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COMBINATION OF ANAEROBIC-AEROBIC BIOFILTER METHODS IN LIQUID WASTE TREATMENT

Kombinasi Metode Biofilter Anaerob-Aerob pada Pengolahan Limbah Cair

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ABSTRAK

Limbah cair merupakan hasil buangan berupa cairan yang muncul selama kegiatan produksi berlangsung. Umumnya limbah langsung dibuang ke perairan tanpa proses pengolahan. Hal ini beresiko terjadinya kerusakan lingkungan. Penelitian ini bertujuan untuk mengetahui kualitas parameter TSS, BOD, COD, minyak lemak, amoniak, phospat dan total coliform pada limbah cair domestik setelah dilakukan perlakuan dengan metode biofilter anaerob-aerob. Metode yang digunakan yaitu true experiment dengan rancangan pretest-posttest. Populasi sekaligus sampel penelitian adalah limbah cair domestik sebanyak 490 liter. Analisis data dilakukan dengan uji Paired T-Test. Hasil pengukuran awal menunjukkan parameter BOD 32mg/l, TSS 41mg/l, COD 118mg/l, amoniak 12mg/l, minyak lemak 9,3mg/l, phospat0,26 mg/l dan total coliform 8980. Sedangkan pada kelompok setelah perlakuan parameter TSS19,3 mg/l, BOD 22,667mg/l, COD 87,667mg/l, minyak lemak 5,2mg/l, amoniak 4,4mg/l, phospat 0,11mg/l dan total coliform 4940/100 ml. Disarankan bagi peneliti berikutnya yang akan melanjutkan penelitian ini untuk menambahkan kaporit sebagai tahap akhir pengolahan guna membunuh bakteri pada limbah cair domestik.

***Kata kunci**: biofilter anaerob-aerob, limbah cair domestik*

ABSTRACT

Liquid waste is waste in the form of liquid that arises during production activities. Generally, waste is disposed of directly into waterways without undergoing any treatment process. This poses a risk of environmental damage. This research aimed to determine the quality of TSS, BOD, COD, oil and fat, ammonia, phosphate, and total coliform parameters in domestic wastewater after treatment using the anaerobic-aerobic biofilter method. The method used is a true experiment with a pretest-posttest design. The research population and sample consisted of 490 liters of domestic wastewater. Data analysis was conducted with a Paired T-Test. Initian measurements of parameters show BOD 32mg/l, TSS 41mg/l, COD 118mg/l, ammonia 12mg/l, oil and fat 9,3mg/l, phosphate 0,26mg/l and total coliform 8980. Meanwhile, in the group after treatment the TSS parameters were 19,3mg/l, BOD 22,667mg/l, COD 87,667mg/l, oil and fat 5,2mg/l, ammonia 4,4mg/l, phosphate 0,11mg/l and total coliform 4940/100ml. It is recommended that future researchers who continue this research add chlorine as a final treatment step to kill bacteria in domestic wastewater.

Keywords: anaerobic-aerobic biofilter, domestic liquid waste

INTRODUCTION

Liquid waste is the liquid waste produced during production activities. Generally, this waste is collected and then processed, although in some cases, it is discharged directly into surrounding waters. This practice is risky because it can cause contamination with hazardous substances. The toxins in this waste are difficult for natural microorganisms in the environment to break down.[1] Therefore, processing liquid waste before disposal is an important step to prevent environmental damage.[2]

To minimize the environmental impact of liquid waste disposal, proper

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management is necessary. One crucial step is understanding the characteristics of the waste so that its management can be carried out effectively and safely. Liquid waste can be classified into three categories: physical, chemical, and biological. Physical parameters include temperature, color, odor, and turbidity, while chemical parameters include BOD, COD, hardness, pH, and other indicators.[3] Meanwhile, the biological aspect includes various types of organisms found in liquid waste.

The primary goal of liquid waste treatment is to separate or remove substances from wastewater. These substances can be dissolved or solid materials that can potentially harm the treatment system or equipment. Furthermore, if left untreated, these substances can disrupt or hinder subsequent wastewater treatment processes. Therefore, the initial treatment stage is crucial for ensuring safe handling of liquid waste. With proper treatment, negative impacts on the environment and infrastructure can be minimized.

Anaerobic-aerobic biofilter is a wastewater treatment method that utilizes microorganisms in the process.[4] This method uses a biological approach by integrating anaerobic and aerobic processes. This study aims to determine the quality of TSS, BOD, COD, fatty oil, ammonia, phosphate, and total coliform parameters in domestic wastewater after treatment with the anaerobic-aerobic biofilter method.

