VOLUME 11 NOMOR 2 DECEMBER 2024 ISSN 2548 – 611X

JURNAL
BIOTEKNOLOGI & BIOSAINS INDONESIA

Homepage Jurnal: http://ejournal.brin.go.id/JBBI/index

COMBINED TREATMENT OF LANDFILL LEACHATE USING COAGULATION-FLOCCULATION AND ANAEROBIC-AEROBIC BIOFILTER WITH BIOBALL

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ABSTRACT
Piles of waste in landfills can produce leachate that smells bad and contains organic and inorganic materials as well as some pathogenic bacteria. A biofilter is a simple method that can be used to degrade pollutant parameters dissolved in leachate. This research aims to determine the efficiency value of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solid (TSS) concentrations in the leachate of Blandongan Landfill, Pasuruan City. The leachate treatment process uses the coagulation method as pretreatment with aluminum sulfate coagulants ($Al_2(SO_4)_3$) and Ferric Chloride ($FeCl_3$) followed by biofilter using bioball media. The variables in this research were the differences in the concentration of the coagulant used and the bioball media with a height of 15 cm. The results show that in bioball media the value of reduction efficiency is better in reducing COD levels by 77.73%, BOD by 79.40%, and TSS by 81.48%. This research combines leachate treatment technology, where the coagulation-flocculation method becomes the pre-treatment of the leachate before continuing with an anaerobic-aerobic biofilter.

***Keywords**: Bioball, Biofilter, Coagulation, Flocculation, Landfill leachate*

ABSTRAK
Tumpukan sampah di Tempat Pemrosesan Akhir Sampah menghasilkan air lindi yang bau, mengandung bahan organik, anorganik, dan bakteri patogen. Biofilter merupakan salah satu metode sederhana yang dapat digunakan untuk mendegradasi polutan pada air lindi. Penelitian ini bertujuan untuk mengetahui efisiensi penurunan kadar Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), dan Total Suspended Solid (TSS) pada air lindi TPA Blandongan Kota Pasuruan. Proses pengolahan air lindi menggunakan metode koagulasi sebagai pretreatment dengan koagulan aluminium sulfat ($Al_2(SO_4)_3$) dan Ferric Chloride ($FeCl_3$) dilanjutkan dengan biofilter menggunakan media bioball. Variabel penelitian ini adalah perbedaan konsentrasi koagulan yang digunakan dan media bioball dengan tinggi 15 cm. Hasil penelitian menunjukkan pada media bioball nilai efisiensi penurunan kadar COD sebesar 77,73%, BOD sebesar 79,40%, dan TSS sebesar 81,48%. Penelitian ini menggabungkan teknologi pengolahan lindi, dimana metode koagulasi-flokulasi menjadi prapengolahan lindi sebelum dilanjutkan dengan biofilter anaerobik-aerobik.

Kata kunci: *Bioball, Biofilter, Coagulation, Flocculation, Landfill leachate*

***Received**: 29 July 2024* ***Accepted**: 10 December 2024* ***Published**: 21 December 2024*

INTRODUCTION

Every big city in Indonesia has provided a landfill. In general, landfills only focuses on waste processing. Piles of waste in landfills can produce foul-smelling leachate containing organic and inorganic materials as well as some pathogenic bacteria (Darnas et al., 2020). If this leachate enters the soil, it has the potential to contaminate groundwater and river water around the landfill which can harm public health.

One way to treat liquid waste is to use the coagulation-flocculation process. The coagulation method refers to the addition of chemicals by rapid mixing (Iwuozor, 2019). It can be used to combine colloids by destroying the stability of the colloidal particles, which is called chemical coagulation. The coagulation process requires several types of chemicals known as coagulants (Febrianti et al., 2024). Materials that are often used as coagulants are usually aluminum compounds and iron compounds. The commonly used aluminum compounds are alum ($Al_2(SO_4)_3$) and Poly Aluminum Chloride (PACl), while the iron compounds commonly used are ferrous sulfate ($FeSO_4$). These three materials are often used because of higher ability in the floc formation process and the resulting floc is more stable compared to other coagulants (Lee et al., 2014). Flocculation is the process of floc formation caused by the movement of the media (water) during the stirring process. Small particles will settle. Thus, the pollutants in the liquid waste can be reduced (Kusuma, 2021).

