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Optimization of Domestic Wastewater Treatment with Biological Aerated Filter (BAF) Method Based on Bioball

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ABSTRACT

Domestic wastewater treatment using Biological Aerated Filter (BAF) method based on bioball is a technological innovation that combines biological and physical processes to improve effluent quality. This study studied the use of a Biological Aerated Filter (BAF) modified with bioball media and variations in residence time to improve waste treatment efficiency and ensure effluent quality by established standards. The study consisted of four stages: preparation, seeding and acclimatization, use of Biological Aerated Filter (BAF), and analysis of the results. The prepared waste samples are domestic liquid waste from shopping centers that have known sample parameters as influential. Seeding and acclimatization are carried out in BAF reactors. Waste was treated through BAF with variable residence time, then analyzed by testing procedures based on \SNI 6989.72: 2009. The results showed that the bioball media in the BAF reactor were more effective than without media, showing a decrease in TDS (92% in 6 hours), TSS (86%), and an increase in COD and BOD efficiency. Effluent pH results are constant at 6-7 as per environmental standards. Obtaining higher process efficiency required a combination of wastewater treatment methods.

***Keywords*:** aerated, biological, domestic, filter, wastewater.

1. INTRODUCTION

Domestic wastewater treatment is very important to preserve the environment and public health. Wastewater that is not treated properly can contaminate drinking water sources, cause the spread of disease, and disrupt the balance of local ecosystems. Domestic wastewater, especially from shopping malls, contains various pollutants such as organic matter, oils, fats, and chemicals that can damage aquatic ecosystems.

For example, one of the shopping centers in the Dinoyo-Malang area which has complete outlets including department stores, playgrounds, cinemas, bookstores, and restaurants has effluent test results, namely Biological Oxygen Demand (BOD) of 283 mg/L, Chemical Oxygen Demand (COD) of 10,683. 8 mg/L, Total Suspended Solid (TSS) of 521.7 mg/L, and fatty oils of 79.2 mg/L. The parameters did not meet the quality standards set by the regulation of the Minister of Environment and Forestry number 68 years (2016) BOD 30 mg/L, COD 100 mg/L, TSS 30 mg/L, and fatty oil 5 mg/L. These conditions can damage aquatic ecosystems if disposed of without adequate treatment.

One method that can be used to treat domestic waste is the Biological Aerated Filter (BAF) method. BAF combines biological and filtration processes, whereby microorganisms grown in the media in the BAF reactor degrade organic matter in the waste, while the filter media captures suspended particles. In the BAF method, the addition of oxygen to the wastewater [1]. The addition of oxygen is one of the efforts to capture pollutants that depend on the water so that the concentration of pollutants will disappear or even be eliminated. The main purpose of the aeration process is so that O_2

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in the air can react with actions in the processed water. The reaction of cations and oxygen produces oxidation of metals that are difficult to dissolve in water so that they can precipitate. The benefits obtained from this process are the disappearance of taste and odor, the disappearance of unnecessary gases (CO_2, methane, hydrogen sulfide), and increasing the acidity of water (because CO_2 levels are removed) [2].

The BAF treatment is usually used for wastewater treatment with a BOD load that is not too large [3]. The selection of the BAF method is based on its effectiveness and efficiency in reducing pollutants. In addition, the advantages of BAF processing are low cost, safety, and easier of operation because it does not produce gas explosions, has the potential to eliminate odors, less volatile reduction, and is suitable for digesting processes that have mud content with high nutrient levels [4]. The selection of BAF is also supported by the results of research showing that bioball media in BAF can improve the efficiency of waste treatment. The BAF process was able to reduce the organic substance content to 93.14%; the BOD value decreased to 64.76%; and the TSS value decreased to 99.97% [5]. Ablution waste treatment with the BAF method using activated carbon showed a decrease in TSS value from 165 mg / L to 0 mg/ L; on COD from 103.9% to 7.49%; and on BOD from 4.6 mg / L to 2.3 mg/L [6]. The effect of the BAF process to decrease COD content in rubber liquid waste was able to show a decrease in COD concentration before processing by 2400 mg/L while after processing the concentration dropped to 200 mg / L. Some factors that affect the domestic wastewater treatment process using the BAF method are oxygen/air discharge, pH, nutrients, residence time, and the number of microbes.

