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The Performance of Natural Filter in Treating Tapioca Wastewater with and without Aeration

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ABSTRACT

The presence of organic mater in tapioca wastewater causes serious problems to the environment in Indonesia. Many tapioca industries, partly small scale industries, have yet equipped with proper wastewater treatment system. The aim of this study was to improve the quality of tapioca wastewater effluent. The biological treatment was designed to treat tapioca wastewater which combined with different natural filters and the addition of effective microorganism (EM). This experiment was operated in semi-continous system both with and without aeration. The results showed that low concentration of COD, BOD, TSS and coliform was achieved in both systems. The combination of soil filter, the addition of 1% (vv^{-1}) EM inoculum and without aeration did improve the effluent quality and meet with the national standard. Similarly, with aeration system combined with sand filter were also able to meet the national standard even without the addition of EM inoculum.

Keywords: tapioca wastewater, aeration treatment, natural filter, biological wastewater treatment, effective microirganism.

INTRODUCTION

Small-scale agricultural industries are essential to Indonesia's economy, however many do not have proper wastewater treatment system. Tapioca industry production is one such industry, resulting in wastewater discharged to streams with high COD and BOD, as well as posing a serious threat to the environment. Tapioca wastewater is generated during the processing of the tapioca from cassava, approximately at 10-30 m^3 $tonne^{-1}$ of tapioca produced. In addition to high BOD and COD content, tapioca wastewater has high suspended solids content, high total solid [1] [2], a high concentration of sugars and mineral salts [3] a short discharging period [1].

As public and governmental environmental awareness grows, it is increasingly desirable to move the small scale producers towards net-zero waste emissions. One alternative solution to accomplish this is 100% re-use and recycling of wastewater [4]. Producers have a financial incentive to recycle water, because the food industry spends a lot of their operating money on purchasing water.

Tapioca wastewater treatment has been the subject of many previous studies, and the treatment technology has been implemented in both developed and developing countries, including Indonesia. Some example technologies include bioremediation [5], up-flow anaerobic sludge blanket (UASB) [6][7][8], anaerobic pond [9], anaerobic pond with bamboo filter [10], a modified rotating biological contactor (RBC) [11], and a sequenced batch reactor (SBR) using yeast [1].

The tapioca industry in Vietnam applied the closed wastewater system with the combination of primary sedimentation tank, UASB-reactors, aeration tank (attached growth reactor) and oxidation ponds system, generated the effluent that suited for re-used or recyled to both in the agriculture and in the factory [12]. Other treatment technologies are fluidized bed reactor [14], electrochemical treatment by RuO_2/Ti and PbO_2/Ti electrodes [15], an anaerobic hybrid reactor [15], combination of aerobic and anaerobic reactors which resulted good quality effluent and negative tests for fecal and total coliforms [16], and activated sludge [17]. However, the application of these technologies for the small tapioca's producer in Indonesia will be very hard due to high cost operation.

The wastewater treatment technology intended to be used in SME's tapioca industry must be simple to build and inexpensive. An alternative is using aerobic treatment with the combination of EM and natural filters to remove the fine particles from the wastewater, thereby significantly reducing the concentration of COD, BOD, and TSS. Jenie and Pudji [18]) reported that during aerobic condition, the air supplies oxygen for the growth of microorganism in wastewater treatment. Previous study had shown that, the COD removal rate achieved 97% under restricted aeration with $0.375 m^3\ h^{-1}$ of aeration quantity, as well as the use of SBR combined with yeast pretreatment on cassava wastewater treatment was economical and simple [1]. Additionally, by

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using the natural filter, the treated wastewater will be more environmentally friendly and economically feasible for replacing the more costly filter equipment such as membrane system.

The aim of the current research was to investigate whether the use of natural filters and effective microorganism addition to the tapioca's wastewater system improved the quality or the physical properties of effluent.

