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Optimizing Bioky Performance Using Super Small Vessel in Wastewater Treatment Installation at PT. X in Klaten

Joko Waluyo[a], Paryanto[a], Raihan Alamsyah[a], Deni Kurniawan[a], Ibnu Singgih Pranoto[b], Yulinar Pramesti Cahyani[b].

[a]*Chemical Engineering Department, Engineering Faculty, Universitas Sebelas Maret, Surakarta, Indonesia 57126*
[b]*PT. Biosan Mandiri, Karanganyar, Indonesia 57175*

[*]Corresponding author: jokowaluyo@staff.uns.ac.id

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ABSTRACT. One of the causes of environmental pollution is liquid waste generated by industries, especially the printing industry. PT. X is one of the printing industries that produces liquid waste that does not meet quality standards. The purpose of this research is to optimize the performance of Bioky bacteria using the Super Small Vessel in the wastewater treatment plant at PT. X. Treatment involves testing variables such as residence time and bacteria quantity's impact on TSS, MBAS, COD, BOD, pH, and ORP. The study employs anaerobic treatment with observed variables: residence time of 1; 2; and 3 days, and 30% (v/v); 40% (v/v); and 50% (v/v) dosage of bacteria. Samples from each variable are then analyzed for pH, ORP, and TSS. COD, BOD, and MBAS are tested after obtaining the best TSS results from each variable. The research results indicate that longer residence time and increased bacteria quantity lead to a greater reduction in TSS, COD, BOD, and MBAS, while pH approaches neutrality. Optimal conditions occur at a 3-day residence time with 50% (v/v) dosage of bacteria, resulting in a reduction of TSS, COD, BOD, and MBAS against the inlet by 99.75%, 95.47%, 94.84%, and 26.72%. Although the treated waste doesn't meet the established standards, it effectively reduces the pollution levels in PT. X's wastewater.

1. INTRODUCTION

Waste is one of the impacts produced primarily in industries that produce goods and services. Liquid waste from the printing industry has the potential to pollute water and soil by releasing nitrates and heavy metals. Heavy metals contained in printing industry liquid waste include Lead, Chromium, Carbon Monoxide, Manganese, and Tin [1].

The wastewater treatment process anaerobically is a metabolism that occurs without the use of oxygen, carried out by anaerobic bacteria. Anaerobic wastewater treatment is used for wastewater with very high BOD (Biochemical Oxygen Demand). Its main purpose is to decompose the contents of pollutants, especially organic compounds, suspended solids, pathogenic microbes, and organic compounds that cannot be broken down by microorganisms found in nature. The anaerobic process has advantages such as high stability, low biological sludge waste products, low nutrient requirements, and the production of methane gas that can be used as an energy source [2].

PT X is one of the printing industries located in Klaten, Central Java. The production process at PT X generates hazardous waste and has implemented wastewater treatment through physical processes such as flocculation, coagulation, and sedimentation. Based on laboratory analysis results of PT X's liquid waste conducted in March 2020, the BOD content was found to be 3150 mg/L, COD 7800 mg/L, MBAS 66.2577, and TSS 3450 mg/L. From these results, it can be seen that the wastewater treatment process at PT. X has not reached the set standards, namely maximum BOD content of 50 mg/L, COD 100 mg/L, MBAS 5 mg/L, and TSS 100 mg/L according to Regional Regulation of Central Java Province No. 5 of 2012.

This research is necessary to evaluate the performance of the Wastewater Treatment Plant (WWTP) using Bioky bacteria in the Super Small Vessel (SSV) with the use of activated charcoal. The focus will be on determining the effective value of adding Bioky bacteria for treating printing industry wastewater, sourced from a mixture of ink residues, soap, alcohol used in the plate rinsing process, and wastewater from sinks concerning the incoming flow rate. The success of this study will demonstrate the effectiveness of Bioky bacteria in treating printing industry wastewater. Furthermore, it will also provide the optimal quantity of Bioky bacteria required and the water flow rate for treating printing industry wastewater using SSV to meet the quality standards imposed by Regional Regulation of Central Java Province No. 5 of 2012, especially in reducing BOD, COD, MBAS, and TSS levels.