A biofilter is a simple method that can be used to degrade pollutant parameters dissolved in leachate (Muliyadi et al., 2024). The process of wastewater treatment with a biofilter can be carried out in aerobic, anaerobic, or a combination of anaerobic and aerobic conditions. The aerobic processing process requires a supply of dissolved oxygen for wastewater treatment (Kurniawati & Rachmanto, 2024). The anaerobic process of degradation of pollutants originating from sulfate compounds. The anaerobic-aerobic combination uses nitrate as an oxygen source to degrade wastewater (Sugito et al., 2021). The biofilter method is based on the principle of microbial growth with the attached growth method (Lago et al., 2024). Microorganisms in leachate will be attached to the biofilter and form a biofilm as a place to live (Ratnawati & Sugito, 2021). This biofilm will prevent microorganisms from being carried away by the affluent. Hence, they can degrade leachate more continuously.

Research conducted by (Wahyuni dan Sugito, 2016) showed that the treatment of pharmaceutical industrial wastewater using biofilters has an efficiency value of reducing BOD and COD each by 60%. Rezagama et al., (2016) concluded that the efficiency of reducing BOD, COD, and TSS levels in leachate treatment using coagulation-flocculation has successive values of 57%, 61%, and 16%. The coagulant dose using aluminum sulfate with a level of 18 g/L achieves optimal efficiency compared to other doses. Sayuti et al., (2015) treated batik wastewater using a ferric chloride coagulant at a dose of 4.5 g/L and was able to reduce COD by 70.96%. Research on combined coagulation-flocculation integrated biofilters is still limited, therefore this research combines these two processes. The objective of this research to examine the reduction of COD, BOD, and TSS by the coagulation-flocculation process using aluminum sulfate ($Al_2(SO_4)_3$) and ferric chloride ($FeCl_3$) as pretreatment and combined with the biofilter process using media bioballs.

RESEARCH METHODOLOGY

Landfill Leachate

The sample used for the research is leachate from the Blandongan Landfill, Pasuruan City (-7,65498, 112,936). Leachate samples were taken directly from the sedimentation tanks which were treated with a biofilter-integrated coagulation process. Analysis of the leachate characteristics was carried out by examining the levels of COD, BOD, and TSS contained in the Blandongan Landfill. The research was conducted at the Laboratory of the Department of Environment, Sanitation and Landscaping, Pasuruan City. Leachate that had been treated with coagulation and biofilter, was then analyzed in the Laboratory referring to the Leachate Landfill Quality Standards mentioned in the Regulation of the Minister of Environment and Forestry Number 59 of 2016.

Experimental Design

This research is included in the coagulation research with integrated biofilter pretreatment. The leachate treatment process uses the coagulation method as pre-treatment based on previous research where the optimal dosis is using aluminum sulfate ($Al_2(SO_4)_3$) as much as 16 g/L and ferric chloride ($FeCl_3$) as much as 7 g/L (Ratnawati et al., 2024) and biofilter media using bioballs. This research used a continuous system in general, where in principle, the leachate flowed into the reactor was then mixed with a coagulant, and went through a biofilter process within 8 hours (Ratnawati et al., 2024).

Leachate treatment of Blandongan Landfill using coagulation method integrated with biofilter using 2 reactors made of glass which were combined into one process with dimensions of 80 cm x 20 cm x 25 cm f lowing leachate with a debit of 48 L/reactor every day. Seeding and acclimatization were carried out in the biofilter reactor using bioball media for 5 days. The bioball made from PVC, ball-shaped, diameter of 3.8 cm, and black. Permanganate was tested to determine the stability of microorganisms and to dilute the sample 20 times to reduce the pollutant load (Sa'diyah et al., 2024). In the leachate treatment of Blandongan landfill using bioball media with a height of 15 cm.

