JURNAL ILMU LINGKUNGAN
Volume 23 Issue 2 (2025) : 435-442 ISSN 1829-8907

Calla Lily (*Zantedeschia aethiopica (L.) Spreng*) as a Bioremediation Agent of Jatibarang Landfill Leachate Conterminated Waters

Maria Ulfah[1]*, Luhur Pujo Santoso[1], and Atip Nurwahyunani[1]

[1]Faculty of Mathematics Education, Natural Sciences and Information Technology, PGRI University Semarang, Indonesia; e-mail: mariaulfah@upgris.ac.id

ABSTRAK

Air lindi terbentuk ketika sampah bercampur dengan air dan meresap ke dalam tanah. Air lindi mempunyai dampak yang berbahaya karena mengandung bahan pencemar organik/anorganik yang beracun, logam berat dan amonia. Banyak permasalahan yang akan timbul jika air lindi tidak diolah dan dibiarkan begitu saja. Polutan dari air lindi TPA mempunyai efek akumulatif dan merugikan terhadap ekologi dan rantai makanan. Bioremediasi efektif menyembuhkan lingkungan yang telah terkontaminasi oleh polutan dan racun. Tujuan penelitian ini adalah untuk mengetahui efektivitas Calla Lily (*Zantedeschia aethiopica (L.) Spreng*) sebagai penurun BOD dan kekeruhan lindi. Jenis penelitian ini adalah penelitian kualitatif dan disajikan secara deskriptif. Berdasarkan hasil penelitian menunjukkan bahwa calla lily mampu menurunkan BOD dan penghilangan kekeruhan, namun perlakuan yang diberikan tidak memberikan pengaruh yang signifikan. Hasil analisis menunjukkan bahwa parameter fisik dan kimia lindi di TPA Jatibarang yang melebihi baku mutu lindi adalah BOD 464 mg/L (9.2% penurunan), penghilangan kekeruhan 6.3 NTU (96.23% penurunan). Jika air lindi hanya ditampung tanpa pengolahan lebih lanjut, maka akan mengakibatkan air lindi masuk ke sungai pemukiman dan mencemari air sumur di sekitar wilayah Jatibarang dan berpotensi menimbulkan gangguan kesehatan.

Kata kunci: BOD, Bioremediasi, Kekeruhan, Calla Lily, Lindi.

ABSTRACT

The leachates are formed when the waste mixes with the water and penetrates into the ground. Leachate has a dangerous impact because it contains toxic organic/inorganic pollutants, heavy metals and ammonia. Many problems will arise if the leachate is not treated and left alone. The pollutants from landfill leachate have accumulative and detrimental effect on the ecology and food chains. Bioremediation effectively heals the environment when it's been contaminated by pollutants and toxics. The purpose of this study was to determine the effectiveness of Calla Lily (*Zantedeschia aethiopica (L.) Spreng*) as a BOD and leachate turbidity removal. This type of research is qualitative research and is presented descriptively. Based on the results of the research, it was shown that calla lily were able to reduce BOD and turbidity removal, but the treatment had no significant effect. The results of the analysis showed that the physical and chemical parameters of leachate at Jatibarang landfill that exceeded the leachate quality standards were BOD 464 mg/L (9.2% removal), turbidity removal 6.3 NTU (96.23% removal). If the leachate is only collected without further treatment, it will result in the leachate entering residential rivers and contaminating the well water in the surrounding Jatibarang area and possibly causing health problems.

Keywords: BOD, Bioremediation, Turbidity, Calla Lily, Leachate.

Citation: Ulfah, M., Santoso, L. P., dan Nurwahyunani, A. (2025). Calla Lily (Zantedeschia aethiopica (L.) Spreng) as a Bioremediation Agent of Jatibarang Landfill Leachate Conterminated Waters. Jurnal Ilmu Lingkungan, 23(2), 435-442, doi:10.14710/jil.23.2.435-442

1. INTRODUCTION

Wastes in landfills creates serious problems particularly hazardous wastes containing recalcitrant compounds (Gautam, 2021; Antony, 2020). It also frequently has a high chemical (COD) and biological oxygen demand (BOD) (Eggen et al., 2010). The landfills leachate contains macro and micropollutants that might be potentially toxic and carcinogenic (Nurhasanah & Riani, 2021). It always has a high content of suspended and dissolved matter that makes it a dangerous contaminant that must be treated to avoid it to cause contamination of aquifers, rivers, and soil, which in turn poses risk to the natural ecosystem and public health (Keyikogl et al., 2021). Landfill leachate must be appropriately treated and managed, maximizing recovery and minimizing waste disposal (Topal & Atasoy, 2022).

