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UTILIZATION OF LANDFILL LEACHATE AS LIQUID ORGANIC FERTILIZER THROUGH FERMENTATION PROCESS WITH THE ADDITION OF *AZOSPIRILLUM SP.*

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Abstract

This study investigates the utilization of landfill leachate as a raw material for producing liquid organic fertilizer (LOF) through a fermentation process with the addition of Azospirillum sp. The research focuses on evaluating the effects of different dilution levels (20×, 40×, 60×, and 80×) and a 14-day fermentation period under anaerobic conditions on the quality of the resulting fertilizer. The results showed that the 20× dilution produced the most optimal conditions, yielding macronutrient contents (N, P_2O_5, and K_2O) that met the national quality standards for liquid organic fertilizer. Additionally, a decrease in heavy metal concentration, particularly Lead (Pb), was observed during fermentation, indicating improved environmental safety of the final product. Although the C-organic and Fe contents were below the required limits, the neutral pH and absence of microbial contamination confirmed that the fertilizer is environmentally safe for agricultural application. Overall, this study demonstrates that the fermentation of landfill leachate with the addition of Azospirillum sp. provides a sustainable and eco-friendly approach for converting waste into a value-added product that supports environmentally responsible agriculture.

Keywords: *Biofermentation; Azospirillum sp.; landfill leachate; liquid organic fertilizer*

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1. Introduction

The amount of leachate generated at Final Processing Sites in Java Island has shown a sharp increase over the past decade. This trend corresponds with the growing

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population and the increasing volume of waste produced daily (Thomas 2019). The volume of leachate produced at TPAs is considerably large; for example, Ngipik TPA produces approximately 237.75 m^3 per day with an area of 6 hectares, Gunung Panggung TPA generates about 283.3 m^3 per day with an area of 4 hectares, and Talang Gulo Lama TPA produces around 249.4 m^3 per day with an area of 6 hectares. The average leachate discharge from these three sites is about 256.15 m^3 per day (Jauhary, Auvaria, and Nengse 2023). This considerable volume poses a potential environmental hazard if not properly treated.

Leachate is a liquid formed as a result of the decomposition of solid waste when water usually rainfall percolates through the waste pile, dissolving and carrying various organic and inorganic substances (Sudarmaji and Prayogo 2020). This liquid is often classified as hazardous due to its toxic content and potential to carry pathogenic microorganisms (Walid et al. 2020). Furthermore, leachate typically contains heavy metals such as iron (Fe), copper (Cu), zinc (Zn), lead (Pb), cobalt (Co), boron (Br), cadmium (Cd), and mercury (Hg), which can contaminate soil and groundwater (Hidayati et al., 2021). The presence of these pollutants indicates the need for appropriate treatment methods to minimize environmental and health risks.

Despite its hazardous characteristics, leachate also contains valuable nutrients, particularly nitrogen, in the forms of organic nitrogen (10–600 mg/L), ammonium nitrogen (10–800 mg/L), and nitrate (5–40 mg/L) (Rahmi 2019). Nitrogen (N) is an essential macronutrient required by plants for the synthesis of amino acids, proteins, nucleic acids, and chlorophyll. Adequate nitrogen availability supports optimal plant growth and productivity (Purba, Ningsih, and Abdus 2021). However, nitrogen content in soil is generally low, thus requiring fertilizer supplementation to meet crop needs.

Given its chemical composition and organic content, leachate possesses significant potential to be converted into liquid organic fertilizer (LOF) through biofermentation involving nitrogen-fixing bacteria. The process begins with preliminary filtration to separate solid fractions, followed by pH adjustment to the optimal range of 6.5–7.5 to create a suitable environment for fermentative microorganisms (Lesmana and Apriyani 2020). The next stage involves the inoculation of *Azospirillum* sp., a nitrogen-fixing bacterium that enriches nitrogen content in the solution (Dimiati & Hadi, 2017). The fermentation process is carried out anaerobically for 7–21 days, with periodic stirring to maintain nutrient distribution and microbial activity (Nurhasanah and Hedi 2021).

Research by Safitri & Hadi (2017) demonstrated that a 14-day fermentation of leachate with *Azospirillum* sp. effectively increased ammonium concentration from 60.2 mg/L to 300 mg/L, while reducing the BOD value from 500 mg/L to 33 mg/L and COD from 1920 mg/L to 90 mg/L. This result indicates that biofermentation not only decreases pollutant levels but also enhances the nutrient quality of the resulting liquid organic fertilizer.