2. MATERIALS AND METHODS

2.1 Materials and Equipments

In conducting the study, a variety of materials and equipment were employed. The materials encompassed industrial wastewater samples collected from the SSV outlet, distilled water (Aquadest), Bioky bacteria, ice cubes, and activated charcoal. Simultaneously, several pieces of equipment were utilized, including two sets of Super Small Vessel (SSV), beaker glasses, a pH meter, an ORP meter (Oxidation-Reduction Potential meter), 1.5 L bottles, an icebox, and a bucket. These materials and instruments formed an integral part of the experimental setup, facilitating the analysis and treatment process of printing industry wastewater, thereby aiding in evaluating the effectiveness of the Bioky bacteria in wastewater treatment.

2.2 Treatment Method of Printing Waste Using Anaerobic System Utilizing Super Small Vessel

Super Small Vessel (SSV) is a fiberglass wastewater treatment installation with a capacity of 800 Liters. Two SSVs are utilized in this study, interconnected by 1½-inch pipes. The SSV functions as a Pilot Plant Wastewater Treatment Installation on an actual scale. Each vessel comprises several sections, each with its specific function to degrade hazardous contents in the wastewater. Inside each section of the SSV, bioballs are present, serving as attachment sites for bacteria to reduce BOD and COD levels.

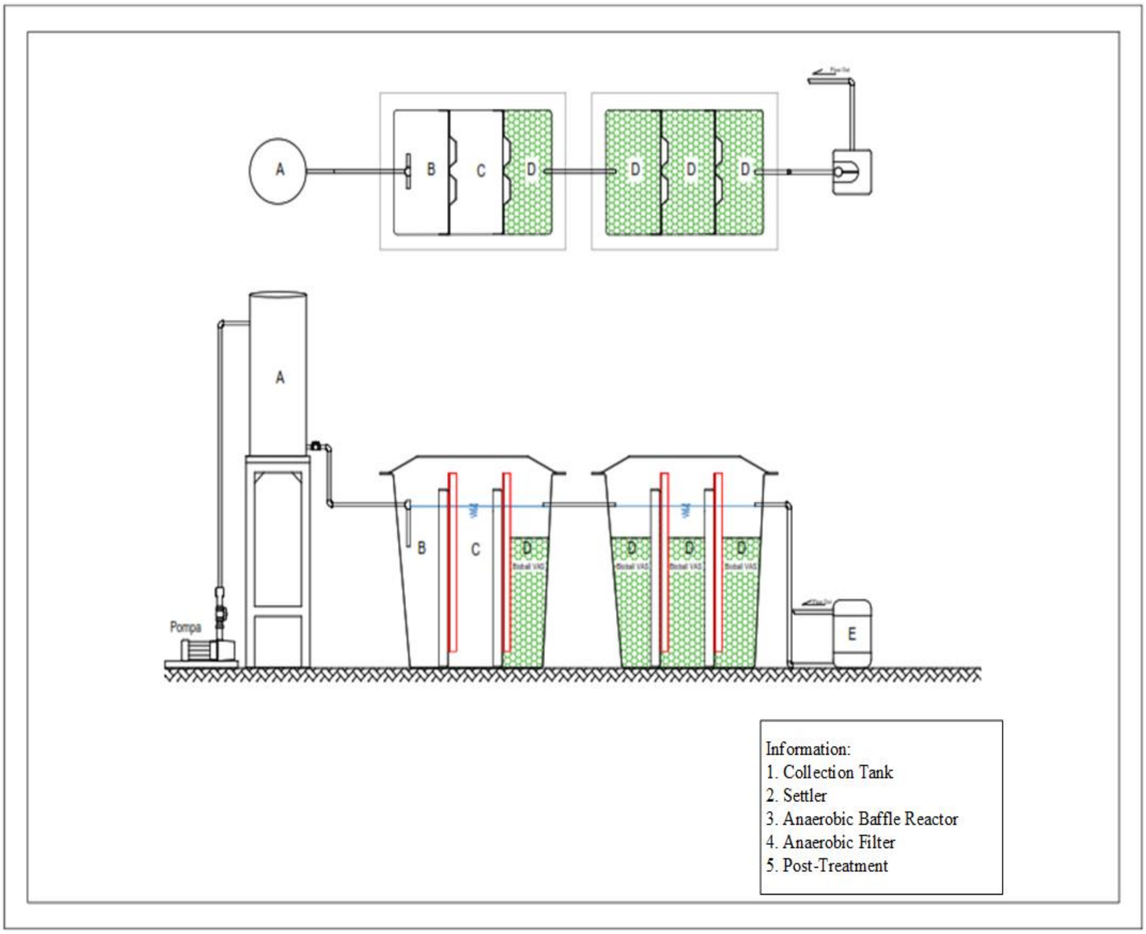

Figure 1. Super Small Vessel PT. X

In this research, we manipulated two variables. Firstly, the residence time variable with durations of 1; 2; and 3 days. The next variable is the bacterial dosage administered to the SSV, 30% (v/v); 40% (v/v); and 50% (v/v) liters of bacteria. The basis for 1 m^3 of printing industry wastewater is 5 liters of bacteria, distributed to each chamber as follows:

a. Settler : 43.75% of the dosage
b. Anaerobic Baffle Reactor (ABR) : 31.25% of the dosage
c. Anaerobic Filter (AF) 1-4 : 25% of the dosage

2.3 Sample Collection and Testing Method

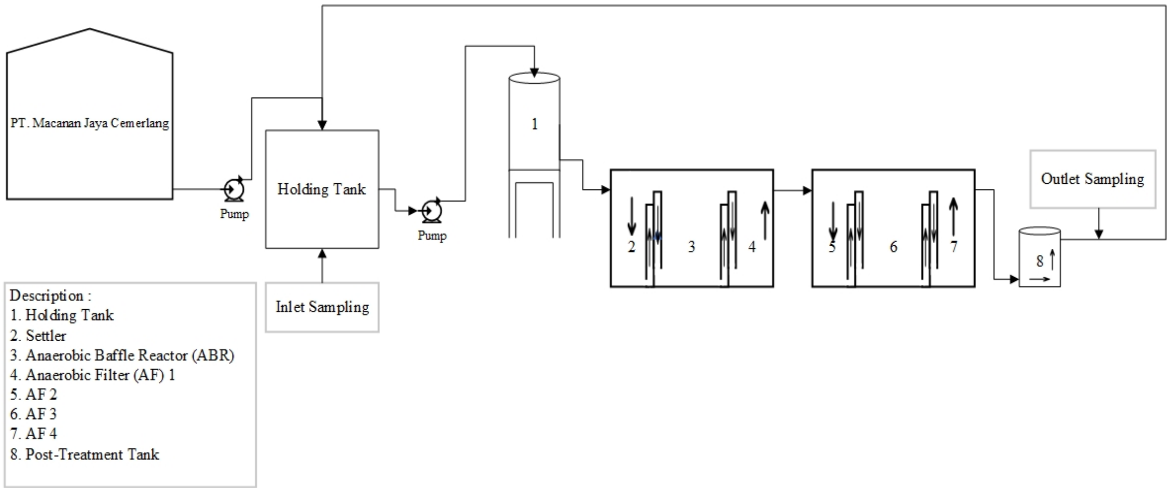

Figure 2. Block Diagram of Liquid Waste Flow

Before taking samples, the installed SSV is first drained and cleaned. Subsequently, a residence time of 1, 2, or 3 days is set to compare the effectiveness of different residence times in reducing pollutant levels. Following this, bacteria are introduced at rates of 30% (v/v); 40% (v/v); and 50% (v/v), aiming to compare the use of varying bacterial quantities.

