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Plant Diversity at the Cipayung Final Waste Processing Site and Its Potential for Phytoremediation

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Abstract

The volume of waste in the Cipayung Final Processing Site (TPA) in Depok City every day in 2024 will reach approximately 1,000 tons. This causes various problems, one of which is heavy metal pollution. However, Cipayung landfill can have some plant species appear in certain seasons. Research on plant diversity and phytoremediation potential in Cipayung landfill was conducted using purposive sampling and line transect method. The results obtained data on plant species richness in Cipayung landfill as many as 41 species with a Shannon Wiener diversity index value at Cipayung landfill of 2.711 which shows the diversity of plant species and community stability is in the medium category. There are three plant species that have the highest abundance index value, namely Biduri (Calotropis gigantea), Ara Sungsang (Asystasia gangetica) and Meniran (Phyllanthus niruri). Calotropis gigantea has the potential to remediate Lead (Pb), Copper (Cu) and Cadmium (Cd) metals. Asystasia gangetica has the potential to be a phytoremediation for metals Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn). Phyllanthus niruri has phytoremediation ability on Mercury (Hg), Lead (Pb) and Cadmium (Cd) metals.

Keywords:Landfill; Phytoremediation; Plants; Waste

1 INTRODUCTION

Landfills play an important role in waste management, but they often cause environmental problems. One of the main issues is soil and water pollution due to leachate runoff containing hazardous materials such as heavy metals and toxic organic compounds. Cipayung Landfill, which is a strategic location for waste management in the Depok area, has similar challenges. Pollutants from landfill activities can pollute the surrounding ecosystem, threaten environmental health, and affect the welfare of the surrounding community (Suyatno et al., 2020). The volume of waste in Cipayung Landfill in 2024 reached 1,000-1,200 tonnes per day, an increase from the previous 2023 which was around 900 tonnes per day. This is influenced by the population of Depok City, which has reached two million people. Since the last three years, Cipayung Landfill has experienced an overload condition, with the height of the waste hill reaching 30 metres, far above the maximum limit of 10 metres. Initially planned to use the Sanitary Landfill system, the management has now changed to Open Dumping. Since the establishment of Cipayung Landfill in 1987 until 2007, the Depok City Government did not have a Waste Processing Unit (UPS), so the waste was only landfilled continuously. This condition causes negative externalities in the form of decreased environmental quality for the surrounding community (Rahmawati, 2023).

Some areas in Cipayung Landfill are overgrown with several types of wild plants such as grasses, shrubs, and vines. Some domestic plants, such as chillies and kale, are also found growing on a small scale as part of the local ecosystem dynamics. Plant diversity around landfills is influenced by soil fertility and the presence of inhibiting factors such as dissolved toxic materials (Sembel, 2015). Certain waste may decompose naturally and improve soil fertility, but other waste takes a long time to decompose, so not all plants can survive. The presence of these plants provides further exploration potential for phytoremediation, which is the process of using plants to improve the quality of polluted environments (Irhamni et al. 2024). Phytoremediation is a plant-based bioremediation method that is one of the innovative approaches to deal with leachate pollution. The phytoremediation process involves the ability of certain plants to absorb, degrade or stabilise pollutants in the polluted environment. Plants with high tolerance to heavy metals, such as vetiver (Chrysopogon zizanioides) and thorn amaranth (Amaranthus spinosus), have been proven effective in remediating polluted soils in various regions (Sarma, 2011; Yadav et al., 2021). The geographical conditions and local biodiversity in Cipayung landfill provide an opportunity to explore the potential of local plants as phytoremediation agents. This research aims to identify the diversity of plant species that are able to adapt to Cipayung landfill and have the potential as phytoremediators. This approach is expected to provide a sustainable solution for landfill environmental management in Indonesia (Kumar et al., 2019).