The growth and activity of microorganisms during fermentation are influenced by several environmental factors, including temperature, pH, oxygen availability, salinity, and substrate concentration, all of which affect cellular metabolism stability (Susanto, 2003). Therefore, studying the growth dynamics of *Azospirillum* sp. during the biofermentation process is essential to understand biomass production and fermentation efficiency.

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This research aims to evaluate the utilization of landfill leachate as a liquid organic fertilizer through a fermentation process with the addition of *Azospirillum* sp. The research focuses on assessing the nutrient content and quality of the resulting liquid organic fertilizer (LOF). This approach offers a sustainable and environmentally friendly solution for managing landfill leachate while producing a value-added product that can replace chemical fertilizers in supporting sustainable agriculture.

2. Method

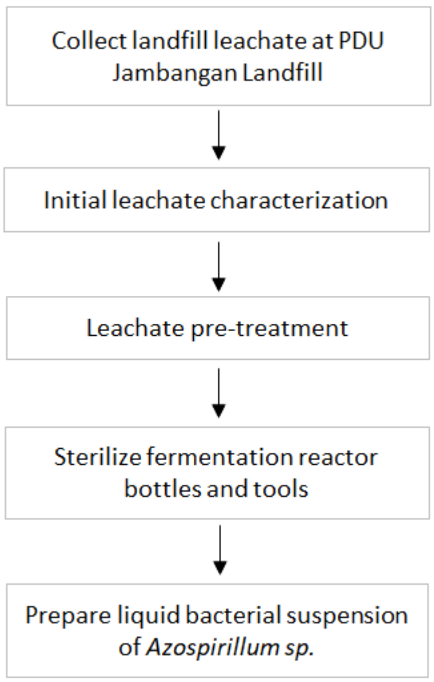
2.1 Objective and Scope of Research

This research aims to evaluate the utilization of landfill leachate as a liquid organic fertilizer through a fermentation process with the addition of *Azospirillum* sp. The study focuses on examining the effects of different leachate dilution levels and fermentation durations on the characteristics and quality of the resulting liquid organic fertilizer (LOF). The objective is to identify optimal fermentation conditions that produce nutrient-rich and environmentally friendly fertilizer suitable for sustainable agricultural applications.

2.2 Research Variables

This study consists of three groups of variables. The dependent variables include the physical, chemical, and nutrient characteristics of the resulting liquid organic fertilizer. The independent variables are the leachate dilution levels (20×, 40×, 60×, and 80×) and the fermentation durations is 14 days. The controlled variable is the fermentation environment, which was maintained in a closed and dark condition without sunlight exposure to ensure consistent fermentation performance throughout the process.

This flowchart outlines the step by step process of fermenting leachate into liquid organic fertilizer.



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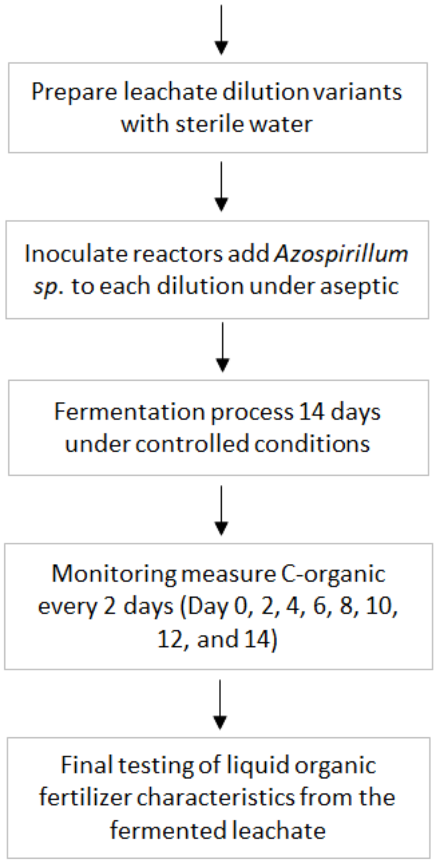

Figure 1. flowchart outlines process of fermenting leachate into liquid organic fertilizer

2.3 Research Tools and Materials

The equipment used in this study included measuring cylinders, 100 mL beaker glasses, pipettes, an autoclave, a pH meter, 1 L glass bottles, and bottle caps. All equipment was cleaned and sterilized before use to prevent contamination during the fermentation process. The materials used in this study included leachate, distilled water (aquadest), Azospirillum sp. culture, cotton, gauze, string, and label paper.