Waste has properties that have the potential to cause pollution and health problems if not managed properly (Teng et al., 2021). Poorly maintained landfills pose a high risk to human health and the environment (Gómez et al., 2022). Piles of rubbish can later release a black, unpleasant smelling liquid called leachate. Landfill leachate comprised of a variety of constituents and has a dark color (Elmaadawy et al., 2020). Leachate will appear in the layers of waste heaps and seep into the soil layers below. Leachate arises from the entry of water into waste heaps, leachate is a liquid effluent that originates through the interaction between rainwater and degraded waste products from landfills (Wijekoon et al., 2021), dissolving and washing away materials, including organic materials resulting from biological decomposition (Saniy, 2017). Landfill leachate, also known as leachate, is an inevitable secondary pollutant in landfill (Chengjun et al., 2021), mainly from precipitation, water contained in garbage and organic wastewater generated by anaerobic decomposition of microorganisms.

Leachate is generally toxic due to the presence of pollutants and incomplete decomposition that occurs in the waste. Leachate contains organic and inorganic materials as well as pathogenic bacteria which have the potential to cause environmental pollution (Hartini & Yanto, 2018). Leachate may contain suspended and dissolved solid pollutants, chemicals both organic and inorganic with high concentrations such as ammonia, nitrates, nitrites, sulfides, heavy metals, nitrogen, and others. If it is not managed properly, it could potentially pollute the environment and water bodies (Ahmad, 2021; Chaudhary, 2021; Vaccari, 2019). There are many kinds of pollutants, complex components and high concentration. Liu Jun et al, used GC-MS to analyze the organic components in the landfill leachate, and founded that there were 63 organic compounds, most of which were difficult to biodegrade, such as phenols, heterocyclic, heterocyclic aromatic and polycyclic aromatic compounds, accounting for more than 70% of the organic components in the leachate. High concentration of organic matter, high concentration of COD and BOD, up to tens of thousands of mg/L (Zhang, 2022).

Leachate produced from waste management at the Jatibarang landfill has the potential to cause water pollution in the Kreo River because its flow is at the lower end of the landfill. The condition of the leachate pond which is leaking also plays a role in causing pollution of the Kreo River because the leachate water will flow into the river water body. The leachate collected in the holding pond will have its material content reduced through an aeration process, then the leachate will flow into the Kreo River (Kurniawati et al., 2015). Surface water that is polluted by leachate during the biological decomposition process will deplete the oxygen content in the water and ultimately life in the water that depends on the presence of dissolved oxygen will die (Thomas & Dian, 2019).

Biological Oxygen Demand (BOD) and turbidity removal can be used as parameters in measuring water quality. The lower the BOD contained in a body of water, the better the quality of the water. Turbidity removal determines the amount of brightness entering the waters and is related to the need for sunlight for the assimilation process. Examination of BOD and turbidity removal is necessary to determine the pollution load that occurs.

Jatibarang landfill leachate had a BOD of 1,200 mg/L and a turbidity of 300 NTU (Rezagama et al., 2017). This research shows that the leachate from the Jatibarang landfill has a BOD of 1,395 mg/L and a turbidity of 300 NTU (Nofiyanto et al, 2019). It can be seen that the BOD and leachate turbidity removal of the Jatibarang Landfill each year exceed the quality standards stipulated in the Republic of Indonesia Minister of Environment and Forestry Regulation No. 59 of 2016 and RI Minister of Health Regulation no. 32 of 2017, where the BOD quality standard is 150 mg/L and turbidity removal is 25 NTU.

One effort that can be made to overcome environmental pollution due to leachate is bioremediation. Bioremediation is a series of processes for breaking down complex pollutants into molecules that are simpler and less harmful to the environment. Bioremediation is a cost effective and eco friendly technique. Bioremediation is in line with the 'green' and 'ecological' development trends and is significant in many ways for sustaining sustainable and healthy development (Tan et al, 2022). Phytoremediation is a technology that emerged as a result of the combined activities of plants and their association with groups of microorganisms to degrade, transfer and reduce toxic substances in soil and water (Sari, 2019). Phytoremediation technology consists of the use of plants to eliminate pollutants from soil, water, or air. It has been widely studied for leachate treatment due to its relative simplicity with low operational and maintenance costs, as well as being an environment-friendly system (Ilmasari, 2022; Ismail, 2020). A suitable treatment method should be affordable in terms of maintenance and operation cost, simple to use, efficient, and ecologically friendly to reduce energy consumption and surplus sludge production (Omran et al, 2021).

Hyperaccumulator plants are plants that could concentrate contaminants in their biomass at high levels (Rachmawati, 2020). Hypertolerant plants are plants that can adapt and survive environmental conditions with high levels of contaminants. Calla lily (*Zantedeschia aethiopica (L.) Spreng*) have dense, fibrous roots that spread in various directions, so they have a high ability to absorb pollutants. Calla lily have rhizosphorus which functions to carry pollutants in the planting medium to the root cells which will then be degraded by enzymes found in the roots.