METHODS

This research was conducted in 2023 in Bengkulu. This research is a true experiment with a pretest-posttest design with a control group. The study population was domestic liquid waste, with a sample of 490 liters. The data collected included primary and secondary data. The variables in this study were dependent variables, independent variables, and control variables. The dependent variables were TSS levels, BOD levels, COD levels, Ammonia levels, oil and fat levels, phosphate levels, and Total Coliform. The treatment of domestic liquid waste treatment with an anaerobic-aerobic biofilter system was determined as the independent variable in this study. The control variables were domestic liquid waste samples before treatment (pretest) and a control group without treatment. The instruments used included a pH meter, a thermometer, and laboratory test equipment for the analysis of TSS, BOD, COD, Ammonia, Oil & Fat, Phosphate, and Total Coliform.

The method of data collection is by taking samples of domestic liquid waste for initial measurements (pretest) of all pollutant parameters according to the quality standards of the Minister of Environment and Forestry Regulation No. P.68/2016.[5], then treatment was carried out. Repeat measurements (3 times) for each parameter. The data obtained were then analyzed using univariate and bivariate analysis, with the application of the Paired T-Test.

RESULTS

Table 1. Initial Measurement Results of Pollutant Levels

Parameter	Unit	Analysis results	Mark Quality standards	Note
pH	-	7.79	6–9	MS
Temperature	OC	27	27	-
BOD	Mg/L	32	30	TMS
TSS	Mg/L	41	30	TMS
COD	Mg/L	118	100	TMS
Ammonia	Mg/L	12	10	TMS
Oil and fat	Mg/L	9.3	5	TMS
Phosphate		0.26	0.2	TMS
Total *Coliform*	Amount/ 100ml	8980	1000	TMS

Referring to Table 1, initial measurement results showed BOD of 32 mg/L, TSS of 41 mg/L, COD of 118 mg/L, ammonia of 12 mg/L, oil and grease of 9.3 mg/L, phosphate of 0.26 mg/L, and total coliform of 8980/100 ml. These values are still above the quality standards stipulated in the Regulation

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of the Minister of Environment and Forestry.[5]

Table 2. Distribution of Average Parameter Levels

Parameters/Repetition	Control	*Post Test*
TSS level (mg/L)		
1	28	19
2	26	20
3	25	19
Average	26.3	19.33
BOD level (mg/L)		
1	27	25
2	28	23
3	27	20
Average	27.3	22.67
COD level (mg/L)		
1	92	90
2	90	88
3	91	85
Average	91	87.67
Oil and Fat (mg/L)		
1	8.6	5.3
2	8.7	5.4
3	8.4	4.9
Average	8.57	5.2
Ammonia (mg/L)		
1	8.6	4.4
2	8.2	5.2
3	9.7	3.7
Average	8.83	4.4
Phosphate (mg/L)		
1	0.24	0.11
2	0.21	0.12
3	0.22	0.1
Average	0.22	0.11
Total Coliform (100/ml)		
1	8980	4940
2	8980	4940
3	8980	4940
Average	8980	4940

Laboratory examination in table 2 with 3 repetitions shows that in the control group, the highest values for TSS levels are 280mg/L, BOD 28mg/L, COD 92mg/L, fatty oil 8.7mg/L, ammonia 9.7mg/L, phosphate 0.24mg/L, and total coliform 8980. And the highest values in the post-test group for TSS levels are 20mg/L, BOD 25mg/L, COD 95mg/L, fatty oil 5.4mg/L, ammonia 5.2mg/L, phosphate 0.12mg/L, and total coliform 4940.

Based on Table 3, most water quality parameters showed significant improvement after treatment. TSS decreased significantly between pre–control (Δ = 29.66; p = 0.02) and pre–post (Δ = 15.6; p = 0.006). BOD also showed significant reductions for pre–control (Δ = 4.67; p = 0.005) and pre–post (Δ = 9.33; p = 0.023). COD declined markedly in both comparisons (Δ = 27; p = 0.000 and Δ = 30.33; p = 0.002). Ammonia levels dropped significantly (pre–control Δ = 3.16; p = 0.019; pre–post Δ = 7.5; p = 0.03). Oils and fats showed improvement only in the pre–post comparison (Δ = 4.1; p = 0.001). Phosphate also decreased significantly post-treatment (Δ = 0.15; p = 0.001), while total coliforms showed no significant change (Δ = 6960; p = 0.180).