2.4 Research Implementation

The implementation of this research began with the preparation of fermentation reactors, leachate sampling, and pre-treatment prior to the biofermentation process. A total of twelve glass bottles with a capacity of 1 liter were sterilized at 121 °C for 30 minutes to ensure aseptic conditions. Each bottle was then filled with leachate collected from PDU Jambangan, Surabaya, using the grab sampling method in accordance with the Indonesian National Standard (SNI) 6989-59:2008. The collected leachate was first analyzed to determine its initial characteristics, including heavy metal concentration, C-organic content, and pH value. These parameters were measured to understand the baseline condition of the raw material prior to fermentation. The leachate samples were then subjected to filtration and heating at 75–100 °C for 30 minutes to deactivate indigenous microorganisms, ensuring that microbial activity during fermentation was solely influenced by the inoculated *Azospirillum* sp.

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Following the pre-treatment stage, pure cultures of *Azospirillum* sp. were prepared as liquid bacterial suspensions using Tryptic Soy Broth (TSB) medium. The cultures were incubated until they reached the McFarland 0.5 turbidity standard, which indicates that the bacterial concentration was appropriate for inoculation into the fermentation media. The fermentation experiment was conducted under four different leachate dilution levels—20×, 40×, 60×, and 80×—using distilled water (aquadest) as the diluent due to its neutral properties and absence of interfering compounds. The purpose of dilution was to reduce the concentration of both organic and inorganic substances present in the leachate, allowing for optimal bacterial activity during the fermentation process. Each dilution level was prepared from an initial 10 mL leachate sample, producing final volumes of 200 mL, 400 mL, 600 mL, and 800 mL, respectively.

The calculation for dilution was performed using the following formula:

$$\text{Final Volume} = \text{Dilution Factor} \times \text{Leachate Volume}$$
$$\text{Final Volume} = 20 \times 10\ \text{mL}$$
$$\text{Final Volume} = 200\ \text{mL}$$

Diluent Volume = Final Volume − Leachate Volume = 200 mL − 10 mL = 190 mL. Each treatment reactor was filled with the appropriately diluted leachate and inoculated with 10 mL of *Azospirillum* sp. suspension, while control reactors contained only leachate without bacterial inoculation. The fermentation process was maintained at a temperature of 28–30 °C for 14 days under anaerobic and dark conditions to prevent photochemical interference and ensure optimal microbial metabolism. This experimental setup was designed to evaluate the effect of varying dilution levels on the biofermentation performance of *Azospirillum* sp., particularly in terms of macronutrient enhancement and heavy metal reduction in the resulting liquid organic fertilizer (LOF).

2.5 Data Analysis

Analysis of Liquid Organic Fertilizer (LOF) Characteristics

Upon completion of fermentation, the quality of the liquid organic fertilizer was evaluated according to the parameters specified in the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 70/Permentan/SR.140/10/2011. The analysis included organic carbon content, heavy metals, pH, macronutrients (N, P, K), micronutrients (Fe), and microbial contaminants such as *Escherichia coli*. All analyses were performed using standardized laboratory methods as summarized in Table 1.

Table 1. Parameters and Methods for Liquid Organic Fertilizer Quality Testing

No	Parameter	Method	Reference Standard
1	C-Organic	Titration	SNI 19-7030-2004
2	Heavy metals (As, Hg, Pb, Cd)	ICP-MS	MU 11-2-5
3	pH	pH Meter	SNI 06-6989.11:2004
4	Nitrogen (TKN)	Kjeldahl	AOAC 976.06
5	Phosphorus (P_2O_5)	Murphy & Riley	APHA 4500-P

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No	Parameter	Method	Reference Standard
6	Potassium (K_2O)	ICP-OES	APHA 3500
7	Iron (Fe total)	AAS/ICP-OES	APHA 3500
8	*Escherichia coli*	Membrane Filtration (MPN)	SNI 01-2332.3:2015

2.6 Experimental Matrix

Throughout the fermentation process, measurements of organic carbon concentration and bacterial colony counts were conducted periodically in each reactor. Four dilution levels (20×, 40×, 60×, and 80×) were applied, each with distinct reactor codes and observed over a 14-day period. These data provided an overview of the relationship between dilution levels, fermentation duration, and bacterial activity during leachate biofermentation.