Outlet samples are collected using a beaker glass. The samples' pH and ORP are measured in the field. Afterward, the samples are stored in 1.5 L bottles for laboratory measurements of COD, BOD, TSS, and MBAS parameters at the FT Laboratory and the Yogyakarta Health and Calibration Laboratory. Inlet sampling is conducted twice for each variation, taken from the holding tank at the PT. X WWTP. Outlet sampling, after the activated charcoal treatment, is conducted three times for each variation from the discharge point.

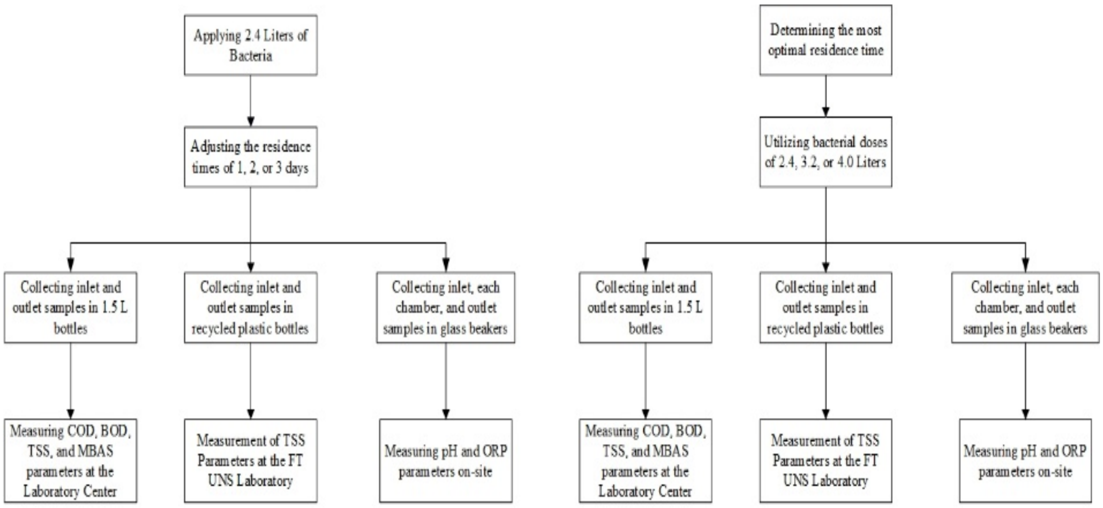

Figure 3. Flowchart of Sample Collection and Testing Procedure

2.4 Analysis of Results and Calculations

Following the sample testing in the laboratory, the results are observed, and a table is compiled to summarize the sample test outcomes, comparing them against the industrial wastewater quality standards (Regional

Regulation of Central Java Province No. 5 of 2012). Subsequently, the analysis results for each sample are compared concerning the residence time and the addition of the bacterial quantity used to obtain the percentage of effectiveness based on the reduction in each tested parameter compared to the initial reference value (inlet). Additionally, the BOD/COD ratio is calculated for each tested sample. The effectiveness of bacterial usage is calculated based on the reduction in the parameter levels tested compared to the sample levels before treatment. This is expressed as efficiency values in percentage(%). This effectiveness can be applied to parameters such as Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and MBAS [3]. This calculation refers to the general formula presented in the book by Metcalf & Eddy [4], as cited in Lestari & Rohaeni [3], which is as follows:

$$E = \frac{So - S}{So} \; x \; 100\% \tag{1}$$

Where:

E = Wastewater treatment efficiency (%)

S_0 = Inlet concentration T_0 (mg/L)

S = Outlet concentration T_n (mg/L)