Table 3. Differences in Parameters in the Pre, Control, and Post Groups

Treatment Variable	Mean	SD	SE	*p*-value
TSS				
Pre and Control	29.66	2.08	1.20	0.002
Pre and Post	15.6	2.09	1.17	0.006
BOD				
Pre and Control	4.67	4.67	0.33	0.005
Pre and Post	9.33	2.51	1.45	0.023
COD				
Pre and Control	27	1.0	0.57	0,000
Pre and Post	30.33	2.51	1.45	0.002
Ammonia				
Pre and Control	3.16	0.77	0.44	0.019
Pre and Post	7.5	0.75	0.43	0.03
Oils and Fats				
Pre and Control	0.73	0.15	0.08	0.14
Pre and Post	4.1	0.26	0.15	0.001
Phosphate				
Pre and Control	0.03	0.01	0.008	0.53
Pre and Post	0.15	0.01	0.005	0.001
Total Coliform				
Pre-Control	6960	2856	2020	0.180
Post				

DISCUSSION

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The anaerobic–aerobic biofilter combination is a combination of mechanistically complementary stages: the anaerobic process is more efficient in decomposing organic waste due to strong substrate degradation (reducing initial COD/BOD, producing less sludge) and energy savings, while the aerobic stage continues the oxidation of residual organic matter and improves effluent quality (e.g., reducing dissolved BOD, partial nitrification). This combination provides greater organic load reduction and more stable effluent than either stage alone, especially for domestic or industrial wastewater with medium to high organic content.[6]

The effectiveness of this combined anaerobic-aerobic biofilter method also excels in terms of design simplicity, relatively low investment costs, ease of operation, and scalability for wastewater with low to moderate organic loads. For BOD/COD/TSS parameters, this biofilter method shows competitive reductions compared to conventional activated sludge systems under certain load conditions, but activated sludge often produces effluent with better microbiological quality when supported by a disinfection process. For industrial wastewater with very high organic content or for energy recovery needs, large anaerobic reactors (UASB, CSTR) or other integrated systems may be more effective. This biofilter is also suitable as a cost-effective solution for small to medium-scale plants, or as a pretreatment stage before further processing.[7]

The consideration for selecting this method is the operational and maintenance costs of the biofilter system, which is more energy efficient because aeration is reduced in the anaerobic stage and produces less sludge, so the potential costs are lower, and it is also easy to apply in the field.[8]

The main factors affecting biofilter performance are temperature, pH, dissolved oxygen (DO), influent organic loading rate (OLR)/BOD, hydraulic retention time (HRT), and media characteristics (surface area, porosity). Temperature changes affect microbial activity; DO is important for the aerobic stage; pH affects the balance of the microbial community, especially in the anaerobic stage.[9]

The potential for implementation at the household/MSME scale is quite good because the biofilter design is relatively simple, does not require large aeration equipment (if anaerobic integration is first introduced), and can be manufactured with locally available media. For industrial scale, design modifications are required: increased size (HRT), hydraulic control, pretreatment to reduce coarse particles or toxic substances, and integration of disinfection and odor control units. The literature on scalability indicates that scale-up procedures (calculation of HRT, EBRT, specific media area) must be adapted—as well as pilot testing—before commercial implementation. We therefore recommend medium-scale pilot testing to optimize HRT, media, and disinfection systems (e.g., chlorination/UV) before industrial implementation.[10]

Field tests conducted included temperature, pH, and DO. The temperature was 27 degrees Celsius, and the pH was 7.9, indicating normal wastewater pH, as it ranges between 6 and 9. Meanwhile, wastewater pollutant parameters such as TSS, BOD, COD, ammonia, oil and grease, phosphate, and total coliform are explained below.[11]

Decrease in TSS Levels

The initial TSS value before processing reached 41 mg/L, which exceeds the quality standard of 30 mg/L.[5] The highest TSS value in the control group was 28 mg/l, and 20 mg/L was the highest value in the treatment group.

Based on the bivariate test results, the difference between the pre- and control groups was 14.67 with a standard deviation of 1.52 and a p-value of 0.004, indicating a significant difference because the p-value was

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less than 0.05. In the pre- and post-groups, it was 21.67 with a p-value of 0.00, which also indicated a significant difference.

This study demonstrated that an anaerobic-aerobic biofilter could treat restaurant wastewater with a TSS degradation efficiency of 80.2% after a retention time of 15 days. TSS, or Total Suspended Solids, are solid materials, such as sand, silt, and clay, that float and do not dissolve in water.[13] TSS is the first sediment component to form and can inhibit the production of organic matter in water. Suspended solids block sunlight from reaching the surface and into the water, preventing photosynthesis from occurring optimally.