3. Results and Discussion

3.1 Initial Characteristics of Leachate

Before being used as a fermentation medium with the addition of *Azospirillum* sp., the leachate collected from PDU Jambangan, Surabaya, was first analyzed to determine its initial physicochemical characteristics. This analysis aimed to identify the baseline composition of the leachate and evaluate its potential as a suitable substrate for biofermentation. The parameters examined included C-organic content, pH, temperature, and heavy metal concentration. These data served as the foundation for assessing the leachate's quality before and after fermentation, particularly to evaluate pollutant reduction and nutrient enhancement in the resulting liquid organic fertilizer (LOF).

The initial characterization process began with filtration and pre-treatment to remove coarse particles and ensure sample uniformity. The C-organic concentration was measured using the titration method, serving as the substrate indicator for the fermentation process. The pH of the leachate was then compared to the optimal range for *Azospirillum* sp. activity (6.5–7.5), while the original leachate showed a much lower pH value. In addition, the heavy metal content was analyzed to assess potential environmental risks and to evaluate the detoxification capacity of the biofermentation process. The results of this preliminary analysis are presented in Table 2.

Table 2. Initial Characteristics of Leachate

No.	Parameter	Unit	Result
1	C-Organic	%	18.4
2	pH	–	1.67
3	Temperature	°C	30.4
4	Arsenic (As)	mg/L	0.24
5	Mercury (Hg)	mg/L	0.32
6	Lead (Pb)	mg/L	13.40
7	Cadmium (Cd)	mg/L	0.04

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The data show in table 2 that the leachate had acidic properties and contained elevated levels of heavy metals, particularly Pb, which can pose environmental hazards. Therefore, the biofermentation process using *Azospirillum* sp. was expected to improve the leachate quality, making it a safer and more nutrient-enriched raw material for producing liquid organic fertilizer (LOF).

3.2 Leachate Fermentation Results

Changes in C-Organic Concentration During Fermentation

The concentration during the fermentation process was carried out periodically over 14 days, with measurements taken every two days, specifically on days 2, 4, 6, 8, 10, 12, and 14. The determination of C-organic concentration in leachate at various dilution levels in this study was conducted using the titration method. The results of the C-organic concentration analysis are presented in Figure 1, which shows the changes in C-organic concentration throughout the fermentation process.