Calla lily can be used as a phytoremediation agent because it is able to accumulate and decompose pollutant substances. Plants that are used as agents for absorbing heavy metals or pollutants must have phytoremediator properties, namely having hyperaccumulator properties and hypertolerance to highly polluting substances (Nofiyanto et al., 2019). In general, aquatic plants are used as aquatic phytoremediators because they have fast growth and absorption of pollutants. This research aims to determine the effectiveness of calla lily as a phytoremediation agent BOD and leachate turbidity removal.

2. METHODS

This research was carried out in Januari-February 2024 at Jatibarang Landfill, Semarang, Central Java, Indonesia. The weather in Indonesia in January-February is warm, wet and humid. According to Joel C, *et.al* (2017), the seasonal variation does not affect the performance of wastewater treatment system.

Measurements of BOD and leachate turbidity removal were carried out at the Semarang City Environmental Service Laboratory. The research is an experimental study using a one-factorial Completely Randomized Design (CRD) with three treatment levels and three replications, resulting in 9 research units. The treatment given in this research was as follows P0 (10 L of leachate without calla lily), P1 (10 L of leachate + 200 gr of calla lily), P2 (10 L leachate + 400 gr calla lily). Before the research, acclimatization was carried out on calla lily for 1 week using distilled water which aims to make calla lily can adapt to new environmental conditions.

The leachate samples used in this research were taken from the leachate reservoir of the Jatibarang Landfill. Before treatment is given, a preliminary test is carried out on leachate samples to determine the initial BOD and leachate turbidity removal. Then testing was carried out again on days 1, 3 and 7 of the research to determine the development of BOD and leachate turbidity removal during the research. The model's validity is verified by analyzing values in the ANOVA and Two-Way Analysis of Variance for BOD and turbidity removal.

3. RESULTS AND DISCUSSION

3.1. Characteristics of Jatibarang Landfill Leachate

The leachate from the Jatibarang landfill has a dark black color, cloudy, and distinctive, strong organic aroma. Physically, the leachate from the Jatibarang Landfill appears to be completely dissolved because there is no sediment at the bottom of the research unit and there are no lumps floating on the surface of the leachate. Test results for initial BOD and turbidity removal of Jatibarang landfill leachate in Table 1.

Based on the results of these data, the initial BOD and leachate turbidity removal of the Jatibarang Semarang Landfill still exceed the quality standards set in the Republic of Indonesia Minister of Environment and Forestry Regulation No. 59 of 2016 and RI Minister of Health Regulation no. 32 of 2017, where the quality standard for BOD is 150 mg/L and turbidity parameter with a value of 25 NTU.

3.2. Effect of Variables on BOD

Biological Oxygen Demand (BOD) is the amount of dissolved oxygen needed by microorganisms to decompose dissolved and suspended organic matter in waters (Anwar, 2019). BOD is an important parameter for assessing water quality that can be used to evaluate the quality of landfill leachate (Mishra et al., 2022).

Calla lily can reduce leachate BOD levels because it has properties as a hyperaccumulator and hypertolerant to pollutant substances. Data on the reduction in BOD levels during treatment can be seen in Table 2; Table 3; and Table 4.

Table 1. Characteristics of the Jatibarang Landfill Leachate

Parameter	Unit	Level	Quality Standards
BOD	mg/L	511	150
Turbidity	NTU	167	25

Table 2. BOD Level of Leachate on the 1st Day of Treatment

Treatment	Average Initial Grade (mg/L)	Final Grade Average (mg/L)	Decline (%)
P0	511	472.3	7.57
P1	511	464	9.2
P2	511	482.3	5.61

Table 3.BOD Level of Leachate on the 3rd Day of Treatment

Treatment	Average Initial Grade (mg/L)	Final Grade Average (mg/L)	Decline (%)
P0	511	464.3	9.13
P1	511	476	6.85
P2	511	477.3	6.59

Table 4.BOD Level of Leachate on the 7th Day of Treatment

Treatment	Average Initial Grade (mg/L)	Final Grade Average (mg/L)	Decline (%)
P0	511	503	1.56
P1	511	488.3	4.44
P2	511	502	1.76

