equalization Tank are calculated as follows:

Waste discharge (Q) = 960 m3 /day, 9 working hours
= (960 m3/day)/(9 hours)
=106.6 m3 / day

Dimension Calculation

The waiting time in the tub is as follows:

Waiting time (td) = 4 hours (Ministry of Health of the Republic of Indonesia, 2011)

Required Tub Volume:

Volume = $\frac{td}{24\ jam} x\ Q$

= $\frac{4jam}{24\ jam}\ x\ 106{,}6\ m^3/hari$ = 17,7 m^3

Required dimensions:

The width and depth are determined by the researcher (*trial*)

Width = 1.6 m (according to the width of vacant land available in the factory)

Depth =2.5 m

Length = $\frac{volume}{Lebar\ x\ Kedalaman}$

= $\frac{17{,}7}{1{,}6x2{,}5}$ = 4.5 m

Dimensions = Length x width x depth
= 4.5 x 1.6 x 2.5
= 18 m3 >17.7 m3

2. The dimensions of the Initial Settling Tub are calculated as follows:

Discharge that enters the initial deposition tub

Waste discharge (Q) = 106.6 m3/day
= 106.6/9
= 11.8 m3/day
Dimension Calculation
Dwell time in the reactor 2 hours (Hidayati, 2017)
Volume required in the reactor
Volume = Q x td
= 11,8 x 2 = 23,6 m3
Required dimensions
Width and depth set (*trial*)
Width = 1.6 m (according to the width of vacant land available at the factory)
Depth = 2.5 m
Length = $\frac{volume}{lebar\ x\ kedalaman}$
= = 6 m $\frac{23,6}{1,6\ x\ 2,5}$
Dimensions =length x width x depth
= 6 x 1.6 x 2.5 = 24 m3
Check Stay Time
td = $\frac{Vtotal}{Q}$
= 2 jam$\frac{24}{11,8}$

3. The dimensions of the Anaerobic Biofilter Bath are calculated as follows:

BOD and COD loads in liquid waste (kg/day)
BOD = Q x BOD Rate
= 106,6 m3/hari x 26 g/m3
= 2,771.6 g/day
= 2.7 kg/day
COD = Q x COD Rate
= 106,6 m3/hari x 77,4 g/m3
= 8,250.84 g/day = 8.2 kg/day
According to Metcalf & Eddy (2003). The BOD load used is set at 2 kg BOD/m3.day
$V_{media\ biofilter}$ = $\frac{beban\ BOD}{Standar\ beban\ BOD}$
= $\frac{2,7 kg/hari}{2\ kg\ BOD/m3\ hari}$ = 1,35 m^3
The volume of biofilter media is 60% of the total number of reactors (BPPT, 2011), so that:
Need to be able to do that= $\frac{100}{60}\ x\ V\ media\ biofilter$
= = 2.2 m3$\frac{100}{60}\ x\ 1,35\ m3$
Required dimensions:
Width and depth (*trial*)
Width = 1.6 m (according to the width of vacant land available in the factory)
Depth = 2.5 m
Length = $\frac{Volume}{lebar\ x\ kedalaman}$

$= \frac{2,2}{1,6 \; x \; 2,5} = 0.6$ m

Dimensions = Length x width x depth

= 0.6 x 1.6 x 2.5= 2.4 m3

4. The dimensions of the Final Settling Tub are calculated as follows:

Discharge that enters the initial deposition tub

Waste discharge (Q) = 106.6 m3/day

= 106.6/9

= 11.8 m3/day

Dimension Calculation

Dwell time in the reactor 2 hours (Hidayati, 2017)

Volume required in the reactor

Volume = Q x td

= 11.8 x 2 = 23.6 m3

Required dimensions

Width and depth set (*trial*)

Width = 1.6 m (according to the width of vacant land available at the factory)