The BOD/COD ratio serves as an indicator of the degradation level of wastewater. According to Dincer [5] as cited in Al-Rosyid [6], the BOD to COD ratio is used to determine the biodegradability level of wastewater. The degradation level is directly proportional to the BOD/COD ratio value in domestic wastewater. The BOD/COD ratio is categorized into three zones: biodegradable, slow biodegradable (biodegradable with treatment), and non-biodegradable. As the degradation level of wastewater increases, the BOD/COD ratio proportionally becomes larger. A BOD/COD ratio < 0.3 indicates non-biodegradability, 0.3-0.6 suggests biodegradability but requires treatment, and > 0.6 signifies biodegradability [7]. The BOD/COD ratio can be calculated using the formula:

$$Ratio = \frac{BOD}{COD} \tag{2}$$

3. RESULTS AND DISCUSSION

3.1 Industrial Liquid Waste

Industrial wastewater is water resulting from the processes in an industrial facility. This type of water is considered to have poor quality due to the contaminants it contains. The contaminants in industrial water vary depending on the specific processes that generate the water [8]. For example, the printing industry involves processes requiring water for rinsing printing plates. This water carries residues of ink, soap, and alcohol used in the plate rinsing process. PT. X, located in the Klaten Regency, Central Java Province, adheres to [9] as the standard for its WWTP (Wastewater Treatment Plant) processes. The table below shows the condition of liquid waste before the process and the quality standards.

Table 1. Quality Standards for Wastewater from Businesses with Undefined Standards

Parameters	Units	Quality Standards	Inlet (March 2020)
pH	-	6.0-9.0	8.73
Temperature	C	38	35
BOD	mg/L	50	**3150**
COD	mg/L	100	**7800**
MBAS	mg/L	5	**66.257**
TSS	mg/L	100	**3450**

3.2 Determining the Optimal Residence Time

To determine the optimal residence time, this study utilizes TSS as an indicator to identify the most effective duration. TSS (Total Suspended Solids) is a parameter that measures the level of turbidity in wastewater. Total Suspended Solids (TSS) are residues of total solids that are retained by a filter with a maximum particle size of 2 micrometers larger than colloidal particles [10]. Total Suspended Solids (TSS) also represent the residue of total solids from heterogeneous reactions, serving as the earliest-forming sediment material that can hinder the organic substance production capacity in a water body [11]. According to Winnarsih [12], TSS values increase with the rising turbidity of wastewater. The more waste content degraded by microorganisms, the better the quality of the waste [13] .For industrial wastewater, the TSS standard set by [9] is a maximum of 100 mg/L. If the TSS value exceeds this standard, the industrial wastewater is deemed unfit for discharge into the environment.

Table 2. The TSS parameter value for the outlet with a residence time of 1 day and a bacterial dosage of 30% (v/v)

	TSS (mg/L)	Description
1st Week	520	Exceeding the Standard
2nd Week	380	Exceeding the Standard
3rd Week	160	Exceeding the Standard

Based on the table above, the TSS concentration at the SSV outlet with a residence time of 1 day still exceeds the established quality standard (>100 mg/L). However, the addition of Bioky bacteria shows a positive effect, with the TSS concentration decreasing and approaching the specified quality standard.

Table 3. The TSS parameter value for the outlet with a residence time of 2 days and a bacterial dosage of 30% (v/v)

	TSS (mg/L)	Description
1st Week	242	Exceeding the Standard
2nd Week	240	Exceeding the Standard
3rd Week	380	Exceeding the Standard
4th Week	300	Exceeding the Standard

Based on the table above, the TSS concentration at the outlet with a residence time of 2 days exceeds the established quality standard (>100 mg/L). However, a 2-days residence time shows a TSS concentration worse than the 1-day residence time.

Table 4. The TSS parameter value for the outlet with a residence time of 3 days and a bacterial dosage of 30% (v/v)

	TSS (mg/L)	Description
1st Week	120	Exceeding the Standard
3rd Week	120	Exceeding the Standard
5th Week	420	Exceeding the Standard
6th Week	26	Meeting the Standard

Based on the table above, the TSS concentration in the SSV outlet with a residence time of 3 days is approaching the water quality standard set by [9]. Moreover, in the 6th Week, TSS concentration was already below the standard with a value of 26 mg/L. Therefore, it can be concluded that a residence time of 3 days is the most optimal duration.