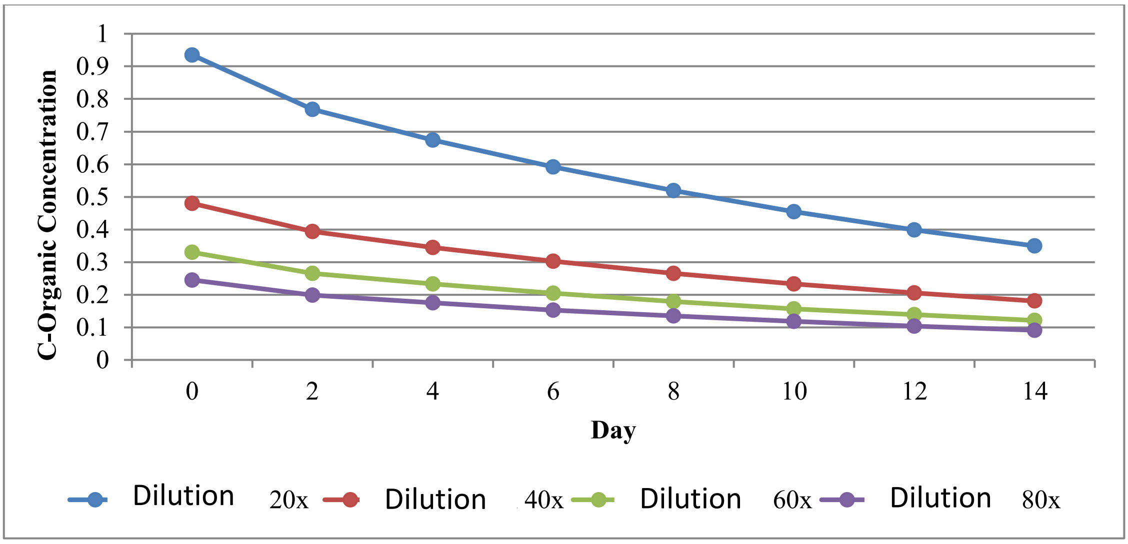

Figure 2. Changes in C-Organic Concentration During 14 Days of Fermentation

Based on Figure 1, the C-organic concentration decreased gradually across all dilution variations as the fermentation period progressed. The most significant reduction occurred at the 20× dilution, where the concentration decreased from 0.95 mg/L to 0.35 mg/L on the 14th day, indicating that Azospirillum sp. actively utilized organic compounds as an energy source during fermentation. Lower dilution levels resulted in more optimal microbial activity because the nutrient concentration remained sufficiently high to support bacterial growth, whereas at higher dilution levels (60× and 80×), the decrease in C-organic concentration occurred more slowly due to limited substrate availability. Therefore, it can be concluded that the 20× dilution provided the most efficient fermentation conditions for supporting bacterial growth and converting substrates into beneficial fermentation products.

3.3 Results of Liquid Organic Fertilizer (LOF) Characterization Tests

After the fermentation process was completed, the quality of the liquid organic fertilizer obtained was analyzed according to the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 70/Permentan/SR.140/10/2011 concerning Organic Fertilizers, Biofertilizers, and Soil Conditioners. The tested parameters included C-organic content, pH, heavy metals, macronutrients (N, P_2O_5, K_2O), micronutrients (Fe), and microbial contaminants (*E. coli*).

Table 3. Results of Liquid Organic Fertilizer (LOF) Characterization Tests

No	Parameter	Unit	Quality Standard	Test Result	Remark
1	C-Organic	%	Min. 6	0.35	Not Fulfilled
2	Heavy Metal (Pb)	ppm	Max. 12.5	12.5	Fulfilled
3	pH	-	4–9	7.4	Fulfilled
4	Nitrogen (N)	%	3–6	3.05	Fulfilled
5	Phosphorus (P_2O_5)	%	3–6	3.08	Fulfilled
6	Potassium (K_2O)	%	3–6	3.06	Fulfilled
7	Microbial Contaminant (*E. coli*)	MPN/mL	Max. 10^2	Negative	Fulfilled
8	Iron (Fe total)	ppm	90–900	0.77	Not Fulfilled

From the results table 3, it can be seen that the LOF produced through fermentation met most of the required quality standards, particularly in terms of pH and macronutrient parameters (N, P_2O_5, and K_2O). However, the C-organic and Fe total contents were still below the minimum required limits. This may be attributed to the high dilution levels and long fermentation duration, which could have caused part of the organic carbon to degrade into inorganic forms.

3.4 Discussion

The results of this study show that a 20× dilution level with a 14-day fermentation period produced the most optimal conditions for the utilization of landfill leachate as liquid organic fertilizer through fermentation with the addition of *Azospirillum* sp. The nutrient analysis of the resulting fertilizer indicated that the macronutrient contents (N, P_2O_5, and K_2O) met the minimum quality standards for liquid organic fertilizer as stated in the Regulation of the Minister of Agriculture No. 70 of 2011. This finding is consistent with the study conducted by Safitri & Hadi (2017), which reported that leachate fermentation with nitrogen-fixing microorganisms achieved optimal nutrient levels at a 50× dilution with the addition of 10 mL of bacterial inoculum. The present study supports this conclusion, as the smallest dilution (20×) resulted in the highest organic carbon (C-organic) value on the 14th day of fermentation. The high C-organic content is significant because it serves as an essential carbon source that improves soil fertility, enhances soil structure, and supports the activity of beneficial soil microorganisms contributing to nutrient availability.

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In addition, a study by Permono (2024) demonstrated that fermentation of landfill leachate using EM4 and *Pseudomonas fluorescens* produced liquid organic fertilizer with macronutrient concentrations exceeding 3%, fulfilling the standard quality requirements. This aligns with the findings of the present research, which also achieved optimal macronutrient levels at the 14-day fermentation period.

Furthermore, analysis of heavy metal content particularly lead (Pb) revealed a decrease from 13.40 mg/L to 12.50 mg/L during fermentation. This reduction indicates that *Azospirillum* sp. exhibits biosorption ability, whereby heavy metal ions are bound to the functional groups present on the bacterial cell wall, thus lowering metal concentrations in the solution. This result is in accordance with Antonia et al. (2022), who reported that *Azospirillum* sp. can reduce Pb levels through interactions between metal ions and functional groups on the bacterial cell surface. Overall, these findings demonstrate that the fermentation of landfill leachate with the addition of *Azospirillum* sp. has strong potential to produce nutrient-rich and environmentally safe liquid organic fertilizer suitable for sustainable agricultural applications.