MATERIALS AND METHODS

Materials

Tapioca wastewater was collected fresh from the SME's tapioca industry in Kediri city, East Java Indonesia and stored at room temperature. This wastewater contains large quantity of organic materials (as shown in Table 1). Effective microorganism (EM – commercial product) was used in this work because EM is easly and sinergically adapt with other microorganism [19], able to live in acid or alkali medium and aerobic or anaerobic condition [20]. The EM inoculum was prepared by mixing 10 ml EM with 1 l tapioca wastewater and 10% sugar (w/w). Then, this mixture was incubated for 24 hours at room temperature in order to activate the microorganism. Various concentration of the EM inoculum was added into the fermentation thank at 0%vv^{-1}, 1%vv^{-1}, 2% vv^{-1}, respectively.

Five different types of natural filters include sand, gravel, soil (entisol type), coconut's fibre and bamboo plait were used because these material are abundant, cheap, and easy to find in Indonesia. The diameter of sand, gravel and soil was as follow < 1 mm, 6-7 mm, and 3.28 mm. The preparation procedures for the natural filter were including: (1) the filter media was washed and dried . (2) Sand, gravel and soil were sieved to remove larger particles and obtain homogeneous size. (3) These filters were added into the second column of the fermentation tank with the height of 25 cm (for sand, gravel and soil), while for coconut's fiber and bamboo plait, the dimension should be maintained at 25 cm (width and height).

Experimental Set-up

The experiment for wastewater treatment was designed in semi-continuous system using open fermentation tank made from stainless steel with the dimension size of 30 W x 60 L x 30 H cm^3 (see Fig. 1). This tank has three connected columns having different functions. The first column of the tank was functioned as primary sedimentation tank to store the wastewater influent, as well as to allow gravity sedimentation occurs. The second column, filled with natural filters, was acted as purifiying tank which filtered the rest of suspended solid, as well as allowed the microorganism to grow and degraded the organic substances in the wastewater. The third column was secondary sedimentation tank to settle down the effluent from the previous column. The purpose of using these columns was to obtain a longer settling time. The effluent from this system will then be recycled back to the tapioca's processing plant. Semi-continuous operation was achieved by manually removing effluent through an outlet port in the base plate before adding the tapioca wastewater in the first column of the tanke. The experiment was repeated triplicate for statistical significance and guarantess the reproducibility of the samples.

The wastewater flowrate was maintained at 2 l d^{-1} and retention time of 15 days. It was designed that the incubation time in this system was 24 hours. Every 5 days, the effluent sample was collected and analysed to monitor the changes on pH, BOD, COD and TSS, as well as the amount of coliform.

Aeration rate measurement

In the system with aeration, the measurement of aeration rate is crucial to supply the oxygen for improving the growth rate of microorganism that plays an important role in degrading organic substances. In this research the rate of aeration was fixed at 66.66 ml s^{-1}.

Analytical methods

Wastewater characteristics

The physical, chemical and biological parameters of tapioca wastewater were measured in this work based on APHA Standard Methods of Examination of Water and Wastewater (APHA, 1995). The physical parameters included color, odor and solid (Total Suspended Solid/TSS). The chemical parameters were Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and pH. The biological parameter was the amount of *coliform*.

The best treatment was selected based on the parameters value on the effluent that meets the national standard for discharge which is the Governor Regulation No. 45 year 2002 about Wastewater Effluent Quality Standard of Tapioca Industries in East Java and multiple attribute method. The removal efficiency was calculated using the equation [21]:

$$\% \text{ removal efficiency (BOD/COD/ TSS)} = \left| \frac{Co - Ce}{Co} \right| \mathbf{X}\ 100\%$$

Note:

Co = initial concentration of pollutant (BOD/COD/TSS) (mg l^{-1})

Ce = the concentration of pollutant (BOD/COD/TSS) after treatment (mg l^{-1})