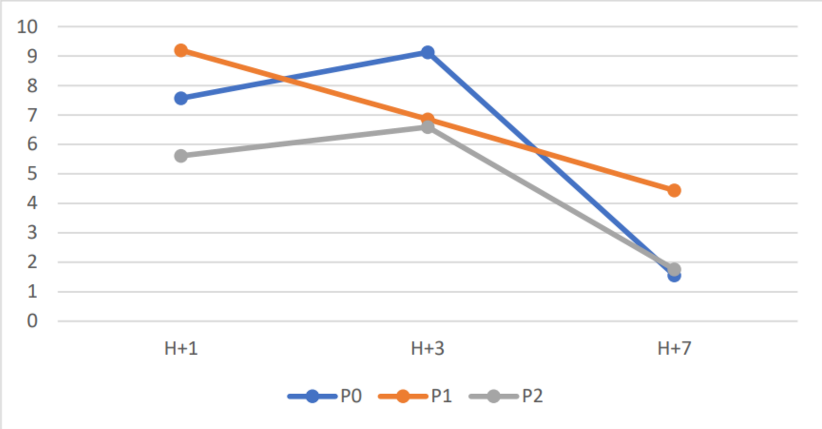

Figure 1. BOD Removal

Table 5. Two-Way Analysis of Variance for BOD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4982.519[a]	8	622.815	0.822	0.594
Intercept	6248671.148	1	6248671.148	8247.659	0.000
Concentration	574.519	2	287.259	0.379	0.69
Time	3767.185	2	1883.593	2.486	0.111
Contretation * Time	640.815	4	160.204	0.211	0.929
Error	13637.333	18	757.63		
Total	6267291	27			
Corrected Total	18619.852	26			

a. R Squared = .268 (Adjusted R Squared = -.058)

Based on ANOVA for BOD, the results were *p-value* > 0.05 it can be concluded that the average BOD on the 1st (p *value* 0.865), 3rd (p *value* 0.558), 7th (p *value* 0.194) day of treatment, content in each treatment is not significantly different. The final average BOD during the study continued to fluctuate in each treatment. The most optimal effectiveness of reducing BOD levels occurred in treatment P1 on day 1: 464 mg/L (9.2% removal); while the effectiveness of reducing BOD levels was lowest in treatment P0 on day 7 : 502 mg/L (1.56% removal) (see figure 1).

Based on Two Analysis of Variance for BOD (see table 5), the results were the sig value of 0.69 is greater than 0.05 (0.69>0.05), it can be concluded that there is no significant difference in the BOD results based on concentration treatment, the sig value of 0.111 is greater than 0.05 (0.111>0.05), then it can be concluded that there is no significant difference in the BOD results based on time treatment and the sig value of 0.929 is greater than 0.05 (0.929>0.05), then it can be concluded that there is no interaction between concentration and time treatment in the BOD results. The decrease in leachate BOD levels was caused by the phytoremediation process carried out by calla lily rhizofiltration. Rhizofiltration is the process of deposition of pollutant substances by the roots which are then translocated to the stem through transport vessels and spread to all parts of the plant (Irhamni et al. 2017). In this process, the absorbed organic substances will undergo a biological reaction and accumulate in the plant stem and then be transferred to the leaves (Ahmad & Adiningsih, 2019). The ability of calla lily to absorb organic material in leachate is also due to the presence of rhizosphere microbes in the roots. Rhizosphere microbes are a form of symbiosis between bacteria and fungi that can break down organic and inorganic materials found in water and use them as a source of nutrition (Khaer & Nursyafitri, 2017).

In the phytodegradation process, leachate organic materials will be broken down by dehalogenase and oxygenase enzymes through plant metabolic processes. The decrease in leachate BOD levels is also a result of the phytodegradation process, where organic compounds in water that are absorbed by plant roots will experience decomposition through metabolic processes in plant organs (Fitriana & Kuntjoro, 2020). Based on Abbas's research used aquatic plants for the phytoremediation of landfill leachate and reported high efficiencies in terms of BOD (Abbas et al, 2019).

The ability of calla lily to excrete certain chemical compounds can degrade organic materials trapped in the root area and then the degraded organic materials will be easier to translocate to the stems and leaves. Calla lilies do not directly absorb organic materials in leachate but will adapt and provide conditions that allow the decomposition process of organic materials by microorganisms.

The decrease in leachate BOD levels was also caused by the presence of lactic acid bacteria (*Lactobacillus sp.*) in leachate. Lactic acid compounds can accelerate the breakdown of organic materials through an anaerobic fermentation process (Damsir et al. 2016). Renovating microbes will carry out the process of breaking down organic materials into simple compounds such as amino acids and fatty acids until ammonia, nitrate, nitrite, and nitrogen are obtained. The longer the time for the anaerobic process to take place and the easier the organic material degradation process in the leachate to occur, the lower the leachate BOD level will be, the closer it is to the quality standard value that is safe for the environment. Therefore, during the anaerobic process, leachate BOD levels fluctuate at any time because of the use of organic material by microbes to be converted into body cells and other harmless compounds and some are converted into volatile materials, such as CO_2.

During the research, leachate BOD levels tended to fluctuate, indicating that the decomposition process of leachate organic material was still ongoing by microorganisms. The fluctuating increase in leachate BOD levels in P1 and P2 indicates that the calla lily was less able to contribute significantly to reducing the total organic matter in the leachate. Parts of calla lily that cover the surface of the leachate will prevent sunlight from entering the bottom of the water, so that photosynthetic organisms cannot photosynthesize properly. This causes dissolved oxygen levels in the leachate to decrease, so that the decomposition process of organic material by aerobic microorganisms is disrupted. Dead plant parts become a source of aquatic organic matter. The biomass of dead calla lily will mix with leachate, resulting in an increase in leachate organic matter and BOD levels will increase again.