TSS measurements are conducted to assess the level of water pollution; the higher the TSS value, the higher the level of pollution in the water, which ultimately prevents sunlight from entering the water. Floating solids are usually organic, while settled solids can be either organic or inorganic. High TSS levels can significantly disrupt the balance of aquatic ecosystems.

BOD Level Reduction

The initial BOD value before treatment reached 32 mg/L. This value exceeds the quality standard limit of 30 mg/L. The highest BOD value in the control group was 28 mg/L, while in the treatment group, the highest value was 25 mg/L. Bivariate analysis showed significant differences in the pre-control group (4.67; p=0.005) and pre-post (9.33; p=0.023).

The anaerobic-aerobic biofilter process has a significant effect in reducing BOD levels in household wastewater, as confirmed by a journal study, which stated that the combination of anaerobic-aerobic biofilters is more effective in reducing BOD levels in wastewater compared to anaerobic or aerobic biofilters alone.

High BOD values in wastewater indicate a high pollutant content, especially organic materials.[14]BOD reduction in wastewater occurs through the decomposition of organic matter by microorganisms. Microbes that form biofilms in the media use dissolved oxygen to accelerate the breakdown of organic compounds.

COD Level Reduction

The COD value of 118mg/L in the initial measurement exceeded the quality standard value of 100mg/L.[5]The results of the study showed that the highest COD levels in the control group reached 92 mg/L, and in the treatment group, it was 90 mg/L.

Bivariate testing revealed a difference of 4.67 between the pre- and control groups, with a p-value of 0.005, indicating a significant difference ($p < 0.05$). Meanwhile, in the pre- and post-groups, a difference of 9.33 with a p-value of 0.023 also indicated a significant difference.

The use of anaerobic–aerobic biofilters has an effect on reducing COD concentrations in household wastewater, as confirmed by previous studies, which stated the effectiveness of this method in reducing COD.[15]

High COD values in wastewater indicate a predominant concentration of organic pollutants. COD reduction occurs due to the activity of microorganisms that degrade organic compounds during the treatment process. Biofilms formed on the surface of the media use dissolved oxygen to accelerate the decomposition of organic matter in the wastewater.

Ammonia Level Reduction

The initial ammonia level of 12 mg/L has exceeded the established quality standard of 10 mg/L.[5]The results of the study showed that the highest ammonia value in the control group reached 9.7 mg/L, and 5.2 mg/L was the highest value in the treatment group.

Based on the bivariate test, the difference between the pre- and control groups was 4.67 with a standard deviation of 4.67 and a p-value of 0.005, indicating a significant difference because the p-value was less than

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0.05. Meanwhile, the difference between the pre- and post-groups was 9.33 with a standard deviation of 2.51 and a p-value of 0.023, which also indicated a significant difference. The anaerobic-aerobic biofilter process has been proven to be effective in reducing ammonia levels in household wastewater.[16]

Wastewater with high ammonia levels reflects a high level of pollution, especially that originating from organic material content.[17] Reduction of ammonia levels in the wastewater treatment process is caused by the decomposition of organic compounds by microorganisms.[18]

Reducing Oil and Fat Levels

The initial oil and fat content ratio before processing was 9.3 mg/L, exceeding the established quality standard of 5 mg/L.[5]The highest value of oil and fat in the control group was 8.7 mg/L, and reached 5.4 mg/L in the treatment group.

Bivariate testing showed a difference of 0.73 between the pre- and control groups with a p-value of 0.14, indicating no significant difference ($p > 0.05$). Conversely, the difference between the pre- and post-groups was 4.1 with a p-value of 0.001, indicating a significant difference ($p < 0.05$).

High oil and grease levels occur because there is no dedicated filtering system. This results in a foul odor. The foul odor arises because the water is covered in oil and grease, preventing oxygen from entering. Therefore, the application of anaerobic-aerobic biofilters is crucial for reducing oil and grease content in domestic wastewater. This process can reduce concentrations from 28 mg/L to 1 mg/L, with an efficiency of 28.57%.[12]

Decreased Phosphate Levels

The initial level before processing for phosphate value was 0.26mg/L, this value exceeds the quality standard of 0.2mg/L.[5]The results of the phosphate examination in the control group showed the highest value was 0.24 mg/l and in the treatment group the highest value was 0.12 mg/l.

Bivariate analysis showed that the difference between the pre- and control groups was 0.03 with a standard deviation of 0.01 and a p-value of 0.53, indicating no significant difference ($p > 0.05$). Conversely, the comparison between the pre- and post-groups resulted in a difference of 0.15 with a standard deviation of 0.01 and a p-value of 0.001, confirming a significant difference ($p < 0.05$). A significant decrease in phosphate was observed on days 0, 3, 6, and 9, with ANOVA showing a p-value < 0.05.