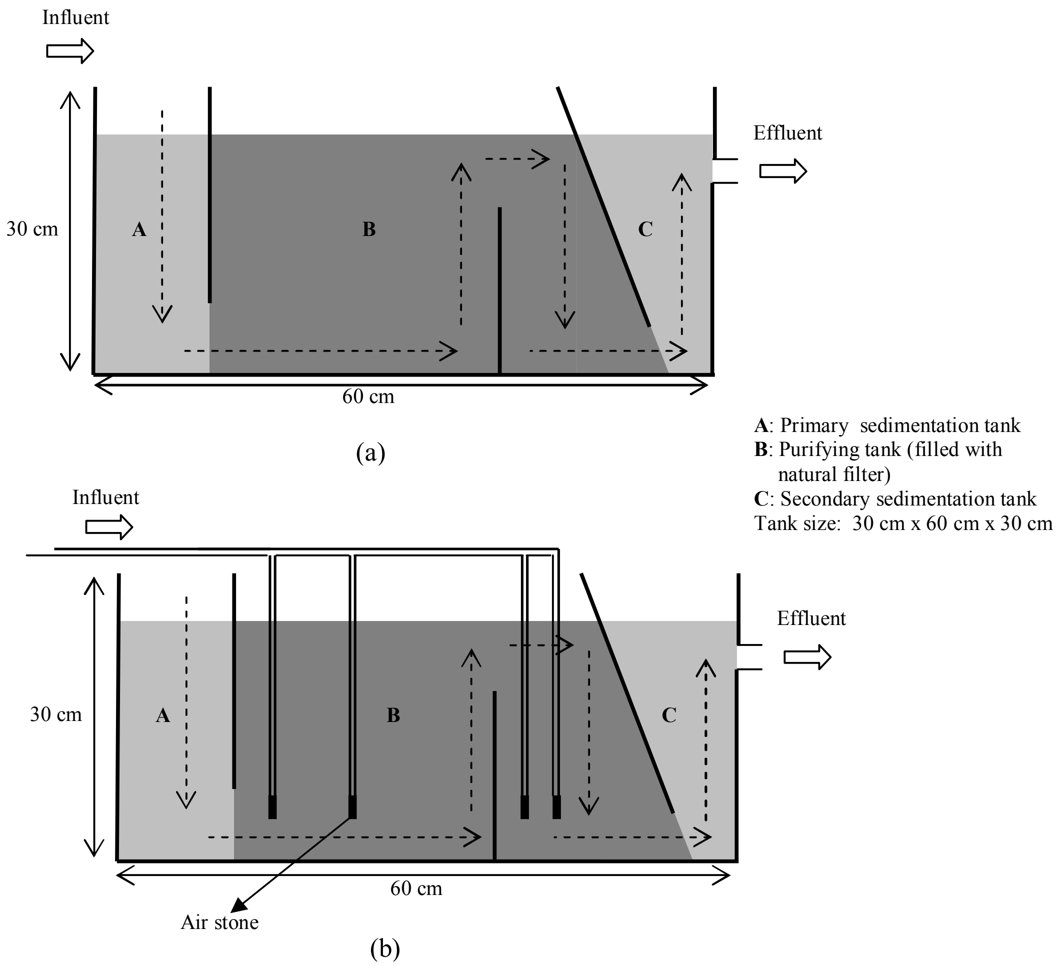

Figure 1 Diagram of fermentataion tank used in experiment

RESULTS AND DISCUSSION

1. The physical parameters of the effluent quality before and after treatment

This study showed the significant change on the physical parameters of the effluent from the tapioca wastewater treatment for all samples. As can be seen from Table 1, the initial color for all samples without treatment (control) was cloudy white. After treated, the filter media of soil generated effluent the clearest color compared with other treatments. For odor, the effluent from the treatment using soil, gravel, and sand filter was odorless, while coconut's fibre and bamboo plait treatment remained at the same condition as the untreated wastewater. In term of solid, the concentration of TSS in influent was 206.6 mg l^{-1}, exceeded the national standard value (100 mg l^{-1}) (Table 2). TSS value after treatment, both with and without aeration, will be further discussed in next section.

2.The chemical parameters of the effluent quality

Before treatment

Initial concentration of chemical parameters of tapioca wastewater (BOD, COD and pH) was generally higher than that of the national standard value for discharge. As can be seen from Table 2, the BOD concentration of the tapioca wastewater was 1702.1 mg l^{-1} which much higher than that of the standard value (150 mg l^{-1}). The COD concentration was also higher than 300 mg l^{-1}, measured at the level of 6,370.4 mg l^{-1}. While, pH value (5.8) was slightly lower than the standard (pH = 6).