3.3. Effect of Variables on Turbidity Removal

Turbidity removal is a condition where the transparency of a liquid is reduced due to the presence of insoluble substances (Fajri et al., 2014). Turbidity levels are influenced by the presence of suspended solids, both organic and inorganic. High levels of turbidity removal in waters will disrupt the penetration of light entering the waters. Calla lily could reduce leachate turbidity because they are hyperaccumulators and hypertolerant of pollutants. Data on reducing turbidity in leachate during treatment can be seen in Table 6; Table 7; and Table 8.

Table 6. The Turbidity of Leachate on the 1st Day of Treatment

Treatment	Average Initial Grade (NTU)	Final Grade Average (NTU)	Decline (%)
P0	167	7.47	92.53
P1	167	6.99	95.81
P2	167	6.82	95.91

Table 7. The Turbidity of the Leachate on the 3rd Day of Treatment

Treatment	Average Initial Grade (NTU)	Final Grade Average (NTU)	Decline (%)
P0	167	6.9	95.88
P1	167	6.5	96.11
P2	167	6.3	96.23

Table 8. The Turbidity of Leachate on the 7th Day of Treatment

Treatment	Average Initial Grade (NTU)	Final Grade Average (NTU)	Decline (%)
P0	167	6.58	96.06
P1	167	7.15	95.72
P2	167	7.06	95.77

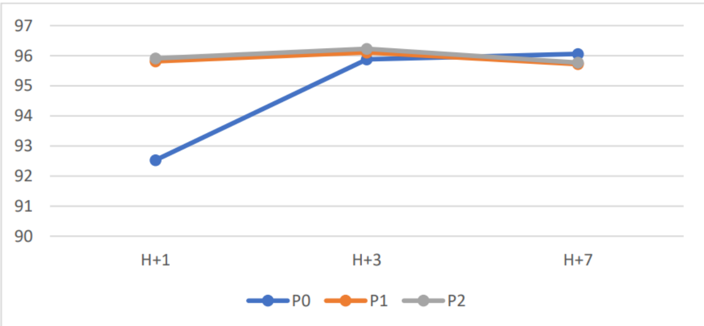

Figure 2. Turbidity Removal

Table 9. Two-Way Analysis of Variance for Turbidity Removal

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.296[a]	8	0.412	4.295	0.005
Intercept	1257.199	1	1257.199	13106.44	0.000
Concentration	0.134	2	0.067	0.699	0.510
Time	1.135	2	0.568	5.917	0.011
Contretation* Time	2.026	4	0.507	5.281	0.005
Error	1.727	18	0.096		
Total	1262.221	27			
Corrected Total	5.022	26			

a. R Squared = .656 (Adjusted R Squared = .503)

Based on ANOVA for turbidity, the results were p *value* > 0.05 it can be concluded that the average turbidity removal on the 1st (*p value 0.194*) and 7th (*p value 0.480*) day of treatment, content in each treatment is not significantly different, For 3rd day of treatment (*p value 0.019*), the results were p *value* < 0.05 it can be concluded that the average turbidity removal, content in each treatment is significantly different. Abilities of calla lily in reducing leachate turbidity due to its hyperaccumulator and hypertolerant properties. In this study, the most optimal percentage reduction in leachate turbidity occurred in treatment P2 on the 3rd day: 6.3 NTU (96.23% removal). Meanwhile, the lowest percentage reduction in leachate turbidity removal occurred in the P0 treatment on 1st day: 7.47 NTU (92.53% removal) (see figure 2).

Based on Two Analysis of Variance for turbidity (see table 9), the results were the sig value of 0.51 is greater than 0.05 (0.51 >0.05), so it can be concluded that there is no significant difference in the turbidity result based on concentration treatment, the sig value of 0.011 is less than 0.05 (0.011<0.05), so it can be concluded that there is a significant difference in turbidity results based on time treatment, and the sig value of 0.005 is less than 0.05 (0.005<0.05), then it can be concluded that there is an interaction between concentration and time treatment in the turbidity results.

Suspended solids are closely related to turbidity removal, the higher the suspended solids, the higher the turbidity (Ahmad & Adiningsih, 2019). However, high levels of dissolved solids are not always accompanied by high levels of turbidity removal. Turbidity removal is an optical property of a solution, namely the scattering and absorption of light that can pass through it. High levels of turbidity removal not only endanger aquatic biota but also cause waters to become unproductive because they can prevent sunlight from entering the waters, thereby inhibiting the photosynthesis process, and reducing dissolved oxygen levels in the water.

In the P0 treatment, the decrease in leachate turbidity removal occurred due to the decomposition of organic and inorganic materials carried out by microorganisms contained in the leachate. Meanwhile, the decrease in leachate turbidity in P1 and P2 was caused by the ability of the roots of calla lily to absorb pollutants, both in water bodies and sediment.