4 Conclusion

The biofermentation of landfill leachate using *Azospirillum sp.* proved effective in transforming leachate into a safer and more nutrient-rich liquid organic fertilizer (LOF). The optimal condition was achieved at a 20× dilution with a 14-day fermentation period, producing the highest bacterial activity, efficient organic carbon utilization, and macronutrient levels (N, P_2O_5, and K_2O) that met national quality standards. Although the C-organic and Fe contents remained below the required limits, the neutral pH, reduced Lead (Pb) concentration through biosorption, and absence of microbial contamination indicate that the resulting LOF is environmentally safe and suitable for agricultural use. Overall, this study confirms that *Azospirillum sp.*-based biofermentation offers a sustainable and eco-friendly method for converting landfill leachate into valuable organic fertilizer while reducing environmental pollution.

REFERENCES

Antonia, M, A Mendoza-Herrera, V Bocanegra-García, and G Rivera. 2022. “Azospirillum Spp. from Plant Growth-Promoting Bacteria to Their Use in Bioremediation.” *Microorganisms* 10 (5): 1–13. doi:10.3390/microorganisms10051057.

Jauhary, A M, S W Auvaria, and S Nengse. 2023. “Redesain Instalasi Pengolahan Air Lindi Di TPA Ngipik, Kecamatan Gresik, Kabupaten Gresik.” *Environmental Engineering Journal ITATS* 3 (2): 80–94. doi:10.31284/j.envitats.2023.v3i2.3865.

Lesmana, R Y, and N Apriyani. 2020. “Pengaruh Air Lindi Terhadap PH Dan Zat Organik Pada Air Tanah Di Tempat Penampungan Sementara Kelurahan Pahandut Kota Palangkaraya.” *Jurnal Manusia Dan Lingkungan* 25 (2): 60–68. doi:10.22146/jml.39489.

Nurhasanah, and Hedi. 2021. “Sosialisasi Pengolahan Lindi Menjadi Pupuk Cair Di TPS-3R Kelurahan Talang Kelapa Kecamatan Alang-Alang Lebar Palembang Sumatera

Manuscript received 18 Oct 2025; revised 20 Oct 2025; accepted 21 Oct 2025

Selatan.” *Jurnal Widya Laksana* 10 (1): 36–42. https://www.researchgate.net/publication/368057569.
Purba, T, H Ningsih, and P Abdus. 2021. *Buku Tanah Dan Nutrisi Tanaman*.
Rahmi, A. 2019. “Identifikasi Pengaruh Air Lindi (Leachate) Terhadap Kualitas Air Di Sekitar Tempat Pembuangan Akhir (TPA)” 11 (1): 1–6.
Safitri, N D, and W Hadi. 2017. “Pengaruh Pengenceran Lindi Dan Penambahan Bakteri Starter Terhadap Pertumbuhan Tanaman Pangan.” *Jurnal Teknik ITS* 6 (2). doi:10.12962/j23373539.v6i2.25064.
Sudarmaji, S, and B A Prayogo. 2020. “Hubungan Pencemaran Lindi Tempat Pembuangan Akhir Sampah Benowo Dengan Kadar Merkuri (Hg) Pada Ikan Hasil Tambak Dan Kesehatan Konsumennya.” *Jurnal Kesehatan Lingkungan Unair* 4 (2): 31–38.
Thomas, D H S. 2019. “Potensi Pencemaran Air Lindi Terhadap Air Tanah Dan Teknik Pengolahan Air Lindi Di TPA Banyuroto Kabupaten Kulon Progo.” *Sustainability (Switzerland)* 11 (1): 1–14. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf.
Walid, A, R G T Kusumah, E P Putra, W Herlina, and P Suciarti. 2020. “Pengaruh Keberadaan TPA Terhadap Kualitas Air Bersih Diwilayah Pemukiman Warga Sekitar: Studi Literatur.” *Jurnal Ilmiah Universitas Batanghari Jambi* 20 (3): 1075–82. doi:10.33087/jiubj.v20i3.1025.

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