2 RESEARCH METHODS

This study used line transect (Hidayat et al. 2018) and purposive sampling (Giday et al. 2009) methods to identify the phytoremediation potential of plants in the Cipayung Landfill. This method was chosen because it is suitable for evaluating plant diversity in a large and heterogeneous area such as a landfill. The research was conducted at Cipayung Landfill, Depok City, West Java. The research site covers the main area of the landfill, including the active waste disposal zone, passive zone, and surrounding areas that have the potential for the presence of plants with phytoremediation capabilities. The research was conducted from May to July 2024. The following is a map of the research location (Figure 1).

The line transect method was used to systematically map the distribution of plants in the research area (Hidayat et al. 2018). Line transects were carried out by walking along the Cipayung landfill area which contained plants along 100 x 4 metres with a transect size of 2 m to the right and 2 m to the left and a road length of 100 metres. Observations were made on all plant species found in the designated area. Data collected in the form of plant species identification and environmental data collection, such as soil pH, and humidity. Tools and materials include GPS for determining transect coordinates, measuring tape for measuring transect length, field equipment: small shovels, sample bags, and identification labels, other equipment such as digital cameras, stationery and observation sheets. Sampling was carried out by purposive sampling to identify plant species growing in several zone areas.

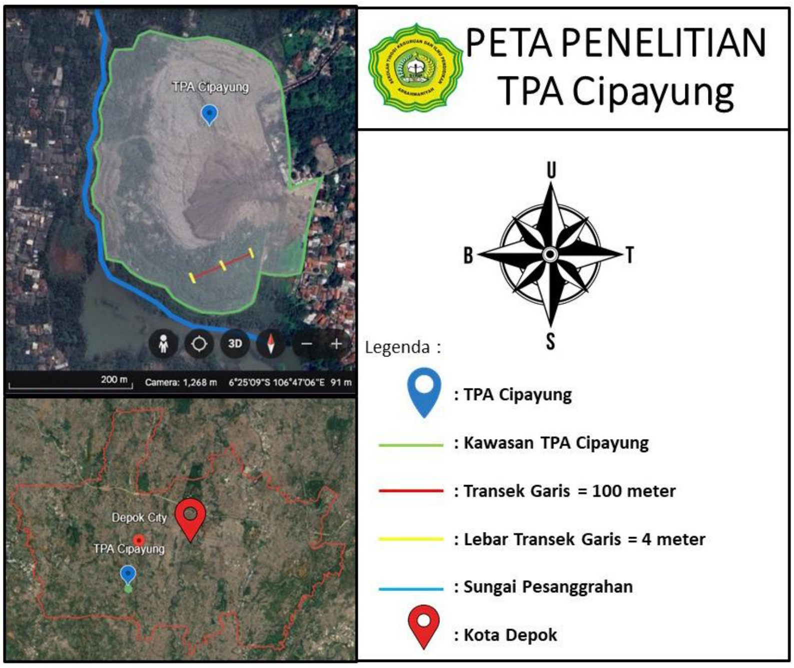

Figure 1: Research location

These areas represent areas with high pollutant concentrations, such as leachate inundation zones, waste hill banks, and degraded areas. Plants that appeared dominant or had high tolerance to extreme environmental conditions were selected for further analysis. Each plant found in the observation plots was identified to species level using flora guidebooks and plant identification apps. Morphological characteristics, such as plant height, leaf type, and roots, were also recorded. Plant Diversity data were analysed using the Shannon-Wiener diversity index (H') as follows:

$$\boxed{H' = -\sum \text{pi Ln pi}, \text{pi} = \frac{n}{N}}$$

Description:
H' = Species diversity index
Pi = Proportional abundance of the i-th species, Pi = ni/Nni
ni = Number of individuals of the i-th species
N = Total number of individuals
Phytoremediation Potential is plants with the ability to live in waste piles where other plants cannot live are considered to have phytoremediation capabilities. Analysis of phytoremediation potential uses the Ludwig and Reynolds relative abundance formulation (Nento et al., 2013) as follows:

$$\boxed{RA_i = \frac{n_i}{N} \times 100\%}$$

Description:
RA_n = Relative Abundance of the i-th species.
n_n = Number of individuals of the i-th species.
N = Total number of individuals of all species.
The relative abundance index is used in the analysis of phytoremediation potential because species that have a high relative abundance generally indicate that the species is able to survive in a particular environment. Plant species with high abundance often show adaptations to environmental conditions, such as tolerance to pollutants or the ability to absorb contaminants. Data on species that have a high relative abundance index will henceforth be discussed using literature studies.