The ability of calla lily to absorb organic material in leachate is also due to the presence of rhizosphere microbes. Rhizosphere microbes are a form of symbiosis between bacteria and fungi that can break down organic and inorganic materials in water and use them as a source of nutrition (Khaer & Nursyafitri, 2017). The ability of calla lily and rhizospheric microbes in the roots is supported by the root's large absorption and accumulation capacity for pollutants, causing leachate turbidity to decrease. Organic and inorganic materials in leachate can be reduced by rhizospheric microbes found in the roots of calla lily. In plant roots, pollutant materials are absorbed from water bodies and sediments and then accumulated in other parts of the plant (Novita et al., 2020). The roots of the calla lily will act as a filter in the process of absorbing colloidal particles floating in water bodies. In the rhizofiltration process, plant roots will retain solid particles contained in wastewater (Nasrullah et al, 2017). Pollutant substances will be accumulated into dissolved materials in various parts of the plant, so that the level of suspended solids in the waste is reduced (Santoso et al., 2014). Reducing the value of suspended solids will be accompanied by decreasing turbidity.

Reducing turbidity removal in waters can make it easier for sunlight to penetrate the waters, so that photosynthetic microorganisms can carry out the photosynthesis process perfectly and dissolved oxygen levels in the waters increase. Waters with high levels of dissolved oxygen can support the life of aerobic microorganisms which play a role in the decomposition process of pollutants in waters. In addition, low turbidity removal in waters can reduce the incidence of disease in the digestive and immune systems, due to the low potential for contamination by viruses and bacteria that attach to suspended solids.

4. CONCLUSION

Based on the results of the study, it can be concluded as follows: The bioremediation process was used to observe the impact calla lily for the removal of BOD and turbidity from landfill leachates. In this study, the most optimal effectiveness of reducing BOD levels occurred in P1 on 1st day: 464 mg/L (9.2% removal); while the effectiveness of reducing BOD levels was lowest in P0 on 7th day: 502 mg/L (1.56% removal). The most optimal percentage reduction in leachate turbidity occurred in P2 on the 3rd day: 6.3 NTU (96.23% removal). Meanwhile, the lowest percentage reduction in leachate turbidity removal occurred in the P0 on 1st day: 7.47 NTU (92.53% removal). Leachate from Jatibarang Landfill was successfully reduced after being treated by the calla lily bioremediation process. Therefore, this indicated that the calla lily bioremediation process gave good response for the treatment of leachate samples.

REFERENCES

Abbas Z., Arooj F., Ali S., Zaheer I. E., Rizwan M. and Riaz M. A. (2019). Phytoremediation of landfill leachate waste contaminants through floating bed technique using water hyacinth and water lettuce. International Journal of Phytoremediation, 21, 1356–1367, https://doi.org/10.1080/15226514.2019.1633259

Ahmad H. A., Ahmad S., Cui Q., Wang Z., Wei H., Chen X., Ni S.-Q., Ismail S., Awad H. M. and Tawfik A. 2021. The environmental distribution and removal of emerging pollutants, highlighting the importance of using microbes as a potential degrader: a review. Science of The Total Environment, 809, 151926, https://doi.org/10.1016/j. scitotenv.2021.151926

Ahmad, H. & Adiningsih, R. 2019. Efektivitas Metode Fitoremediasi menggunakan Tanaman Eceng Gondok dan Kangkung Air dalam Menurunkan Kadar BOD dan TSS pada Limbah Cair Industri Tahu. Jurnal Farmasetis, 8(2): 31-38.

Antony J., Niveditha S. V., Gandhimathi R., Ramesh S. T. and Nidheesh P. V. (2020). Stabilized landfill leachate treatment by zero valent aluminium-acid system combined with hydrogen peroxide and persulfate based advanced oxidation process. Waste Management, 106, 1–11, https://doi.org/10.1016/j.wasman.2020.03.005

Anwar, M. H. 2019. Efektivitas Tanaman Kiambang (Pistia stratiotes L.) dalam Menurunkan Kadar BOD dan COD pada Fitoremediasi Limbah Cair Industri Tahu dan Implementasinya pada Petunjuk Praktikum Pencemaran Lingkungan. Universitas PGRI Semarang: Indonesia.

Chaudhary R., Nain P. and Kumar A. (2021). Temporal variation of leachate pollution index of Indian landfill sites and associated human health risk. Environmental Science and Pollution Research, 28(22), 28391–28406, https://doi.org/10.1007/s11356-021-12383-1

Damsir et al. 2016. Karakteristik Lindi Hasil Fermentasi Anaerobik Sampah Kota dalam Lisimeter dan Potensi Pemanfaatannya menjadi Pupuk Cair. Jurnal Teknologi Industri Pertanian, 26(2): 125-133.