Table 1. The comparison of the physical parameters of the effluent quality before and after treatment

Physical Parameters	Before treatment	After treatment				
		Gravel (Diameter of 6-7 mm)	Soil (Diameter of 3.28 mm)	Sand (Diameter of < 1mm)	Coconut's fibre	bamboo
Colour	cloudy white	white	clear/ transparent	cloudy white	green	green
Odor	stink	odorless	odorless	odorless	stink	stink

Table 2. The comparison of the parameters of the effluent quality with the national standard for discharge

Chemical parameters	The value of tapioca wastewater	Maximum value of the national standard for discharge tapioca industry's wastewater*
BOD (mg l^{-1})	1702.10	≤150
COD (mg l^{-1})	6370.4	≤300
TSS (mg l^{-1})	206.6	≤100
pH	5.8	6-9

* The Governor Regulation No. 45 Year 2002 about Wastewater Effluent Quality Standard of Tapioca Industries in East Java

After treatment

a. Without Aeration

The experiment highlighted that the addition of the EM inoculum correlated with the siginificant reduction of BOD concentration (Table 3). The addition of 1% (v v^{-1}) EM inoculum and the use of coconut's fibre as filter media resulted in the highest reduction of BOD concentration from 1702.10 mg l^{-1} to 18.5 mg l^{-1}. In the other hand, without adding EM, it demonstrated that at any given filter media the BOD concentration remained high and exceeded that of in the initial influent. Therefore, EM has a significant influence in reducing BOD concentration of tapioca wastewater.

Table 3. The chemical parameters of the effluent quality on the tapioca wastewater treatment without aeration

Inoculums (%, v v^{-1})	Natural filter types	Parameters			
		BOD (mg l^{-1})	COD (mg l^{-1})	TSS (mg l^{-1})	pH
0	Gravel	2872.2	9568.4	65.6*	6.5
	Soil	2665.2	7875.3	101.0	7.2*
	Sand	5167.5	6542.6	120.3	6.1*
	Coconut's fibre	2066.3	8137.2	79.4*	5.4
	Bamboo plait	2250.0	7634.7	73.5*	5.7
1	Gravel	537.4	966.5	135.4	6.5*
	Soil	127.5*	323.3**	59.6*	6.4*
	Sand	211.8	1362.9	112.6	6.5*
	Coconut's fibre	18.1*	1155.3	166.3	5.9
	Bamboo plait	1406.5	5093.5	236.7	5.2
2	Gravel	1508.7	5813.8	124.5	6.5*
	Soil	670.8	2204.2	36.0*	6.8*
	Sand	1318.7	5129.6	64.5*	5.7
	Coconut's fibre	1723.7	6927.8	244.5	5.2
	Bamboo plait	1527.0	6149.5	373.6	5.5
The national standard for discharge		≤ 150	≤ 300	≤ 100	6-9

Note: * allowed value by the national standard for discharge

The same pattern has also showed in COD concentration. The experiment with the addition of 1% (v v^{-1}) EM decreases the initial COD concentration in the influent. Partly in the use of soil as the filter media, the COD concentration was 323.3 mg l^{-1}, although this value was slightly higher than that of the standard value (≤ 300 mg l^{-1}). Other treatments had much higher COD concentration from 966.5 mg l^{-1} to 9568.4 mg l^{-1}.

In the use of soil and sand, as the EM inoculum concentration increased, the TSS concentration significantly decreased at slightly below the TSS standard value. This was probably caused by the possibility of anaerobic condition created by these filter media. This condition further inhibited the microorganism to grow well. However, using filter media such as bamboo plait, coconut's fibre and gravel, the increase of the EM inoculum added was followed by the increase of TSS concentration, where some of the samples exceeded the initial TSS value.

The pH was within the range of 5.2 to 7.2. The pH value met the national standard of tapioca wastewater for discharge (pH 6-9) was achieved from the gravel, soil and sand media treatment both without and with 1% (vv^{-1}) EM inoculum. While, in the adition of EM inoculum at 2% (vv^{-1}), only the filter media of gravel and soil resulted the required pH. Furthermore, at the given filter media (coconut's fibre and bamboo plait), the pH value decreases var from 5.2 – 5.7 as the EM inoculum concentration increases.