3 RESULT AND DISCUSSION

The presence of plants in Cipayung Landfill is influenced by several factors, one of which is rainfall. Seeds that come from household organic waste and dispersal of surrounding plants. The results of the study obtained various types of plants found, including herbaceous plants, food plants and ornamental plants as recorded in table 1.

Table 1. Abundance and Diversity of Plant Species in Cipayung Landfill

No.	Local Name	Scientific Name	Total Number of Individuals	Relative Abundance (RAi)	−pi·ln(pi)
1.	Fierce Cat	*Acalypha indica*	30	6,160	0,172
2.	Meniran	*Phyllanthus niruri*	73	14,990***	0,284
3.	Gletang	*Tridax procumbens*	14	2,875	0,102
4.	Biduri	*Calotripis gigantea*	99	20,329*	0,324
5.	Suri cucumber	*Cucumis melo* L.	3	0,616	0,031
6.	Watermelon	*Citrullus lanatus*	2	0,411	0,023
7.	Ara sungsang	*Asystasia gangetica*	81	16,632**	0,298
8.	Ciplukan	*Physalis angulata*	27	5,544	0,160
9.	Teki Ladang	*Cyperus rotundus*	2	0,411	0,023
10.	Wild Soybeans	*Glycine ururiencis*	6	1,232	0,054
11.	Kremah	*Alternanthera sessilis*	17	3,491	0,117
12.	Bejanggut pedas	*Mentha piperita* L.	1	0,205	0,013
13.	Knob Grass	*Cyperus kyllingia*	1	0,205	0,013

14.	Sambung rambat	*Mikania micrantha*	2	0,411	0,023
15.	Seruni	*Wedelia* sp.	1	0,205	0,013
16.	Tumpang air	*Ludwigia octovalvis*	10	2,053	0,080
17.	Chicken tongue grass	*Pouzolzia zeylanica*	21	4,312	0,136
18.	Tapak Liman	*Elephantopus scaber*	2	0,411	0,023
19.	Kersen	*Muntingia calabura*	6	1,232	0,054
20.	Kriminil	*Alternanthera ficoidea*	19	3,901	0,127
21.	Jariji Grass	*Digitaria sanguinalis*	2	0,411	0,023
22.	Elephant grass	*Isolepis cernua*	1	0,205	0,013
23.	Cucumber	*Cucumber sativus*	10	2,053	0,080
24.	Oregano	*Origanum vulgare*	2	0,411	0,023
25.	Urang aring	*Eclipta prostrata*	4	0,821	0,039
26.	Green carpet	*Mollugo verticillata*	1	0,205	0,013
27.	Gewor	*Commelina* sp.	21	4,312	0,136
28.	Regular bracelet	*Portulaca oleracea*	3	0,616	0,031
29.	Green Beans	*Vigna radiata*	5	1,027	0,047
30.	Kencana Ungu	*Ruellia angustifolia*	2	0,411	0,023
31.	European Nettle	*Celtis australis*	3	0,616	0,031
32.	Telang	*Clitoria ternatea*	3	0,616	0,031
33.	Japanese papaya	*Cnidoscolus aconitifolius*	2	0,411	0,023
34.	Little bel	*Ipomoea triloba*	2	0,411	0,023
35.	Sweet Potato	*Ipomoea batatas*	2	0,411	0,023
36.	Rambusa	*Passiflora foetida*	1	0,205	0,013
37.	Bullet tree	*Terminalia buceras*	1	0,205	0,013
38.	Mengkirai	*Trema orientalis*	1	0,205	0,013
39.	Mexican clover	*Richardia scabra*	1	0,205	0,013
40.	Sengon	*Albizia chinensis*	1	0,205	0,013

41.	Browse	*Lantana camara*	2	0,411	0,023
		Total	487	100%	2,711

Based on table 1. 41 plant species were found. There are three plant species that have the highest abundance index value. namely Biduri (Calotropis gigantea) with a value of 20.32, Ara Sungsang (Asystasia gangetica) with a value of 16.63 and Meniran (Phyllanthus niruri) with a value of 14.98. The three plant species can be found along the transect made. This can show that the three species are able to survive and adapt to the conditions found in Cipayung landfill.