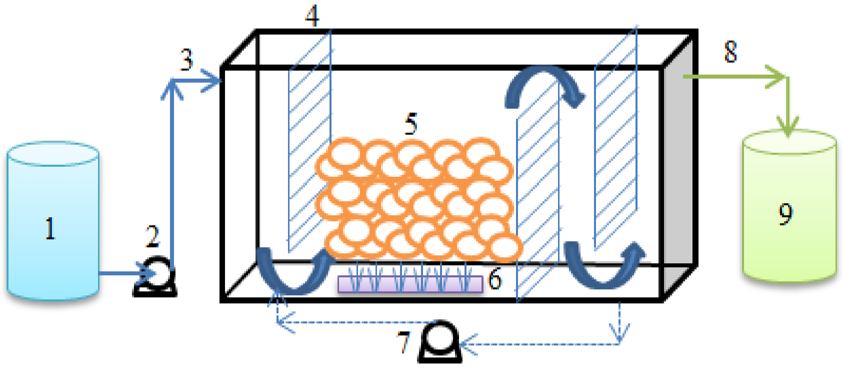
Based on the above description, it will be studied and analyzed the effect of the BAF method modified with a bioball filter and variation of residence time (4 and 6 hours). The parameters analyzed were pH, Total Dissolved Solid (TDS), TSS, Turbidity, BOD, and COD. This research is expected to produce wastewater treatment technology in shopping centers that is more applicable and produce effluent quality by established quality standards.

2. RESEARCH METHODS

In the research steps, there are four (4) stages of preparation, seeding and acclimatization, biological aerated filter (BAF), and analysis of the results.

2.1. Preparation

Liquid waste samples were taken from the influent WWTP shopping center which has parameters pH = 6, TDS = 3,378 mg/L, TSS = 434 mg/L; turbidity = 826 NTU; COD 6,310 mg/L and BOD = 2,373 mg / L. The BAF reactor is designed for batch processing at 3-point installation. The first Buffle regulates the direction of the incoming influence from top to bottom, aiming to expand contact with the bioball medium. The second and third baffles set the flow direction for recirculation before exiting into the effluent. The BAF reactor is arranged as shown in Figure 1:



Keterangan:
1. Influent Tank
2. Inlet Pump
3. Reactor Inlet
4. Baffle
5. Bioball Media
6. Aerator Diffuser
7. Circulation Pump
8. Reactor Outlet
9. Effluent Tank

Figure 1. Filter Biological Aeration Reactor.

The BAF reactor used is 4 (four) pieces having a capacity of 25 liters (containing liquid) and equipped with 3 baffles. The inlet and cycle pumps used power of 10 watts, output 1700 liters/hour, and height of 1.7 meters. The diffuser aerator used is round with a size of 5 centimeters. BAF reactors are composed of media and without media. The media used is a bioball made from PVC, ball-shaped, diameter of 3.8 centimeters, and blue.

2.2. Seeding and Acclimatization

Seeding is the process of breeding microorganisms into a new environment and acclimatization is the process of adaptation of the organism to the environment or new media. The media used for seeding is liquid waste to be treated with a volume of 10% of the total liquid waste to be treated (20 liters). During the 14-day seeding process, bacterial cultures were given nutrients that had the following composition: glucose 10 g, NH4Cl 1 g, KH2PO4: 0.2 g, MgSO4 0.04 g, CaCl2.2h2o 0.6 g and 1 liter of aquadest. The acclimatization process is carried out in batches by adding new media, namely liquid waste from the same source as much as 10% of the total waste volume. The acclimatization process is carried out every 3 days with continuous circulation. Seeding and acclimatization are carried out simultaneously in the BAF reactor.