Based on those parameter values, the best performance in this experiment was from the addition of 1% (vv^{-1}) EM with the soil as the filter media because the effluent quality meets the national standard requirement. Moreover, this treatment was more economical compared other treatments due to the highly supply of soil and less expensive technology.

b. With Aeration

As shown in Table 4, the addition of EM inoculum was not significantly influence the BOD reduction for any filter media. Without EM inoculum (0% v v^{-1}), the experiments have shown a significant reduction of BOD concentration which were below the standard value of 150 mg l^{-1}, except on the use of bamboo plait filter (183.3 mg l^{-1}). Results from the addition of EM (1% and 2% v v^{-1}) were found to be different and depended on natural filter media being used. Soil and sand filter can reduce the initial BOD concentration, but the value was still higher than the requirement. Coconut's fibre, gravel and bamboo plait, showed the higher BOD concentration, therefore, these material are not suitable to use as filter media in the treatment with aeration.

The results also indicated that without the addition of inoculum (0%), gravel, sand, and coconut's fibre performed better in reducing the COD concentration, except soil and bamboo plait showed considerable higher COD concentration compared to that of the standard value. In the test using 1% (vv^{-1}) EM inoculum combined with gravel, coconut's fibre and bamboo plait filter media, there was also an increase of COD concentration. These results pointed out a clear trend that the increase of EM inoculum concentration was not proportional to the COD reduction.

Table 4. The characteristics of the effluent quality on the tapioca wastewater treatment with aeration

Inoculums (%, v v^{-1})	**Natural filter types**	**Parameters**			
		BOD (mg l^{-1})	COD (mg l^{-1})	TSS (mg l^{-1})	pH
0	Gravel	26.3*	90.5*	22.8*	7.3*
	Soil	126.6*	394.7	18.2*	6.8*
	Sand	25.0*	82.2*	26.3*	8.0*
	Coconut's fibre	30.3*	97.1*	27.5*	7.2*
	Bamboo plait	183.3	1469.3	97.7*	6.9*
1	Gravel	1732.1	6855.7	138.9	6.7*
	Soil	475.5	1487.9	45.0*	7.1*
	Sand	403.8	625.4	56.4*	6.4*
	Coconut's fibre	2110.5	7454.2	197.7	6.9*
	Bamboo plait	2550.1	8142.2	135.3	5.5
2	Gravel	912.3	3350.3	221.8	7.0*
	Soil	173.5	503.8	54.3*	6.6*
	Sand	784.0	2827.5	98.4*	6.0*
	Coconut's fibre	874.0	3115.9	99.4*	7.1*
	Bamboo plait	2218.8	1329.6	166.8	5.9
The national standard for discharge		≤ 150	≤ 300	≤ 100	6-9

Note: * allowed value by the national standard for discharge,

The similar results had also shown for TSS concentration, where in all treatments without EM inoculum showed considerable reduction in TSS. All the filter media were able to remove suspended solid in wastewater effectively, within the range of 18.2 to 97.7 mg l^{-1}. However, at the EM inoculum concentration of 1% (vv^{-1}), gravel, coconut's fibre and bamboo plait failed to reduce the TSS as this value of the effluent was still higher than 100 mg l^{-1}. In test using 2% (vv^{-1}) EM inoculum, only gravel and bamboo plait resulted higher value of TSS. These results clearly demonstrated that there is no proportional effect between the addition of inoculum and the types of filter media. Furthermore, it was also supported that soil and sand are a suitable alternative for filtration process. Most of all the treatments, the pH was higher than 6, except in the test using bamboo plait as filter media with 1% (vv^{-1}) and 2% (vv^{-1}) EM inoculum, the pH was 5.5 and 5.9, respectively. The results also showed that increasing the concentration of inoculum tend to increase the pH value.

Accordingly, concerning the above parameters, the best treatment in the experiment with aeration was the use of sand as filter media without EM. This option has been chosen particulary due to sand is abundant, inexpensive, simple and common to used, as well as can be reused using backwashing system.

