Horizontal Biofilter System in Tapioca Starch Wastewater Treatment: The Influence of Filter Media on the Effluent Quality

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Abstract

The aim of this research was to analyse the use of different filter media at laboratory scale under a horizontal biofilter system treating tapioca starch wastewater (TSW) to improve the effluent quality that met the national standard. The completely randomized design was used in this study. A horizontal biofilter system was designed and filled with filter media, include sand, gravel, soil (entisol type), coconut fibre and bamboo plait, in each unit. Prior feeding to the biofilter unit, TSW was inoculated with Bacillus sp. N-09. The TSW flow rate was maintained at 6 l d^{-1} and operated for 1-month period. The results showed that the use of sand as filter media gave a better performance in improving the TSW effluent quality followed by gravel, coconut fibre, soil and bamboo plait. The horizontal biofilter system packed with sand filter media removed 98.53 % BOD, 98.71 % COD, 88.96 % TSS, and increased pH to 8.0.

Keywords: *Natural filter media; horizontal biofilter; tapioca starch wastewater; Bacillus sp. N-09; wastewater treatment*

1. INTRODUCTION

Tapioca starch wastewater (TSW) is generated from washing, extraction and settling process in tapioca starch industry (Lutfi, 2000). According to Suprapti (2005), TSW is consisted of water residue from the following sources: root rinsing, washing or soaking process of peeled cassava, starch washing, purification process, and starch settling or dewatering process. The production of TSW is subjected to the amount of fresh water used in the process. Suprapti (2005) stated that the volume of TSW is about 12 to 15 times of the volume of the processed cassava. In Nigeria, a monthly BOD concentration varied from 0.93 to 11.8 mg l^{-1} with pH value in the range of 3.62 – 6.8, which was in accordance with the diversity of micro-invertebrates (Arimoro, *et al.* 2008).

There are several options to reduce the amount of TSW produced, such as reducing the volume of water used for washing process and recycling back the water residue from washing process (Fukunaga, 1995); using a mechanical separation machine to increase the concentration of TSW through water savings in the production process (Mavroy, 2000); and reducing the water leakage in the packaging process (Ridgway, 1999).

Indeed, several technologies have been applied in wastewater treatment generated from food industries, include physical, chemical and biological process. Biological process can be operated under aerobic or anaerobic condition. In an aerobic process, the most common technology used is an aeration pond and a trickling filter. Horizontal trickling filter, also known as horizontal biofilter, which combined with Bacillus *sp N-09* can reduce the BOD and COD concentration of wastewater containing detergent by more than 80% (Hidayat, *et al.,* 2010).

Biofilter is basically a biological process that utilize wastewater stream passing through a media (or buffer media) containing microorganisms. There are several materials can be used as a biofilter media. Some of these media have been used in wastewater treatment. Using sand as biofilter media in treating wastewater from dyeing process reduced the BOD concentration to below the standard value after 20 days; however it did not have any significant effect on COD concentration (Suyasa and Dwijani, 2008).

The soil is a formidable system because of its capability to acts as a filter by removing sediment and degrading the pollutant into less harmful materials. The ability to neutralize these pollutants made soil as a suitable option as a recipient of waste (organic and inorganics). Coconut fibre, which is naturally available and abundance, has characteristic similar to sand, which can absorb, store and drain off the water (Wang, *et.al*. 2001).

2. MATERIAL AND METHODS

2.1. Tapioca Starch Wastewater (TSW)

Untreated TSW was used as the medium in this experiment and was freshly collected from primary pond in tapioca wastewater treatment.

2.2. *Bacillus sp. N-09*

Bacillus sp N-09 obtained from the Laboratory of Bioindustry of Agricultural Technology Faculty of Brawijaya University Malang was grown in Nutrient Broth or LB Broth (Difco) for 24 h at 30^{0}C. The concentration of inoculums for treatment was 1%.

2.3. Filter Media

Five different types of filter media were used include sand, gravel, soil, coconut fibre and bamboo plait. Prior placing to the biofilter unit, gravel and sand were washed, while coconut fibre and bamboo plait were cleaned from the dirt, then all these filter media were dried. Soil was sieved to remove larger particles and obtain homogeneous size. The type of soil used in this experiment was entisol type. These filter media were then filled into the biofilter unit with the dimension of 25 cm H x 30 cm W.

2.3. Horizontal Biofilter System Design

The horizontal biofilter system in this experiment was designed as an open tank made from stainless steel which constructed in three connected compartments with dimension size of 30 cm W x 60 cm L x 30 cm H (see Fig. 1).