Eggen T., Moeder M. and Arukwe A. (2010). Municipal landfill leachates: a significant source for new and emerging pollutants. Science of the Total Environment, 408(21), 5147–5157, https://doi.org/10.1016/j.scitotenv.2010.07.049

Elmaadawy K., Liu B., Hu J., Hou H. and Yang J. (2020). Performance evaluation of microbial fuel cell for landfill leachate treatment: research updates and synergistic effects of hybrid systems. Journal of Environmental Sciences, 96, 1–20, https://doi.org/10.1016/j.jes.2020.05.005

Fajri et al. 2014. Perancangan dan Penerapan Alat Ukur Kekeruhan Air Menggunakan Metode Nefelometrik pada Instalasi Pengolahan Air dengan Multi Media Card (MMC) sebagai Media Penyimpanan (Studi Kasus di PDAM Jember). Berkala Sainstek 2014, 2(1): 17-21.

Fitriana, N., & Kuntjoro, S. 2020. Kemampuan Lemna minor dalam Menurunkan Kadar Linear Alkyl Benzene Sulphonate. LenteraBio, 9(2): 109-114.

Gautam P. and Kumar S. (2021). Characterisation of hazardous waste landfill leachate and its reliance on landfill age and seasonal variation: a statistical approach. Journal of Environmental Chemical Engineering, 9(4), 105496, https://doi.org/10.1016/J. JECE.2021.105496

Gómez-Sanabria A., Kiesewetter G., Klimont Z. and Haberl H. (2022). Potential for future reductions of global GHG and air pollutants from circular waste management systems. Natural Communication, 13, 106, https://doi.org/10.1038/s41467-021-27624-7

Hartini, E., & Yanto Yulianto. 2018. Kajian Dampak Pencemaran Lindi Tempat Pemrosesan Akhir (TPA) Ciangir terhadap Kualitas Air dan Udara. Jurnal Siliwangi, 4(1):27-32.

Ilmasari D., Sahabudin E., Riyadi F. A., Abdullah N. and Yuzir A. 2022. Future trends and patterns in leachate biological treatment research from a bibliometric perspective. Journal of Environmental Management, 318, 115594, https://doi.org/10.1016/J.JENVMAN.2022.115594

Irhamni et al. 2017. Kajian Akumulator beberapa tumbuhan air dalam menyerap zat polutan secara fitoremediasi. Jurnal Serambi Engineering, 1(2): 75-84.

Ismail S., Nasr M., Abdelrazek E., Awad H. M., Zhaof S., Meng F. and Tawfik A. (2020). Techno-economic feasibility of energy-saving self-aerated sponge tower combined with up-flow anaerobic sludge blanket reactor for treatment of hazardous landfill leachate. Journal of Water Process Engineering, 37, 101415, https://doi.org/10.1016/j.jwpe.2020.101415

Joel C , Ezekiel K. Kiprop, Lizzy A. Mwamburi. 2017. Effect of Seasonal Variation on Performance of Conventional Wastewater Treatment System. Journal of Applied & Environmental Microbiology, 2017, Vol. 5, No. 1, 1-7 Department of Biological Sciences, University of Eldoret, Eldoret, Kenya. http://pubs.sciepub.com/jaem/5/1/1 ©Science and Education Publishing DOI:10.12691/jaem-5-1-1

Keyikoglu R., Karatas O., Rezania H., Kobya M., Vatanpour V. and Khataee A. (2021). A review on treatment of membrane concentrates generated from landfill leachate treatment processes. Separation and Purification Technology, 259, 118182, https://doi.org/10.1016/j.seppur.2020.118182

Khaer, A. & Nursyafitri, E. 2017. Kemampuan Metode Kombinasi Filtrasi Fitoremediasi Tanaman Teratai dan Eceng Gondok dalam Menurunkan Kadar BOD dan COD Air Limbah Industri Tahu. Jurnal Sulolipu: Media Komunikasi Sivitas Akademika dan Masyarakat, 17(2): 11-18.

Kurniawati, A., Ary Susatyo Nugroho, & Fibria Kaswinarni. 2015. Dampak Lindi TPA Jatibarang terhadap Keanekaragaman dan Kelimpahan Plankton di Perairan Sungai Kreo Kota Semarang. Seminar Nasional XII Pendidikan Biologi FKIP UNS 2015: 708-713.

Li Chengjun, Liu Yongqiang, Liu Xiaojuan. 2021.Leather Production and Environmental Protection Technology. 2021(21)

Mishra R., Kumar A., Singh E. and Kumar S. 2022. Carbonaceous nanocomposites derived from waste material for wastewater treatment. In: Biorenewable Nanocomposite Materials, Vol. 2: Desalination and Wastewater Remediation, D. Pathania and L. Singh (eds.), American Chemical Society, Washington, DC, pp. 43–73.