2.3. Biological Aeration Filter Process (BAF)

Influential domestic liquid waste from shopping centers of as much as 20 liters flowed into the BAF reactor with a flow rate of 5 liters/hour or 3.33 liters/hour (adjusted for residence time variables of 4 and 6 hours). The influence will come into contact with bacteria that have grown, either with media or without media. Effluent is collected in the tank and taken samples for analysis every 2 hours. In this study, there are 4 (four) treatments for waste samples, namely a) treatment with a residence time of 4 hours and without media; b) treatment with a residence time of 4 hours and with bioball media; c) treatment with a residence time of 6 hours and without media; and d) treatment with a residence time of 6 hours and with bioball media.

2.4. Wastewater Quality Analysis

Wastewater quality parameters analyzed include pH using a pH meter, Total Dissolved Solid (TDS) using a TDs-meter, Total Suspended Solid (TSS) using a method based on SNI 06-6989.3-2004 on the method of testing Total Suspended Solid in water and wastewater, Turbidity using turbidity-meter, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) using a method based on SNI 6989.72:2009 on water and wastewater.

3. RESULTS AND DISCUSSION

3.1. Analysis of Data on the Process of Seeding and Acclimatization

During the process of seeding and acclimatization microorganisms in the sample were given nutrients to meet the needs and growth and reproduction during the adaptation phase. In this process, the environmental conditions or growth media of microorganisms must be maintained and controlled so that the adaptation process is optimal. The main condition that must be maintained is acidity (pH) because pH can affect the growth, digestion, and metabolic processes of bacteria [7]. The addition of nutrients also serves to maintain the acidity of the environment where microorganisms grow. The results of the analysis of the pH value after daily administration of nutrients ranged from 4.1 to 6. Based on the results of the one-way ANOVA analysis, F_{count} = 0.5774 > $F_{critical}$ = difference in pH value due to the addition of nutrients. Hydrolysis of organic materials in wastewater produces fatty acids that lower the pH so that the addition of nutrients is needed to maintain pH. Seeding and acclimatization pH range between 4.1 – 6.6 [8].

In the seeding process in the BAF reactor, the bacterial growth curve can be seen in Figure 2:

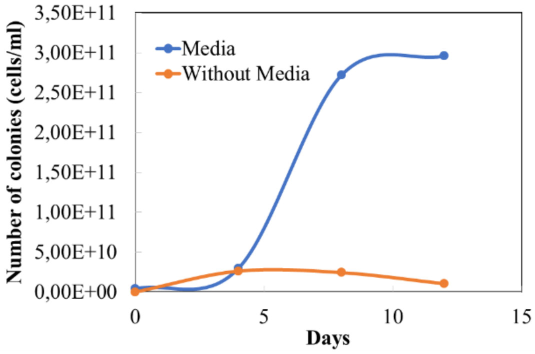


Figure 2. Bacterial growth curve in the seeding and acclimatization process.

The bacterial growth curve in Figure 2 shows that bacterial growth in reactors equipped with bioball media is more optimal than bacterial growth in non-media reactors. The results of the one-way ANOVA analysis is $F_{count} = 0.3559 > F_{critical} = 0.05$, meaning that the use of bioball media in the process of seeding and acclimatization affects bacterial growth. Bioball Media is a place for the growth and development of microorganisms that will coat the surface of the media to form a thin layer and degrade organic matter in liquid waste [9].

Table 1. Analysis Results of Wastewater Treatment using the BAF Method.

Media	Sample	pH	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	COD (mg/L)	BOD (mg/L)
Environmental Quality Standards		**6-9**	**2.000**	**<30**	**-**	**<30**	**<100**
Residence Time = 4 Hour							
None	Influent	6	3.958	478	615	5.080	2.179
	Effluent	6	1.616	190	585	4.300	1.287
	% decline	**constant**	**59%**	**60%**	**5%**	**15%**	**41%**
Bioball	Influent	6	3.178	475	710	7.100	2.468
	Effluent	6	1.176	125	540	4.220	1.346
	% decline	**constant**	**63%**	**74%**	**24%**	**41%**	**45%**
Residence Time = 6 Hour							
None	Influent	6	2.370	313	814	6.430	2.294
	Effluent	6	1.834	233	387	3.570	1.136
	% decline	**constant**	**23%**	**26%**	**52%**	**44%**	**50%**
Bioball	Influent	6	4.005	471	1.165	6.630	2.549
	Bioball	7	315	67	365	3.370	1.175
	% decline	**constant**	**92%**	**86%**	**69%**	**49%**	**54%**