Shannon Wiener diversity index has three categories. If the value of H�much < 1 then the diversity index is categorised as low and community stability is declared unstable, if the value of H' ranges from 1-3 (1 < H' < 3) then the diversity index is categorised as moderate and community stability is declared moderate, and if the value of H' > 3 then the diversity index is categorised as high and community stability is declared high (Basmi, 2000). Based on table 1. obtained Shannon Wiener diversity index value at Cipayung landfill of 2.711. This shows the diversity of plant species and community stability is in the medium category. An aquatic community is classified as very stable if the diversity index value (H') ranges > 2.41 (Odum, 1993).

Plants that potentially have the ability to phytoremediate by referring to the relative abundance index value in table 1 obtained information there are three plant species with the highest value. The three species are Biduri (Calotropis gigantea), Ara Sungsang (Asystasia gangetica) and Meniran (Phyllanthus niruri). The highest abundance index value is Biduri (calotropis gigantea) with a value of 20.32, Ara Sungsang (Asystasia gangetica) with a value of 16.63 and Meniran (Phyllanthus niruri) with a value of 14.98.

Biduri has a classification of the Division Magnoliophyta, Class Magnoliopsida, Order Gentianales, Family Asclepiadaceae, Genus Calotropis and Species Calotropis gigantea (L.). Calotropis gigantea morphology has a taproot type (radix primaria). The stem is woody (lignosus) but soft in young parts. Leaves are oval to oblong (obovate) with rounded edges and arranged in pairs (opposite). Leaf texture is thick, fleshy and has a waxy coating (cuticle). Type of compound flowers (inflorescence) are panicle-shaped. The fruit is pod-shaped with an oval or elliptic shape and the seeds have fine white hairs (pappus) that play a role in the spread of seeds by the wind (anemokori).   Calotropis gigantea plant documentation can be seen in Figure 2.

Research on the potential of Calotropis gigantea as a phytoremediation plant has been conducted on heavy metal content in soil, namely Lead (Pb) by Liwun et al. (2021), Copper (Cu) by Sitompul (2018) and Cadmium (Cd) by Lazar (2015). These three substances can be found in landfills from, among others, leftover electronic equipment, batteries, batteries, leftover oil, paint, and household waste. These heavy metal substances decompose along with the weathering of garbage by hot and rainy weather.

Based on research conducted by Liwun et al. (2021) concluded that Calotropis gigantea has the potential to remediate soil polluted with heavy metal Lead (Pb). The ability to absorb up to 93% at low Pb levels but gets smaller at high levels. Research conducted by Sitompul (2018) showed that Calotropis gigantea is able to absorb Copper (Cu) metal. Accumulation of heavy metal copper (Cu) exposed to the growing medium with concentrations of 250, 500, and 750 ppm in Calotropis gigantea plants are 8.782, 27.788, and 16.175 ppm, respectively. The optimum absorption that can be done by Calotropis gigantea at a copper (Cu) concentration of 500 ppm.

Figure 2. Biduri plant (Calotropis gigantea).
Source: personal documentation

The ability of Calotropis gigantea in absorbing heavy metals Cadmium (Cd) shows the results of the analysis of the accumulation of Cadmium added to the growing medium with a concentration of 250, 500, and 750 ppm in biduri plants are 8,351, 33,436, and 37,325 ppm respectively (Lazar, 2015). This shows the ability of Calotropis gigantea in absorbing heavy metal Cadmium still continues to increase along with the increasing amount of heavy metal concentrations given.