3.3 Test Results for 5 Parameters

After determining the optimal residence time, the testing continued to examine the optimal bacterial dosage. The results for the 5 parameters at 3 dosage levels are presented in the table.

Table 5. Test Results for 5 Parameters at 3 Different Dosages

Parameters	Bacterial dosage					Quality Standards
	30% (v/v)	40% (v/v)		50% (v/v)		
	Outlet	Inlet	Outlet	Inlet	Outlet	
pH	7.77	8.73	8.35	7.01	8.13	6.0-9.05
TSS	26	58	50	**10260**	25	100
COD	***439.04***	**1790.21**	***813.46***	**16875.20**	***764.16***	100
BOD	***142.46***	**391.80**	***148.62***	**3494.63**	***180.27***	50
MBAS	4.270	3.861	3.079	**5.134**	3.762	5

This research examines the parameters of pH, TSS, COD, BOD, and MBAS. The testing of MBAS is due to the use of Methylene Blue dye. Methylene Blue Dye has the potential to pollute the environment with its nondegradable nature [14]. The reduction in the concentration of each parameter at each bacterial dosage yields different outcomes. This occurs because the inflow of wastewater at each dosage varies depending on the ongoing production at that time. Additionally, the performance of the bacteria also affects the results of the wastewater treatment outlet. A dosage of 50% (v/v) bacteria provides a reasonably good reduction outcome with a sufficiently large inlet value. The concentrations of TSS and MBAS could be lowered to meet the established quality standards. The levels of COD and BOD also experienced a significant reduction, although they still do not meet the quality standards. This is due to the production process generating wastewater with high concentrations that surpass the capacity of the given dosage. Inappropriate treatment can also impact the wastewater treatment results.

3.4 pH Parameter

The pH value represents the concentration of hydrogen ions and the acidic nature. According to [9] regarding the Quality Standards for Wastewater from Businesses with Undefined Standards, the current standard for wastewater with defined quality ranges from pH 6-9. The pH data obtained from the sample collection location is as follows.

Table 6. pH Data of Liquid Waste in Determining the Optimal Residence Time

Residence time : 1 day			Residence time : 2 days			Residence time : 3 days		
	Inlet	Outlet		Inlet	Outlet		Inlet	Outlet
1st Week	8.87	8.58	1st Week	8.87	8.58	1st Week	7.68	7.50
2nd Week	7.55	7.38	2nd Week	6.20	6.60	3rd Week	8.85	7.34
3rd Week	7.15	7.23	3rd Week	6.99	7.05	5th Week	7.89	7.40
4th Week	8.72	7.86	4th Week	7.40	7.03	6th Week	8.90	7.90

Table 7. pH Data of Liquid Waste in Determining the Optimal Bacterial Dosage

30% (v/v)			40% (v/v)			50% (v/v)		
	Inlet	Outlet		Inlet	Outlet		Inlet	Outlet
1st Week	7.68	7.50	1st Week	9.50	7.80	1st Week	9.70	8.10
2nd Week	8.85	7.34	2nd Week	9.50	7.90	2nd Week	8.90	7.70
3rd Week	7.89	7.40	3rd Week	9.40	7.60	3rd Week	7.10	8.00
4th Week	8.90	7.90	4th Week	8.80	8.00			

Table 8. ORP Data for Wastewater Outlet with a Residence Time of 1 Day & Bacterial Dosage of 30% (v/v)

	ORP (mV)	Stages of Reaction
1st Week	-325	- *Methane formation*
2nd Week	-120	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
3rd Week	-165	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
4th Week	-166	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*

From tables 6 & 7, it can be observed that the pH values of the SSV inlet for all treatments fall within the range of pH 7.10 – 9.70. This indicates that the liquid waste from PT. X, before undergoing further treatment, already meets the quality standards outlined in [9], even though some data points show that the pH still doesn't fully comply with the standard. Additionally, the pH values at the SSV outlet also meet the quality standards of [9]. The lowest pH value is observed in the treatment with a residence time of 2 days and a bacterial dosage of 30% (v/v), measuring 6.60. The highest pH value recorded is 8.58, following bacterial treatment in the SSV with a residence time of 1 day and a bacterial dosage of 30% (v/v). The increase in pH in the samples may be due to biological reactions that can lead to an elevation in pH through the microbial breakdown of glucose, urea, and NH_4Cl [15]. Based on the pH data, it can be noted that the best percentage reduction occurs in the wastewater treatment with a residence time of 3 days compared to residence times of 1 day and 2 days, with a reduction of 17.06%, meeting the quality standards.