3.2. pH Analysis

The pH value of effluent tends to be constant in the neutral range of 6-7. Based on Regulation of the Minister of Environment Forestry No. 68 of 2016, the permissible pH threshold of water to wastewater is 6 to 9. Effluent pH results showed that the media in the BAF reactor does not affect the pH value. Previous studies have shown that the type of gravel and bioball media does not change the pH value of wastewater [10]. The residence time also does not affect the pH value of the effluent. The pH value is the optimum acidity (range 5.8 – 8.2) for the growth and development of microorganisms [11].

3.3. TDS Analysis

TDs (Total Dissolved Solid) is a solid (all minerals, salts, metals, and anion cations) that decomposes and dissolves in water. Shopping center wastewater treatment using the BAF method with bioball media was able to reduce the TDS value by 63% for a residence time of 4 hours and 92% for a residence time of 6 hours. In the process at the BAF reactor, bioball media containing high-capacity microorganisms will capture solids carried away by waste by forming a layer of dirt on the surface of the media [12]. The value of TDs in effluent is still quite high, so it needs further processing efforts. Some waste samples need to be processed in an integrated manner depending on the nature of the waste, treatment capacity, and available costs. Methods that can be used to reduce the combination of TDS values include reverse osmosis, ion dispersal, electrocoagulation, or chemical deposition process [13].

3.4. TSS Analysis

Total Suspended Solids (TSS) in domestic wastewater is the total amount of solid particles floating in the wastewater. TSS can come from a variety of sources, including food waste and other organic materials dissolved in wastewater at the affectivity of shopping centers. The results in Table 1 showed that the greatest decrease in the value of Total Suspended Solids (TSS) was in the BAF process with bioball media, namely 74% for 4 hours and 86% for 6 hours. the use of ball media is more effective in reducing TSS pollutant parameters because it has a larger and more porous surface so that it can provide an optimal place for the growth of microorganisms and the attachment of pollutants. Bioball media can also act as a physical filter, holding and capturing solid particles to reduce the value of TSS [10].

On the other hand, the value of TSS effluent has not met the quality standard of Regulation of the Minister of Environment Forestry No. 68 of 2016 which states the maximum value of TSS is < 30 mg / L. Liquid waste from this shopping center has very varied characteristics every day because the source of pollutants from various processes with a large capacity so that a combination of liquid waste treatment methods is needed to lower the TSS value. Some alternatives that can be used in combination to reduce TSS are coarse filter, sedimentation, fine filtration, or coagulation-flocculation methods [14].

3.5. Turbidity Analysis

Turbidity is an indicator of turbidity of wastewater, which is caused by solid particles dissolved in it. The results in Table 1 showed that the decrease in turbidity values in reactors with bioball media was higher (69%) than without media (24%). Turbidity value is influenced by the remains of organic matter obtained from activities in shopping centers, especially foodcourt areas. The decrease in turbidity value is because, during the treatment process in the BAF reactor, sludge or solids stick to form a thick layer to reduce turbidity in the effluent [15]. The length of residence time also affects the turbidity value, the longer the contact time in the BAF reactor, the more solid particles are trapped to form Floc, thus reducing the turbidity of effluent.