The research reactor design shown in Figure 1, used a leachate reservoir buffer to facilitate the gravity flow system. The influent source of treated leachate is samples that have been diluted to reduce dissolved pollutant loads. The series of reactors is divided into four parts, the first and second tanks are for the coagulation process with alum (K1) and ferric chloride (K2), while the third and fourth tanks were for biofilters.

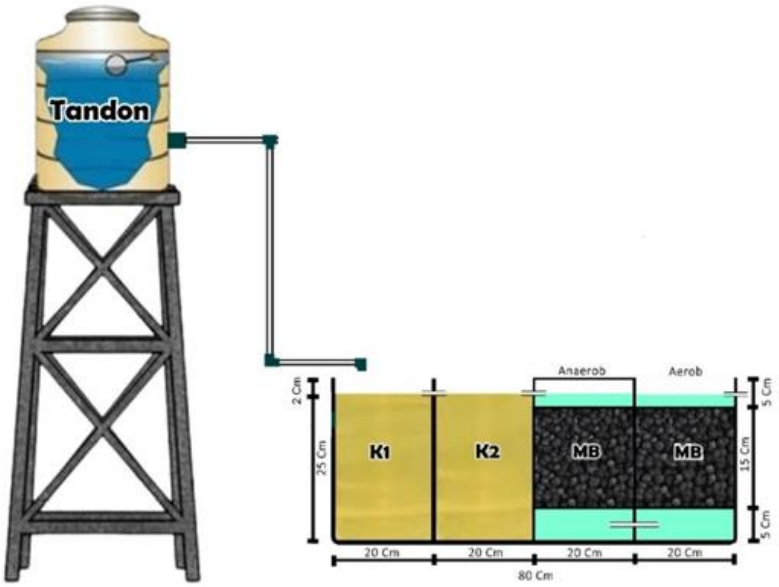

Figure 1. Design of Landfill Leachate Reactor

K1: Coagulation-flocculation process using aluminum sulfate ($Al_2(SO_4)_3$) 16 g/L
K2: Coagulation-flocculation process using ferric chloride ($FeCl_3$) 7 g/L
MB1: Biofilter anaerobic using bioball media
MB2: Biofilter aerobic using bioball media

Sample and Data Analysis

Graphical analysis was carried out to determine changes in the levels of BOD, COD, and TSS contained in the leachate. Sample analysis was carried out in duplicate. Efficiency calculations were carried out to assess the effectiveness of the pretreatment addition of coagulant and bioball media to the biofilter for treating leachate. BOD, COD, and TSS concentration levels were analyzed according to the (American Public Health et al., 2023).

RESULT AND DISCUSSION

Initial Characteristics of Leachate

The leachate used for this research was leachate obtained from wastewater treatment plant sedimentation pond in the Blandongan Landfill. Physically, the leachate used was black with initial conditions as shown in Table 1. Based on the COD, BOD, and TSS parameters, the leachate still does not meet the quality standards according to the Regulation of the Minister of Environment and Forestry Number 59 of 2016.

Table 1. The Initial Characteristics of Leachate

Parameter	Unit	Quality standards*	Results
COD	mg/L	300	5.120±42.4
BOD	mg/L	150	2.331±29.7
TSS	mg/L	100	108±2.8
pH	-	6-9	8.2±0.01
Temperature	°C	-	28.7±0.1

* Regulation of the Minister of Environment and Forestry Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities at Waste Final Processing Sites

The BOD level of 2,331±29.7 mg/L, indicated a high amount of organic matter. Thus, a large amount of oxygen is needed for the biological decomposition process (Rahmi dan Edison, 2019). The COD level of 5,120±42.4 mg/L, indicated that there were many organic compounds in the water. The value of COD is always higher than BOD. This is because many organic substances are chemically oxidized but cannot be oxidized biologically (Royani et al., 2021). The TSS level was 108±2.8 mg/L. The high level of TSS in the waste leachate is due to the accumulation of the decomposition results of organic and inorganic waste that is stockpiled in the landfill (Yatim dan Mukhlis, 2013).

pH measurements were carried out every day. Before the samples were brought to the Laboratory of the Pasuruan Regency Environmental Service. Based on (Zulius, 2017), Solutions with a pH < 7 are considered acidic, and solutions with a pH greater than 7 are said to be basic or alkaline. The initial pH value before treatment was 8.2±0.01. This condition is beneficial because the pH value was still in the pH range that is suitable for biological processing, namely 6-9. In addition, this value still met the quality standard with a set pH standard of 6-9.