The classification of Ara Sungsang comes from the Division Magnoliophyta, Class Magnoliopsida, Subclass Asteridae, Order Lamiales, Family Acanthaceae, Genus Asystasia and Species Asystasia gangetica (L). Morphology Asystasia gangetica has a taproot system with many fibres that have the ability to absorb nutrients efficiently in the topsoil. The stem is green in colour but slightly woody at the base. The leaves are oval in shape with tapered tips and arranged in pairs in opposites.

Asystasia gangetica flowers are trumpet-shaped with bilateral (zygomorphic) symmetry in the corolla. The fruit is a small capsule and has seeds with a hard surface that can withstand extreme conditions (Kumalasari et al. 2020). Documentation of Asystasia gangetica plants can be seen in Figure 3.

Phytoremediation research on Asystasia gangetica species was conducted by Yap et al. (2021) in Peninsular Malaysia as a biomonitor and phytoremediator. The metals tested were Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn). The research was conducted by measuring the presence of these metals in root, stem and leaf organs. Analysis of phytoremediation potential using correlation analysis based on bioconcentration factor (BCF) and translocation factor (TF) data.

Correlation analysis showed that Cu, Pb and Zn were found in the roots. Many metals found in stem organs are Cu, Ni and Zn. While in the leaf organ, Pb, Zn and Cd metals can be found. The BCF and TF results show that Asystasia gangetica is a good phytoextractor for Cd and Ni, and a good phytostabiliser for Cu, Pb and Zn. Therefore, Asystasia gangetica is a good candidate as a phytoremediator for sustainable contaminant recovery subject to appropriate field management strategies (Yap et al. 2021).

Figure 3: Breech fig plant (Asystasia gangetica).
Source: personal documentation

The classification of meniran comes from the Division Magnoliophyta, Class Magnoliopsida, Order Malpighiales, Family Phyllanthaceae, Genus Phyllanthus and Species Phyllanthus niruri (L). The morphology of Phyllanthus niruri has a taproot system with cylindrical stems and grows upright. The leaf type is small, oval and compound. Single flowers are located in the leaf axils facing downwards and are white in colour. The fruit is flat round, with a diameter of about 2 mm and the texture of the fruit is smooth. Documentation of Phyllanthus niruri plants can be seen in Figure 4.

Figure 4 Meniran plant (Phyllanthus niruri).
Source: personal documentation

Phytoremediation research on Phyllanthus niruri species has been conducted by Marrugo-Negrete et al. (2016). The research was conducted on heavy metal mercury (Hg) which is commonly found in mining sites. Based on the results obtained, Phyllanthus niruri obtained a bioconcentration factor (BCF) value of more than 1. This indicates that

Phyllanthus niruri has the ability to accumulate mercury metal above the average of other species.

Another research on phytoremediation on Phyllanthus niruri was conducted by Kever et al. (2019) with Lead (Pb) and Cadmium (Cd) metals at a disposal site. The results revealed the presence of the studied heavy metals found in plant samples and soil samples where the Phyllanthus niruri grows. Pb and Cd metals accumulated in the stem organs and increased in number in the leaf organs of Phyllanthus niruri. Based on these results, Kever et al (2019) recommended the use of hyperaccumulator plants for phytoremediation in heavy metal polluted soil to reduce metal toxicity in the soil.

3 CONCLUSION

The Cipayung Final Processing Site (TPA) in Depok City has a plant species richness of 41 species. The Shannon Wiener diversity index value at Cipayung landfill is 2.711 which shows the diversity of plant species and community stability is in the medium category. There are three plant species that have the highest abundance index value, namely Biduri (Calotropis gigantea) with a value of 20.32, Ara Sungsang (Asystasia gangetica) with a value of 16.63 and Meniran (Phyllanthus niruri) with a value of 14.98. Calotropis gigantea species has the potential to remediate Lead (Pb), Copper (Cu) and Cadmium (Cd) metals. Asystasia gangetica species has the potential to be a phytoremediation for metals Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn). Phyllanthus niruri species has phytoremediation ability on Mercury (Hg), Lead (Pb) and Cadmium (Cd) metals.

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