The anaerobic–aerobic biofilter method with stones as a bacterial biofilm medium plays a role in reducing phosphate levels in domestic liquid waste.[19.20]The bacteria then grow and form a biofilm on the surface of the rock, so that the activity of decomposing organic compounds in the form of phosphate increases during the observation period, which results in an increasing portion of phosphate that can be degraded.

Coliform Level Reduction

The initial measurement results before processing for the total coliform value were 8980, this value exceeded the permitted quality standard value of 1,000.[5]The total coliform test results for the highest treatment value were 4940 and a p-value of 0.180, indicating no significant difference (p-value > 0.05). The high coliform levels were due to the lack of further treatment, namely chlorination. The high total coliform levels necessitate optimization of the wastewater treatment plant (WWTP) evaluation.[21]

This research focuses on domestic wastewater, a significant public issue. The strength of this research lies in its robust experimental design. This study employed a true experiment design with a pretest-posttest, resulting in more valid results in demonstrating the effects of anaerobic-aerobic biofilter

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treatment. This study also employed comprehensive parameter testing, assessing various pollutant parameters (TSS, BOD, COD, ammonia, oil & grease, phosphate, and total coliform), providing a comprehensive picture of wastewater quality before and after treatment.

Significant results across multiple parameters are also a strength of this study. A significant reduction ($p < 0.05$) was observed in almost all pollutant parameters except total coliforms, demonstrating the effectiveness of the anaerobic-aerobic biofilter method.

Despite these advantages, there are limitations, as it is not yet effective in reducing Total Coliform. Results indicate high levels of pathogenic bacteria due to the lack of a disinfection (chlorination) step in the final process. Due to the limited scale of the study, with only 490 liters of wastewater sampled, it is not necessarily representative of a large-scale operation. Furthermore, the duration and operational conditions were not detailed, with no detailed information available regarding retention time, operating temperature, or variations in pollutant load.

The research findings can inform policies and development programs to encourage communities to process liquid waste before disposal. This method can be further developed for applications in areas with limited resources. Anaerobic-aerobic biofilters can be a realistic and scalable alternative for industry to efficiently treat wastewater while preserving the environment. This method offers a cheaper and easier-to-operate wastewater treatment solution than conventional methods, making it suitable for small businesses and MSMEs that often face cost constraints. Furthermore, this technology has proven to be efficient and scalable, allowing its capacity to be adjusted to the volume of waste produced. Therefore, this system is not only suitable for small-scale use but also has the potential for larger industrial applications, as it maintains its efficiency and effectiveness in supporting environmentally friendly waste management.[22]

CONCLUSION

The results of the study showed that the anaerobic-aerobic biofilter method was able to significantly reduce the levels of domestic wastewater pollutants in almost all tested parameters. After treatment, the average TSS levels decreased from 41 mg/L to 19.3 mg/L, BOD from 32 mg/L to 22.67 mg/L, COD from 118 mg/L to 87.67 mg/L, ammonia from 12 mg/L to 4.4 mg/L, oil and fat from 9.3 mg/L to 5.2 mg/L, and phosphate from 0.26 mg/L to 0.11 mg/L. Statistical tests showed significant differences ($p < 0.05$) in most parameters, except for total coliform which was still relatively high (from 8980 to 4940/100 ml) and did not show any significant differences. These results indicate that the combination of anaerobic–aerobic biofilters is effective in reducing the load of organic pollutants, although further steps, such as chlorination, are still needed to suppress the levels of pathogenic bacteria.

The anaerobic-aerobic biofilter method has proven effective in improving the quality of domestic wastewater by reducing the main pollutant parameters (TSS, BOD, COD, ammonia, oil and grease, and phosphate) to near or within the established quality standards. However, high levels of total coliform indicate the need for additional treatment processes in the form of disinfection to ensure environmentally safe wastewater quality. With the advantages of relatively low costs, ease of operation, and treatment effectiveness, this biofilter system has the potential to be applied not only at the household or MSME scale, but can also be developed for industrial scale with capacity adjustments and the integration of advanced technology.

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The results of the study are expected to further researchers who want to conduct research can continue this research by adding chlorine, ozonation, UV or additional filtration as the final treatment of bacteria killers in domestic liquid waste to increase the effectiveness of coliform reduction; For the community to pay attention to domestic liquid waste that comes out of their respective housing, there should be liquid waste processing; And commitment and guidance are needed for the community to process domestic liquid waste as an effort to prevent negative impacts on environmental pollution.

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