Based on the research results during the running of the experiment, the pH value of the reactor was still below 6.0 or it was still acidic (Audina, 2017). According to Norjannah (2015) This drastic change in pH was due to the addition of an acidic $FeCl_3$ coagulant. Thus, the pH decreased drastically. $FeCl_3$ was a salt derived from a strong acid and a weak base, when dissolved in water, it would produce an acidic solution. The higher the addition of the $FeCl_3$ coagulant dose, the greater the percentage of acid that occurred. The normal pH of the leachate reacts with the acidic coagulant and finally resulted in an acidic wastewater condition. The higher the coagulant concentration added, the lower the pH, the higher it will be. The quality standard for the pH value, it does not meet the quality standard based on the Regulation of the Minister of Environment and Forestry Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities at Waste Final Processing Sites.

Temperature measurement can affect controlling the growth of microorganisms. Based on the results of the reactor temperature measurements, stable results were obtained which ranged from 27-28°. This showed that the temperature parameter meets the requirements for the growth of microorganisms in degrading organic matter in the biofilter reactor.

Seeding and Acclimatization

The seeding and acclimatization processes were carried out for 5 days to reach steady state conditions in the experimental reactor. Steady-state conditions can be

determined by performing the permanganate test. The seeding process is the process of growing microorganisms in the media and acclimatization is the process of adjusting microorganisms to live in the reactor (Nurhayati et al., 2022). The results of the permanganate test showed that reactor had experienced steady-state conditions on the 3rd to 5th day. Permanganate value on the 3rd, 4th, and 5th were 71.45±1.34 mg/L, 79.90±0.14 mg/L, and 80.70±0.85 mg/L. Leachate began to be processed because the growth of microorganisms in the biofilter reactor was stable.

Reducing BOD Levels in Leachate Water

The efficiency of reducing BOD levels in leachate waste treated using biofilter integrated coagulation using bioball media with a height of 15 cm can be seen in Figure 2. Based on the results of the research, it was shown that the parameters of leachate wastewater could decrease. The varied characteristics of waste in Indonesia and the suboptimal separation between hazardous and toxic and domestic waste, leachate can contain toxic materials (Ratnawati dan Ulfah, 2020). In the reactor with the type of bioball media, the lowest concentration decreased on day 5 to 480±58.21 mg/L.