The biological parameters of the effluent quality

a. Without Aeration

The initial *coliform* for the tapioca wastewater influent was 17 mg l^{-1}. After the treatment, without aeration, the experimental results clearly defined that the amount of *coliform* was not influenced by the filter media types or the addition of EM inoculum (see Fig 3.). For example, at EM inoculum of 1% (vv^{-1}), the *coliform* was significantly decreased, except in that of with the use of gravel, soil and coconut's fibre as filter. When the EM inoculum increased to 2% (vv^{-1}), the use of gravel and soil as filter were not significantly contributed to reduce the *coliform*, while the bamboo plait showed a better result compared other treatments. The use of bamboo plait with 2% (vv^{-1}) EM inoculum gave the lowest amount of *coliform* (10 mg l^{-1}).

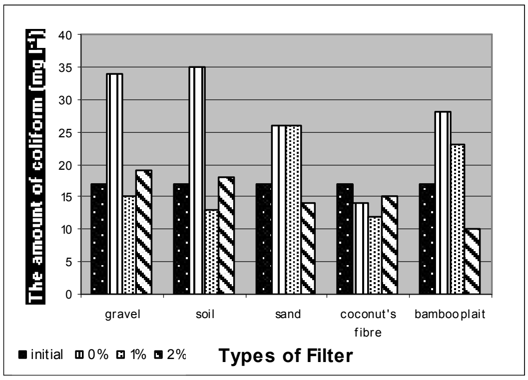

Fig.3. The amount of *coliform* before and after treatment without aeration

b. With aeration

Result from the treatment of tapioca wastewater with aeration is shown in Fig. 4. In all the treatments with 1% (vv^{-1}) EM inoculum performed better than that of with 2% (vv^{-1}) or without EM inoculum. In this experiment, gravel and sand showed significant reduction of *coliform* from 17 mg l^{-1} to 7 mg l^{-1} and 9 mg l^{-1}, respectively. However, as the EM inoculum increases to 2% (vv^{-1}), at any given filter media, the *coliform* increased dramatically exceeded the initial amount. This was assumed that the high concentration of inoculum inhibited the growth of natural microorganism that present on the natural filter or in the fermentation tank. These results obviously demonstrated the reduction of the *coliform* was not driven by the inoculum but influenced by the type of filters, and also select sand or gravel as solution for inexpensive filter media, by which can be applied by small scale agroindustries.

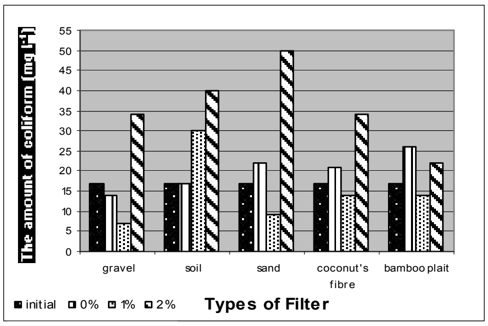

Fig.4. The amount of *coliform* before and after treatment with aeration

The removal efficiency of the selected treatment in the tapioca wastewater treatment with and without aeration

Results for the removal effectiveness of the selected treatment in the tapioca wastewater treatment, with and without aeration, are shown in Table 5. The aeration in the wastewater treatment has a significant effect on removal efficiency. In the treatment with aeration, BOD and COD removal effectiveness was 98.5% and 98.7%, respectively, much higher than that of in the system without aeration. Accordingly, this experiment also showed a high TSS removal (87.3%) compared to that of in the treatment without aeration (71.15%). These results proved that the natural filter and EM inoculum, as well as adding aeration, improved the effluent quality.

Table 5 Removal efficiency of the chemical parameters in the tapioca wastewater treatment with and without aeration

No.	Chemical parameters	The concentration before treatment (mg l^{-1})	The concentration after treatment (mg l^{-1})		Removal efficiency (%)	
			with aeration	without aeration	with aeration	without aeration
1.	BOD	1702.1	25.0	127.5	98.5	92.5
2.	COD	6370.4	82.2	323.3	98.7	94.9
3.	TSS	206.6	26.3	59.60	87.3	71.2

CONCLUSION

The present work found that biologically treating tapioca wastewater using both aeration or without aeration siginificantly improved the performance and the quality of the tapioca wastewater effluent. In without aeration treatment system, the results indicated that the effluent quality from the combination of the addition of EM (1% v v^{-1}) and soil as filter media had the closer value with the national standard value for discharge. However, in the aeration treatment system, using sand as filter media without EM inoculum had performed better to commit with the national standard.

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