Depth = 2.5 m

Length $= \frac{volume}{lebar \; x \; kedalaman}$

$= \frac{23,6}{1,6 \; x \; 2,5} = 6$ m

Dimensions =length x width x depth

= 6 x 1.6 x 2.5 = 24 m3

Check Stay Time

td $= \frac{Vtotal}{Q}$

$= \frac{24}{11,8} = 2$ hours

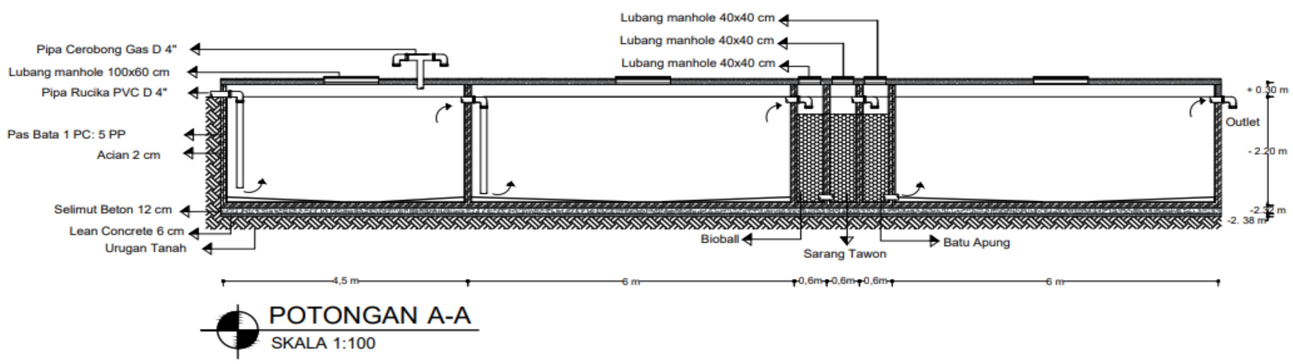


Figure 1. WWTP Construction Design
Source: Author, 2024

The material from the wastewater treatment plant uses this *anaerobic filter upflow* system from bricks, concrete, and biofilter materials (bioball, sarangtawon plastic, bioring).

After calculations were made on the main structure, the results of the calculation of the type of excavation work and repetition were Rp. 22,126,715.36; wall, pipe and manhole work Rp. 32,021,053.83; biofilter installation work Rp. 9,451,750.00. Therefore, the total RAB for the need for a Wastewater Treatment Plant using the *anaerobic filter upflow system* (UAF) at the planning location of Mojoagung Village is Rp. 63,599,519.19 and after being subject to 10% VAT the total becomes Rp. 69,959,471,109 (Sixty-Nine Million Nine Hundred Fifty-nine Thousand Four Hundred Seventy-One One Hundred Nine).

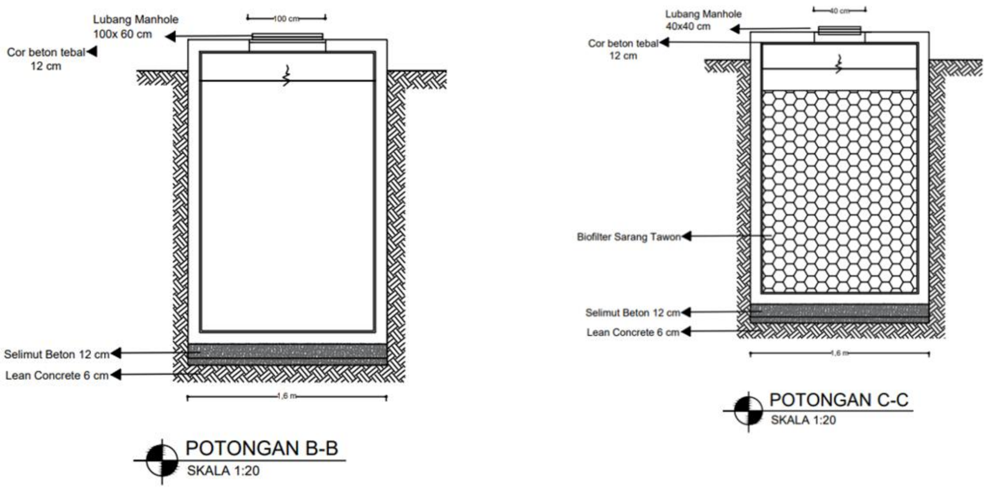


Figure 2. WWTP Construction Design
Source: Author, 2024

CONCLUSION

By referring to several theories and previous research results, the following conclusions can be drawn:

1. The results of the tapioca flour inlet wastewater quality test at the factory in Mojoagung Village, Trangkil District, Pati Regency produced the parameters of BOD, COD, TSS which still met the quality standards while the CN and pH changed to acidic, smelly and cloudy white so that they did not meet the quality standards. Meanwhile, the results of the wastewater quality test of the tapioca flour outlet at the factory in Mojoagung Village, Trangkil District, Pati Regency produced the parameters of BOD, COD, TSS which still met the quality standards while the CN and pH changed to alkaline, smelled bad, changed in black color that was insignificant and foamy so that it did not meet the quality standards.
2. In the construction planning of the WWTP using the UAF (Upflow Anaerobic Filter) system at the tapioca flour factory in Mojoagung Village, Trangkil District, Pati Regency requires an area of 29.28 m3 with a length of 18.3 m, a width of 1.6 and a depth of 2.5 m
3. The planned WWTP construction cost budget at the tapioca flour factory in Mojoagung Village, Trangkil District, Pati Regency requires funds for the needs of a Wastewater Treatment Plant using an *upflow anaerobic filter* (UAF) system at the Mojoagung Village planning location is Rp. 63,599,519.19 and after being subject to a total of 10% VAT to

Rp. 69,959,471,109 (Sixty Nine Million Nine Hundred Fifty Nine Thousand Four Hundred Seventy One One Hundred Nine).

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