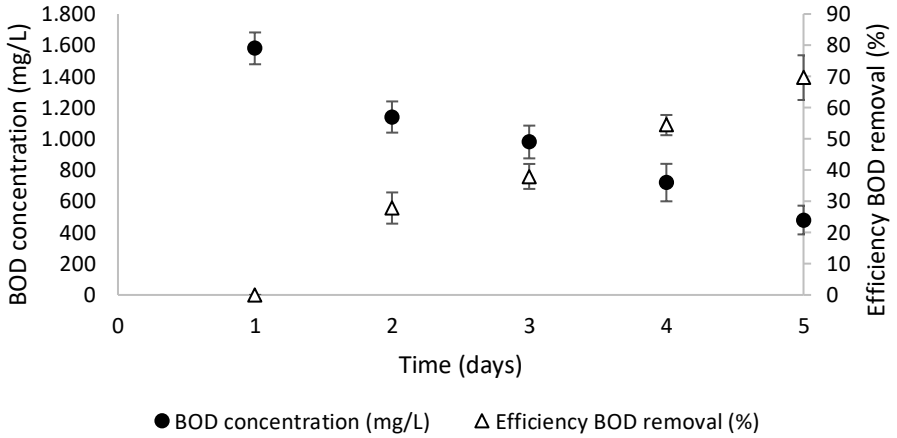

Figure 2. BOD Concentration in Landfill Leachate

The reactor with bioball media had the highest BOD concentration reduction effectiveness on day 5 at 70±7.16%. This indicated that the bioball media is overgrown with microorganisms. Thus, they can degrade organic substances. Based on this research, it can be seen that the decrease in BOD levels was less than optimal because bioballs had a small surface area. Thus, the biofilms that grow tend to be small (Rizkiyanti dan Alfiah, 2018). This decrease in BOD levels shows that microorganisms are working at optimum conditions in decomposing organic matter present in the liquid waste (Ratnawati dan Kholif, 2018; Nurhayati et al., 2022). This decrease in BOD levels showed that microorganisms were working at optimum conditions in decomposing organic matter present in the liquid waste.

The results of reducing the concentration of BOD in this research had higher efficiency than reducing the concentration of COD. The final result of BOD concentration did not meet the quality standards set by the Minister of Environment and Forestry Regulation Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities for Waste Final Processing Sites with a maximum quality standard of 150 mg/L. In addition, different coagulant doses did not impact on BOD decreased of each days (P_{value}>α, α=0.05).

Reducing COD Levels in Leachate Water

The efficiency of reducing COD levels in leachate waste that was processed using integrated coagulation pretreatment integrated biofilter using bioball media with a height of 15 cm can be seen in Figure 3. Based on the results of the research, it was shown that the parameters of leachate wastewater could decrease. The results of the above research can be seen in the

bioball reactor. There was a decrease in concentration on the 5th day of 560±55.00 mg/L. This is indicates that the activity of microorganisms is still in the adaptation stage and grown on all bioball surfaces (Widyastuti et al., 2021).

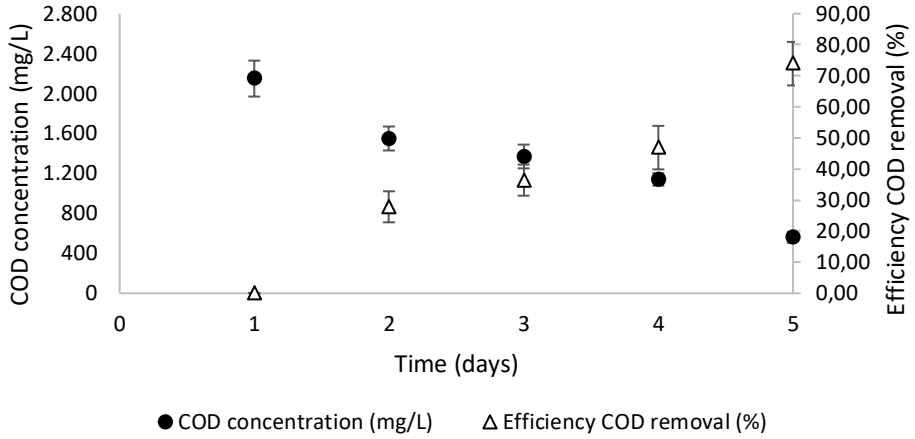

Figure 3. COD Concentration in Landfill Leachate

Bioball media had the highest effectiveness in reducing COD concentrations on day 5 at 74±7.00%. This is influenced by the bioball which functions as a place for bacteria to live and is needed to degrade organic matter in water (Filliazati, 2013; Ratnawati dan Sugito, 2021). In addition, the high value of efficiency on day 5 is due to the activity of microorganisms which are more effective in reducing COD contaminants (Kholif et al., 2021; Ratnawati et al., 2020). Reduced organic matter in the waste would reduce the COD value because the oxygen used by microorganisms to decompose these organic substances in five days becomes reduced (Widiyati, 2013). The results of reducing COD concentrations in this research did not meet the quality standards set by the Regulation of the Minister of Environment and Forestry Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities for Waste Final Processing Sites with a maximum quality standard of 300 mg/L. In addition, the study also showed that different coagulant doses were no significant on TSS decreased (P_{value}>α, α=0.05).