3.5 ORP Parameter

Oxidation-reduction potential (ORP) is the potential voltage value at which oxidation occurs at the anode (positive pole) and reduction at the cathode (negative pole) in an electrochemical cell. The purpose of reviewing the wastewater treatment results with the ORP parameter is to provide a quick assessment/conclusion about the potential of wastewater treatment by understanding the ongoing treatment activities (reactions) [16]. Based on the direct field data collection using an ORP Meter, the obtained data is as follows.

Table 9. ORP Data for Wastewater Outlet with a Residence Time of 2 Days & Bacterial Dosage of 30% (v/v)

	ORP (mV)	Stages of Reaction
1st Week	-13	- *Denitrification* - *Polyphosphate breakdown*
2nd Week	-157	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
3rd Week	-188	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
4th Week	-193	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*

Table 10. ORP Data for Wastewater Outlet with a Residence Time of 3 Days & Bacterial Dosage of 30% (v/v)

	ORP (mV)	Stages of Reaction
1st Week	-185	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
3rd Week	-55	- *Denitrification* - *Polyphosphate breakdown* - *Sulfide formation*
5th Week	-260	- *Methane formation*
6th Week	-159	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*

Table 11. ORP Data for Wastewater Outlet with a Residence Time of 3 Days & Bacterial Dosage of 40% (v/v)

	ORP (mV)	Stages of Reaction
1st Week	-176	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
2nd Week	-147	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
3rd Week	-118	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*
4th Week	-200	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation* - *Methane formation*

Table 12. ORP Data for Wastewater Outlet with a Residence Time of 3 Days & Bacterial Dosage of 50% (v/v)

	ORP (mV)	Stages of Reaction
1st Week	-202	- *Sulfide formation* - *Methane formation*
2nd Week	-61	- *Polyphosphate breakdown* - *Sulfide formation*
3rd Week	-218	- *Sulfide formation* - *Methane formation*

Based on tables 8 - 12, the ORP values at the outlet of the SSV at PT. X after treatment and the addition of Bioky bacteria indicate that the treatment process is in an anaerobic state. The ORP values range from -325 to -13 mV, indicating that the anaerobic treatment process is running well and optimally under fermentative anaerobic conditions, or anaerobic bacteria are working in the absence of oxygen in the process. According to [17,18], an ORP range of -350 to -80 mV indicates anaerobic conditions. The anaerobic treatment process is characterized by the reduction of nitrate to nitrogen gas (denitrification), a decrease in polyphosphate (0 to 200), the formation of sulfide (-50 to -250), the formation of acid (-100 to -200), and the formation of methane at the end of the treatment process (-200 to -350) [19].

3.6 Ratio of BOD to COD Concentrations

Based on the table above, it is known that the BOD/COD ratio at the SSV inlet at PT. X can be categorized as non-biodegradable waste with ratios of 0.218 and 0.207 (< 0.3). The SSV outlet at T_2 and T_3 also shows similar ratios with ratios of 0.182 and 0.235, categorizing them as non-biodegradable waste. Meanwhile, the SSV outlet at T_1 shows a ratio of 0.324, categorizing it as biodegradable waste that requires treatment. This indicates that if the waste is discharged directly into the environment, it would be hazardous as it cannot be further broken down through biological processes by the environment.