3.6. COD Analysis

Chemical Oxygen Demand (COD) is a measure of the amount of oxygen needed to oxidize organic materials in wastewater to carbon dioxide (CO_2) and water. The results in Table 1 showed that the greatest decrease in COD was in the BAF process with bioball media, which was 41% for 4 hours and 49% for 6 hours. The value of cod effluent has not met the Regulation of the Minister of Environment Forestry No. 68 of 2016 which states that the minimum COD limit is 100 mg / L. The COD Parameter has the highest value in shopping center domestic waste. Some of the things that affect them are the source of pollutants that come from foodcourt containing fats, oils, and cleaning agents are high so that oxygen is needed high enough to decompose the organic compounds. The need for oxygen to decompose the compound is measured at high COD values. The value of COD in effluent >1000 mg/L, shows that the BAF method needs to be combined with other methods so that bs lowers COD according to Environmental Quality Standards. Alternative processing methods that can significantly decrease the value of COD are aerobic/anaerobic processing, chemical oxidation, or adsorption [16].

3.7. BOD Analysis

According to the Indonesian Environment & Forestry Regulation No. P.68 / Menlhk-Setjen/2016 on domestic wastewater quality standards states that the maximum BOD level is 30 mg/L [17]. The results in Table 1 show the value of BOD effluent for all variables is still > 1,000 mg/L, meaning that the value of BOD effluent has not met the quality standards. However, the processing process using the BAF method can reduce BOD levels, the most significant variable is the decline in the BAF process with bioball media which is 45% for 4 hours and 54% for 6 hours. One of the sources of pollutants in shopping centers that cause high BOD values is leftover laundry water from foodcourts containing organic matter. Through the method of BAF wastewater containing organic matter will flow into the media, and microorganisms that are based in the media will eat the organic matter to reduce the levels of BOD. This process is also called biodegradation by microorganisms. In addition, the oxidation process with excess air supply encourages organisms to oxidize organic matter into simpler compounds [18].

4. CONCLUSION

The results of data analysis of wastewater treatment of shopping centers by the BAF method showed that the pH of effluent tends to be stable in the neutral range, which is the optimal condition for the growth of microorganisms. The use of bioball media in BAF helps in capturing solids carried by waste, resulting in a decrease in the efficiency of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). However, the COD parameter still shows high values, indicating the need for improvement in the organic processing process. Various factors such as residence time, pH, nutrients, and the number of microbes proved to have a significant influence on the effectiveness of wastewater treatment processes. Therefore, an in-depth understanding of these factors is essential to improve WWTP efficiency and ensure that wastewater can be better treated by established standards.

REFERENCES

[1] B. Manirakiza, A. Cemenovich, Bioaugmentation of nitrifying bacteria in up-flow biological aerated filter's microbial community for wastewater treatment and analysis of its microbial community, *Sci. African*, vol. 14, pp. e00981, 2021.

[2] B. C. Ningtias, S. S. Moersidik, C. R. Priadi, N. I. Said, Pengolahan Air Limbah Domestik Dengan Anoksik-Aerobik Moving Bed Biofilm Reactor (Studi Kasus : Penyisihan Amonia dan Karbon dalam Air Limbah Domestik), *J. Air Indones.*, vol. 8, no. 2, pp. 177–188, 2015.

[3] R. H. Indriatmoko, I. Ikbal, R. Nugroho, S. Setiyono, Aplikasi IPAL Biofilter pada Pengolahan Air Limbah Industri Makanan (Kapasitas 75 m^3/Hari), *J. Air Indones.*, vol. 10, no. 2, pp. 79–89, 2018.

[4] F. N. Rochim, A. Slamet, Perencanaan Instalasi Pengolahan Air Limbah (IPAL) Sentra Wisata Kuliner Bratang, *J. Tek. ITS*, vol. 11, no. 3, pp. 88–92, 2022.

[5] A. Asadiya, N. Karnaningroem, Pengolahan Air Limbah Domestik Menggunakan Proses Aerasi, Pengendapan, dan Filtrasi Media Zeolit-Arang Aktif, *J. Tek. ITS*, vol. 7, no. 1, pp. 18–21, 2018.

[6] E. P. Hadisantoso, Y. Widayanti1, R. H. Adawiyah, V. Amalia, G. G. A. Delilah, Pengolahan Limbah Air Wudhu Wanita dengan Metode Aerasi dan Adsorpsi Menggunakan Karbon Aktif, *al-Kimiya*, vol. 5, no. 1, pp. 1–6, 2018.