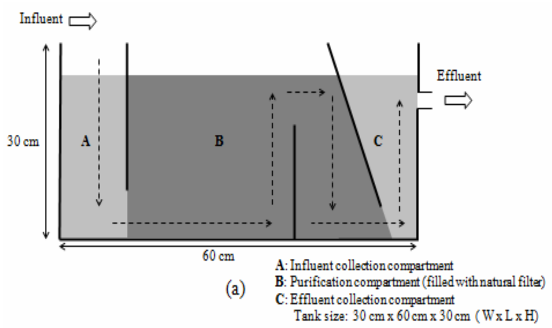

Figure 1. The model of a horizontal biofilter system (Hidayat, *et.al.* 2011)

2.4. Experimental Set-up

Temperature was maintained at room temperature (26^{0}C). A completely randomized design was used in this experiment. After ensuring that the tank was clean and no leakage, the filter media was filled into the second compartment of the biofilter unit with the height of 25 cm. This system was operated under a semi-continuous condition with flow rate maintained at 6 l d^{-1} and observed after 1-month period. The effluent sample was collected and analysed for pH, BOD, COD, and TSS. Furthermore, the percentage reduction (or removal efficiency) of BOD, COD and TSS concentration was also evaluated.

3. RESULTS AND DISCUSSION

3.1. The Characteristic of the TSW's Effluent Quality before Treatment

Untreated TSW has poor quality characterized by its important parameters that did not meet with the standard requirement for TSW's discharge. These characteristics include high turbidity, cloudy-white color, bad odor and foam on the surface of TSW. The high turbidity in TSW was due to the fine starch particles dissolved in water. The findings indicated that TSW has high TSS concentration with the average value of 206.6 mg l^{-1}, representing a large amount of dissolved fine particles.

This value also indicates the high levels of pollution potency, especially for the river where the untreated TSW usually disposed off. The high concentration of TSS in TSW increases its density. This affects the air circulation of the living organisms in the water body and also decreases the solubility of gases such as O_2, which its existence is very vital to the life of organisms (Radojevic, *et al.,* 1999). Furthermore, the high turbidity value limits the sunlight entering into the water (Sugiharto, 1987), which then inhibits the photosynthesis process. Thus, the metabolism of autotroph organism is inhibited and disturbed the ecosystem stability in the surrounding area of the river.

The cloudy-white color of the TSW is usually derived from the water residue from starch washing process containing a large amount of fine starch particles, or from the equipment washing process. Bad odor was resulted from the organic materials degradation process by microorganisms. This problem occurred due to the degraded materials releases some gases such as sulfide or ammonia, as well due to a mixture of nitrogen, sulfur and phosphor generated from the decomposition of proteins in waste (Ginting, 2007).

TSW has a pH in the range of 5.8, which shows that this wastestream is acidic. According to Radojevic *et al.* (1999), with low dissolved oxygen concentration ranged between 0 - 1 mg l^{-1} allowing the growth of acid-producing anaerobic bacteria, thus decreasing the pH value of wastewater is causing wastewater to become more acidic. The amount of organic pollutants in TSW can also be viewed from the initial BOD concentration of 1702.1 mg l^{-1} and COD concentration of 6370.4 mg l^{-1}, exceeded the standard value acceptable for TSW's effluent discharge at 150 mg l^{-1} (BOD) and 300 mg l^{-1} (COD). The comparison of the chemical parameters of the effluent quality with the standard for discharge according to the Governor Regulation No. 4a Year 2002 about Wastewater Effluent Quality Standard of Tapioca Industries is shown in Table 1.

Table 1. The Comparison of the Parameters of the TSW with the Standard Requirement for TSW Effluent Discharge

Parameters	Untreated/ Fresh TSW	Maximum level of the standard for TSW effluent discharge*
BOD (mg l^{-1})	1702.10	$\leq$ 150
COD (mg l^{-1})	6370.4	$\leq$ 300
TSS (mg l^{-1})	206.6	$\leq$ 100
pH	5.8	6-9

* The Governor Regulation No. 4a Year 2002 about Wastewater Effluent Quality Standard of Tapioca Industries in East Java

These findings showed that the quality of untreated TSW did not meet with the standard value. Therefore, directly disposed to the environment, such as river or other water body without proper treatment must be avoided. Unfortunately, due to lack of knowledge and facilities, many tapioca industries still dispose their TSW directly to the river which in the future will create other problems such as water pollution.