Table 13. Ratio of BOD to COD Concentrations in SSV

Description	BOD/COD Ratio
Inlet (T_2)	0.218
Inlet (T_3)	0.207
Outlet (T_1)	0.324
Outlet (T_2)	0.182
Outlet (T_3)	0.235

*Description :

T_1 = Residence Time of 3 Days & Bacterial Dosage of 30% (v/v)

T_2 = Residence Time of 3 Days & Bacterial Dosage of 40% (v/v)

T_3 = Residence Time of 3 Days & Bacterial Dosage of 50% (v/v)

3.7 Sustainability of the Research

After 14 weeks without the addition of bacteria and other treatments, the samples were retested to prove that this research has a sustainable nature. The results of the test for the 5 parameters can be seen in the following table.

Table 14. Comparison of Test Results for 5 Parameters After 14 Weeks Without Treatment

Parameters	Comparisons				Quality Standards
	Before		After		
	Inlet	Outlet	Inlet	Outlet	
pH	7.01	8.13	7.93	8.26	6.0-9.05
TSS	10260	25	124	27	100
COD	**16875.20**	***764.16***	**931.20**	***248.32***	50
BOD	**3494.63**	***180.27***	**380.49**	***100.97***	100
MBAS	5.134	3.762	2.292	0.940	5

Based on Table 14, it can be seen that the SSV outlet results after 14 weeks without treatment are getting closer to the quality standards set in [9]. This indicates that the bacteria in the SSV are still present and the treatment process is ongoing.

Table 15. ORP Parameter on 29/10/2023

Description	ORP (mV)	Stages of Reaction
Inlet	-154	- *Sulfide formation* - *Acid formation*
Settler	-277	- *Methane formation*
ABR	-303	- *Methane formation*
AF 1	-312	- *Methane formation*
AF 2	-302	- *Methane formation*
AF 3	-280	- *Methane formation*
AF 4	-284	- *Methane formation*
Outlet	-188	- *Polyphosphate breakdown* - *Sulfide formation* - *Acid formation*

In Table 15, it is evident that bacteria are still present, and the wastewater treatment reaction is still ongoing. Based on both tables, it can be concluded that Bioky bacteria are effective in reducing pollutant levels in the wastewater produced by PT. X. Additionally, the outlet results also indicate that this research has a sustainable nature.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusions

Based on the research on optimizing the performance of Bioky using the Super Small Vessel (SSV) in the wastewater treatment facility of PT. X, the following conclusions can be drawn:

1. The use of Bioky bacteria in treating wastewater from the printing industry using the SSV at PT. X has been effective in reducing the wastewater content, although the COD and BOD levels still do not meet the standard requirements. A 3-day retention time with a 50% (v/v) dose of bacteria showed the best effectiveness, with a reduction in TSS, COD, BOD, and MBAS levels from the inlet by 99.75%, 95.47%, 94.84%, and 26.72%, respectively.
2. Post-treatment with the addition of activated charcoal as an adsorbent was performed to absorb various organic and inorganic substances in wastewater, aiding in reducing BOD and COD levels.
3. Bioky bacteria demonstrated good performance, and the research showed sustainability even after 14 weeks without additional treatment, resulting in a reduction in TSS, COD, BOD, and MBAS levels from the inlet by 78.22%, 73.33%, 73.46%, and 58.98%, respectively.
4. COD and BOD levels still do not meet standard requirements due to factors such as fluctuating pollution loads based on bacteria usage intensity, varying wastewater content daily, and suboptimal monitoring in the treatment system.

4.2 Recommendations

1. A recommendation for further research is to conduct additional studies by introducing aeration treatment in the post-treatment of the wastewater treatment facility to assist in reducing COD and BOD levels, ensuring compliance with the established standards. According to Amri and Wesen [20], the reduction in BOD levels through aeration processes can reach 81.21% with a retention time of 72 hours. Furthermore, the reduction in COD levels through aeration processes can reach 84% with a retention time of 72 hours [21]. Therefore, the optimal air volume required for the aeration process in this study is 0.016 m3/min.
2. Another recommendation is to provide a more optimal dose of Bioky bacteria, specifically 8 liters of bacteria (100% dosage).

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