Reducing TSS Levels in Leachate Water

TSS is classified into organic solids and suspended solids and suspended solids which can be organic or inorganic (Hasanah dan Sugito, 2017). The reduction in TSS levels in leachate waste which was processed using integrated coagulation biofilter using bioball media with a height of 15 cm can be seen in Figure 4. The research showed that the TSS of leachate decreased. The decreased in efficiency occurred due to the processing of organic matter by microorganisms that grow attached to the biofilter media (Wardhani et al., 2015). The results of the research can be seen in the bioball media reactor. The TSS concentration final of 8±2.20 mg/L.

Bioball media had the highest effectiveness in reducing TSS concentrations on day 5 at 80±4.95%. One of the influential factors in TSS removal is the diameter of the media used. The size of the media affects the removal of organic matter because the media on the biofilter has a filtration function. The TSS content can be filtered through the gaps in the media and the biofilm that wraps the surface of the media (Fitri et al., 2016; Ratnawati dan Ulfah, 2020). The results of reducing the concentration of TSS in this research met the quality standards set by the Minister of Environment and Forestry Regulation Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities for Waste Final Processing Sites with a maximum quality standard of 100 mg/L. The study also showed that different coagulant doses had no impact on TSS decreased of each days (P_{value}>α, α=0.05).

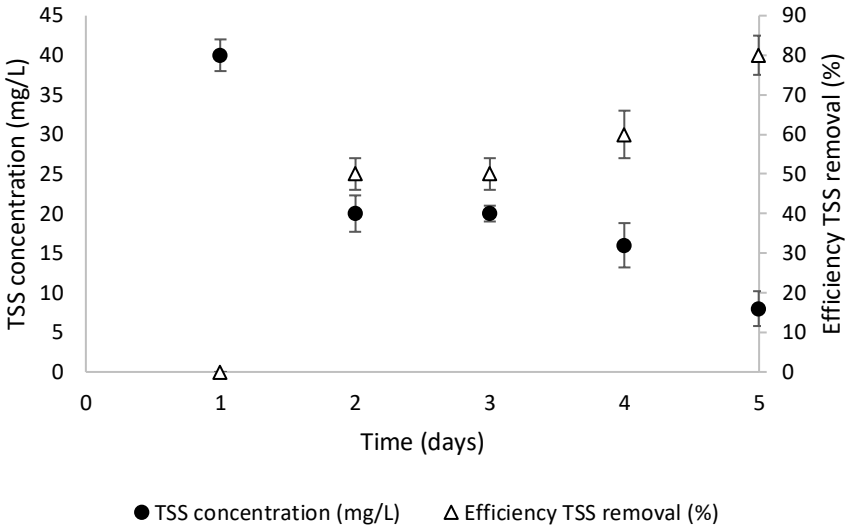

Figure 4. TSS Concentration in Landfill Leachate

The bioball media reactor had a higher TSS concentration reduction effectiveness from day 1 to day 3 of 81.48% (Figure 4). On the 5th day, the bioball media was saturated, due to a large number of suspended particles such as dissolved organic matter, bacteria, and other organisms in the wastewater, causing high levels of TSS to be obtained (Ramadhani, 2017). The death of microorganisms can increase the amount of dissolved sludge content so that the TSS level becomes high.

CONCLUSION

Based on research that has been carried out on leachate from Blandongan landfill, Pasuruan City. It was treated with coagulation pretreatment integrated with biofilter using bioball media. It can be concluded that COD concentrations, BOD, and TSS final of 480±92.00 mg/L, 560±55.00 mg/L, and 8±2.20 mg/L. The efficiency of reducing BOD, COD and TSS levels respectively of 70±7.16%, 74±7.00%, and 80±4.95%. In addition, different coagulant doses did not impact on BOD decreased, COD, and TSS of each days (P_{value}>α, α=0.05). It is recommended that this research be implemented at leachate processing plants at final waste processing sites throughout Indonesia.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Research and Public Service of the Universitas PGRI Adi Buana for the Adi Buana Research Grant, contract No. 190.15/Kontrak/LPPM/IX/2022. We also thank to the Sanitation and Landscaping Service of Pasuruan City, which manages the Blandongan Landfill as the location for conducting the research, and the Laboratory of the Pasuruan Regency Environmental Service, which has assisted in carrying out the analysis of treated water samples to test the parameters of this research.

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