3.2. The Characteristics of the TSW's Effluent Quality after Treatment

3.2.1. BOD

The experimental results showed that after 1-month period, the use of different filter media in a horizontal biofilter unit, which combined with the addition of *Bacillus sp. N-09,* reduced the BOD by 89 – 99% (Table 2). The highest BOD removal value obtained from the use of sand biofilter at 98.45% and the lowest was from bamboo plait at 89.23%. The ability of *Bacillus sp. N-09* to remove organic material was higher compared to *Pseudomonas sp.* which was able to achieve 96% removal efficiency (El-Masry *et al.,* 2004) and *Candida utilis* that only removes 70% BOD concentration in TSW (Razif, *et al.,* 2006).

Table 2. The BOD Concentration and percentage Removal from Different Biofilter Media (In average value)

Type of biofilter media	BOD (mg l^{-1})	Removal efficiency (%)
Sand	25.0	98.53
Gravel	26.3	98.45
Coconut fibre	30.3	98.22
Soil	126.6	92.56
Bamboo plait	183.3	89.23

The use of sand as a biofilter media gave a better performance indicated by high BOD removal efficiency at 98.53%. This result was slightly similar to the BOD removal efficiency of 99% found by An *et al.* (2008) who studied about sand filtration in sewage treatment in Korea. The high BOD removal efficiency obtained from the sand biofilter was due to its characteristics which has a high porosity between its particles, thus giving more surface area for the bacteria to form the biofilms and allowing wastewater to have a maximum contact with the biofilm on the particles, therefore the removal of organic material in wastewater stream was more effective. However Gravel has a larger grain size and a wider pore space between its particles compared to that of sand. This condition caused less biofilms were formed and made the wastewater stream flowed faster which reducing the contact with the biofilm, thus decreasing the removal efficiency. Similar to that has been found in other biofilter media, such as coconut fibre and bamboo plait. Soil has a smaller porosity compared to other media, made the bacteria was not able to effectively create the biofilms due to its limited surface area. Furthermore, using soil biofilter media was causing the wastewater stream moved slowly and reducing the aeration within the media. Therefore, its BOD removal efficiency was lower than that achieved by sand biofilter media.

3.2.2. COD

Table 3 shows the reduction in COD concentration, which demonstrated the same trend as the BOD. Using sand as biofilter media gave an average COD concentration of 82.2 $mgl^{-1,}$ giving the highest percentage reduction of 98.71% Bamboo plait biofilter media; however showed the lowest removal efficieny of 90.18% with the average COD concentration of 625.4 mg l^{-1}, much higher than the acceptable value for TSW effluent discharge. This value was slightly higher than the values of 92 - 94% for anaerobic and 94 - 96% for aerobic condition reported in a previous study (Mai, 2006), and much higher than that found by An *et al.,* (2008) at 91.8%.

Table 3. The COD Concentration and Percentage Removal from Different Biofilter Media (In average value)

Type of biofilter media	COD (mg l^{-1})	Removal efficiency (%)
Sand	82.2	98.71
Gravel	90.5	98.58
Coconut fibre	97.1	98.48
Soil	394.7	93.80
Bamboo plait	625.4	90.18

Sand biofilter media combined with circulation, which applied in a synthetic dairy wastewater treatment, reduced COD concentration by 99.3% (Healy *et al.,* 2004). Although bamboo plait filter media can form biofilms, the degradation of this media was unavoidable which was characterized by a yellowish discoloration of wastewater stream. Therefore, using bamboo plait as a biofilter media in wastewater treatment was considered as not the best option.

3.2.3. TSS

Table 4 shows the TSS concentration and removal efficiency for all treatment. The results showed that the high TSS removal efficiency obtained from treatment using sand as a biofilter media with the average value of 91.19%, while the bamboo plait biofilter media gave the lowest value at 52.37 %. These values were lower than the 90.6 – 95.8 % reported by Mai (2006) and An *et al.,* (2008). The low percentage reduction of TSS concentration using bamboo plait as a biofilter media was due to a degradation and suspension of some part of this media into the waste stream.

Table 4. The TSS Concentration and Percentage Removal from Different Biofilter Media (In average value)

Type of biofilter media	TSS (mg l^{-1})	Removal efficiency (%)
Sand	18.2	91.19
Gravel	22.8	88.96
Coconut fibre	26.3	87.27
Soil	27.5	86.69
Bamboo plait	98.4	52.37

3.2.4. pH

The results showed that the average pH value of the TSW effluent, although varying slightly, was in the range of 6.8 – 8.0 (Table 5). The average pH value for all treatments over a 1-month period remained well within the acceptable value of the standard requirement for TSW effluent discharge set by government at 6 -9. This result was slightly similar to the pH value of 7.03 – 7.76 found by Mai (2006).