[7] F. N. Rimadhini, S. Sumardianto, R. Romadhon, Aktivitas Antibakteri Isolat Bakteri Asam Laktat dari Rusip Ikan Teri (*Stolephorus* Sp.) dengan

Konsentrasi Gula Aren Cair yang Berbeda, *J. Ilmu dan Teknol. Perikan.*, vol. 2, no. 1, pp. 54–63, 2020.

[8] R. Gunawan, A. Kahar, Pengaruh Laju Alir Resirkulasi pada Seeding dan Aklimatisasi Limbah Cair Pabrik Kelapa Sawit (LCPKS) dalam Bioreaktor Anaerobik, *in Prosiding Seminar Nasional Teknologi V*, pp. 122–129, 2019.

[9] V. Z. Atiqoh, M. Apriani, U. P. Astuti, Seeding dan Aklimatisasi Tutup Botol Plastik Bekas Sebagai Alternatif Media Biofilter Aerobik untuk Mengolah Air Limbah Restoran Cepat Saji, *Conf. Proceeding Waste Treat. Technol.*, vol. 5, no. 1, pp. 215–220, 2022.

[10] F. D. Apema, D. E. Rahayu, F. Adnan, W. Waryati, Penggunaan Media Sarang Tawon dan Bioball pada Pengolahan Limbah Cair Laundry, *J. Tek. Lingkung.*, vol. 7, no. 1, pp. 81–89, 2023.

[11] Y. Yasmarli, A. Ahmad, Edward HS, Pengaruh terhadap Alkalinitas, Asam Volatil dan PH dalam Pengolahan Sludge Instalasi Pengolahan Air Limbah (IPAL) Pulp dan Kertas Menggunakan Bioreaktor Hibrid Anaerobik, *Jom FTEKNIK*, vol. 3, no. 1, pp. 1–11, 2016.

[12] K. Khofifah, M. Utami, Analisis Kadar *Total Dissolved Solid* (TDS) dan *Total Suspended Solid* (TSS) pada Limbah Cair dari Industri Gula Tebu, *Indonesian J. Chem. Res.*, vol. 7, no. 1, pp. 43–49, 2022.

[13] W. Putri, A. Nur, Review Pengolahan Air Limbah Menggunakan Upflow Anaerobic Sludge Blanket (UASB) di Negara Berkembang, *J. Civ. Eng. Vocat. Educ.*, vol. 10, no. 2, pp. 753–765, 2023.

[14] S. Martini, E. Yuliwati, D. Kharismadewi, Pembuatan Teknologi Pengolahan Limbah Cair Industri, *Jurnal Distilasi*, vol. 5, no. 2, pp. 26–33, 2020.

[15] M. N. Ainurrofiq, Purwono, M. Hadiwidodo, Studi Penurunan TSS, *Turbidity*, dan COD dengan Menggunakan Kitosan dari Limbah Cangkang Keong Sawah (*Pila ampullacea*) sebagai Nano Biokoagulan dalam Pengolahan Limbah Cair PT. PHAPROS, Tbk Semarang, *J. Tek. Lingkung.*, vol. 6, no. 1, pp. 1–7, 2017.

[16] N. N. Larasati, S. Y. Wulandari, L. Maslukah, M. Zainuri, K. Kunarso, Kandungan Pencemar Detejen dan Kualitas Air di Perairan Muara Sungai Tapak, Semarang, *Indones. J. Oceanogr.*, vol. 3, no. 1, pp. 1–13, 2021.

[17] Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia, Baku Mutu Air Limbah Domestik, Permen Nomor: P.68/Menlhk-Setjen/2016, 2016.

[18] R. M. As'ari, A. Syafiuddin, A. A. Adriansyah, B. Setianto, Fitoremediasi Air Limbah Tempe Menggunakan Tumbuhan Kayu Apu (*Pistia stratiotes*), *J. Kesehat. Masy.*, vol. 10, no. 5, pp. 564–569, 2022.