Nasrullah S., Hayati R., & Kadaria U. 2017. Pengolahan Limbah Karet dengan Fitoremediasi Menggunakan Tanaman Typha angustifolia. Jurnal Teknol Lahan Basah, 5(1): 1-10.

Nofiyanto, E., Tri R. S., & Munifatul I. 2019. Fikoremediasi Kualitas Lindi TPA Jatibarang terhadap Efektifitas Lemna minor L. dan Ipomoea aquatica Forkks. Jurnal Ilmu Lingkungan, 17(1): 107-112.

Novita et al. 2019. Komparasi Proses Fitoremediasi Limbah Cair Pembuatan Tempe Menggunakan Tiga Jenis Tanaman Air. Jurnal Agroteknologi, 13(1): 16-24.

Novita et al. 2020. Fitoremediasi Air Limbah Laboratorium Analitik Universitas Jember dengan Pemanfaatan Tanaman Eceng Gondok dan Lembang. Jurnal Bioteknologi dan Biosains Indonesia, 7(1): 121-135.

Nurhasanah Cordova M. R. and Riani E. (2021). Micro- and mesoplastics release from the Indonesian municipal solid waste landfill leachate to the aquatic environment: case study in Galuga Landfill Area, Indonesia. Marine Pollution Bulletin, 163(January), 111986, https://doi.org/10.1016/j.marpolbul.2021.111986

Omran I. I., Al-Saati N. H., Al-Saati H. H., Hashim K. S. and Al-Saati Z. N. (2021). Sustainability assessment of wastewater treatment techniques in urban areas of Iraq using Multi Criteria Decision Analysis (MCDA). Water Practice and Technology, 16(2), 648–660, https://doi.org/10.2166/wpt.2021.013

Rachmawati, D. 2020. Fitoremediasi menggunakan Melati Air (Echinodorus palaefolius) untuk Menurunkan Logam Besi (Fe). Tugas Akhir. Universitas Islam Negeri Sunan Ampel Surabaya: Surabaya.

Rezagama, et al. 2017. Pengolahan Air Lindi TPA Jatibarang menggunakan Feton (H2O2 – Fe). Jurnal PRESIPITASI, 14(1): 30-36

Saniy, T. H., Sudarno, & Purwono. 2017. Pengolahan Lindi menggunakan Metode Koagulasi Flokulasi dengan Biokoagulan Kitosan dari Limbah Cangkang Udang dan Metode Ozonasi (Studi Kasus: Lindi TPA Jatibarang Kota Semarang). Jurnal Teknik Lingkungan, 6(1): 1-11.

Santoso et al. 2014. Pengolahan Limbah Cair Sasirangan Melalui Kombinasi Metode Filtrasi dan Fitoremediasi Sistem Lahan Basah Buatan Menggunakan Tumbuhan Air yang Berbeda. EnviroScienteae, 10(1): 157-170.

Sari, N. D. 2019. Uji Fitoremediasi pada Limbah Cair Tahu Menggunakan Genjer (Limnocharis flava L.) untuk Mengurangi Kadar Pencemaran Air sebagai Penunjang Mata Kuliah Ekologi dan Masalah Lingkungan. Universitas Islam Negeri Ar-Raniry: Banda Aceh.

Tan B., He L., Dai Z., Sun R., Jiang S., Lu Z., Liang Y., Ren L., Sun S., Zhang Y. and Li C. (2022). Review on recent progress of bioremediation strategies in landfill leachate – a green approach. Journal of Water Process Engineering, 50, 103229, https://doi.org/10.1016/j.jwpe.2022.103229

Teng C., Zhou K., Peng C. and Chen W. 2021. Characterization and treatment of landfill leachate: a review. Water Research, 203, 117525, https://doi.org/10.1016/j.watres.2021.117525

Thomas, R. A., & Dian Hudawan Santoso. 2019. Potensi Pencemaran Air Lindi terhadap Air Tanah dan Teknik Pengelolaan Air Lindi di TPA Banyuroto Kabupaten Kulon Progo. Jurnal Science Tech, 5(2): 1-12.

Topal A. D. and Atasoy A. D. 2022. Reverse osmosis treatment system for landfill leachate: operation conditions, advantages and challenges. Environmental Research & Technology, 5, 119–127, https://doi.org/10.35208/ert.1027553

Vaccari M, Tudor T and Vinti G 2019 Waste Management.

Wijekoon P., Koliyabandara P., Cooray A., Lam S. S., Athapattu B. and Vithanage M. (2021). Progress and prospects in mitigation of landfill leachate pollution: risk, pollution potential, treatment and challenges. Journal of Hazardous Materials, 421, 126627, https://doi.org/10.1016/j.jhazmat.2021.126627

Zhang Junjiao. 2022. Analysis of the status quo and existing problems of landfill leachate treatment [J]. Resource Conservation and Environmental Protection. 2022(03).