Table 5. The pH Value from Different Biofilter Media (In average value)

Type of biofilter media	pH
Soil	6.8
Bamboo plait	6.9
Coconut fibre	7.2
Gravel	7.3
Sand	8.0

CONCLUSSIONS

Sand, gravel and soil are the most appropriate filter media used in the horizontal biofilter system. Sand as biofilter media; however gave the best performance in improving the TSW effluent quality, showing a significant reduction in the concentration of BOD, COD and TSS by 98.53%, 98.71%, and 88.96%, respectively, with pH increased to 8. Furthermore, these values were remained well within the standard value requirement for TSW's discharge.

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REFERENCES

An, J., J. Kwon., D. Ahn., H. Shin., S. Won, B. Kim. 2008. Performance of a full-scale biofilm system retrofitted with an upflow multilayer bioreactor as a preanoxic reactor for advanced wastewater treatment. *Water Environ. Res.,* Volume 80: 757 – 765.

Arimoro F. O., Ch. M. A. Iwegbue, B. O. Enemudo. (2008). Effects of cassava effluent on benthic macroinvertebrate assemblages in a tropical stream in Southern Nigeria. *Acta Zoologica Lituanica*, Volume 18: 147 – 156.

El-Masry, M.H., E. El-Bestawy, N.I. El-Adl. (2004). Bioremediation of vegetable oil and grease from polluted wastewater using a sand biofilm system. *World Journal of Microbiology & Biotechnology,* Volume 20: 551 – 557.

Fukunaga, I. (1995). Recent advances of the treatment and disposal of wastewater and solid waste in food industry. *Foods and Food Ingredients Journal,* Volume 165: 21 – 30.

Ginting. 2007. Sistem Pengelolaan Lingkungan dan Limbah Industri (Environmental and Industrial Waste Management System). Bandung: Yrma Widya.

Healy, M.G., M. Rodger, J. Mulqueen. (2004). Recirculating sand filter for treatment of synthetic dairy parlor washings. *J. Environ Quality*, Volume 33: 713 – 718.

Hidayat, N., S. Kumalaningsih., Noorhamdani, and S. Wijana. (2010). Pengaruh Laju Aliran Limbah pada Saringan Kerikil dengan Inokulum *Bacillus coagulans* UB-9 terhadap Kualitas Limbah Cair yang Dihasilkan. Makalah Seminar Nasional APTA, 16 Des 2010. Yogyakarta.

Hidayat, N., S. Suhartini., and B.R. Widiatmono. (2011). The Performance of Natural Filter in Treating Tapioca Wastewater with and without Aeration. *J. Agric. Food. Tech.* Volume 1: 204 – 211.

Luthfi, M. (2000). The effect of both bed filter thickeness and kind trickling filter media on various flowrates to decrease. *Jurnal Teknologi Pertanian,* Volume 1: 40 – 44.

Mai, H.N.P. (2006). Integrated Treatment of Tapioca Processing Industrial Wastewater Based on Environmental Bio-Technology. *PhD-thesis*. Wageningen: Wageningen University.

Mavrov, B. (2000). Reduction of water consumption and wastewater quantities in the food industry by water recycling using membrane processes. *Desalination,* Volume 131: 75 – 86.

Razif, M., V.E. Budiarti and S. Mangkoedihardjo. (2006). Appropriate fermentation process for tapioca's wastewater in Indonesia. *J. Applied Sci.*, Volume 6: 2846 – 2848.

Ridgway, H. H. (1999). Controlling of overfilling in food processing. *J. Material Processing Technol.*, Volume 93: 360 – 367.

Radojevic's, M., N. V. Bashkin. 1999. *Practical Environmental Analysis*. London: The Royal Society of Chemistry.

Sugiharto, 1987. Dasar-Dasar Pengolahan Air Limbah (The Basics of Wastewater Treatment). Jakarta: Universitas Indonesia Press.

Suprapti, L. 2005. Tepung Tapioka Pembuatan dan Pemanfaatannya (Tapioca Starch: Processing and Utilisation). Yogyakarta: Penerbit Kanisius.

Suyasa, I.W.B., W. Dwijani. (2008). Kemampuan Sistem Saringan Pasir-Tanaman Menurunkan Nilai *BOD* dan *COD* Air Tercemar Limbah Pencelupan (The ability of the sand-plant filter system to reduce the BOD and COD concentration of the dye polluted water). *Ecotrophic*, Volume 2: 1 – 7.

Wang, Y., J. Banziger., P.L. Dubin., G. Filippelli and N. Nurage. (2001). Adsorptive Partitioning of an Organic Compound Onto Polyelectrolyte Immobilized Micelles on Porous Glass and Sand. *Environ. Sci. Technol.* Volume 35: 2608 – 2611.