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Phytoremediation as a Barrier to Heavy Metal Distribution in Open Dumping Landfill in Peatlands

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ABSTRACT
Landfills with the open dumping method cause many environmental pollution problems, such as pollution, soil, surface water, and groundwater. Pollution cleaning technology (remediation) to reduce the harmful effects in the locations contaminated with heavy metals can be implemented by means of several methods, including using phytoremediation as a barrier to heavy metal contamination in order to preventing contamination distribution to the environment. Ferns (phytoremediation) on the side of the open dumping landfill were investigated as phytoremediation, inhibiting the distribution of heavy metals into the environment. The descriptive-analytic research method was used to analyze the ability of ferns in an open dumping landfill in peatland areas as a barrier to metal contamination distributed to the environment. The results show that ferns can bind heavy metals, such as Hg and Pb, produced from open dumping landfill activities to prevent the distribution of heavy metals to the environment around the landfill. Ferns are able to block the distribution of heavy metals into the environment, especially Pb and Hg. The ability of ferns to become potential plants in peatland areas requires further testing of other heavy metals.

Keywords: phytoremediation, barrier, heavy metal, open dumping landfill.

INTRODUCTION

Garbage or waste is still a common problem in every country. The increasing population and decreasing land area are separate problems in waste management (Njeru, 2006; Melikoglu et al., 2013; Nguyen et al., 2015).The consumptive nature of the available resources has resulted in urban solid waste from industrial to domestic activities (Ayotamuno & Gobo, 2004; Imam et al., 2008; Lebersorger & Beigl, 2011). Improper management of solid waste areas has caused serious ecological, environmental and health problems. Such practices contribute to widespread environmental pollution, as well as the spread of disease. The decline in health status, accidents, flood events and environmental degradation are some of the negative effects of waste in cities. Other environmental effects include contamination of soil, surface and ground water, unpleasant odors, and disturbance of disease vectors (Ojeda-Benítez & Beraud-Lozano, 2003; Misra & Pandey, 2005; Kharlamova et al., 2016; Ogundiran & Afolabi, 2008).

The application of cheap and environmentally friendly waste disposal methods continues to be studied. The use of the open dumping method is still applied today because the costs incurred are relatively cheaper than those incurred by the sanitary landfill method (Luaylik, 2017). Waste processing using the open dumping method has many negative impacts, especially the impact on the environment and the surrounding community (Mahyudin, 2017). Inappropriate location selection for waste processing using open dumping has an impact on environmental pollution due to the spread of heavy metals into the surrounding environment. Contamination can be through infiltration from soil and water media (Cristaldi et al., 2017; Navarro & Carbonell, 2008).

The large amount of solid waste affects the natural decomposition process on a large scale. The decomposition process that occurs will produce a by-product in the form of leachate which accumulates with water that enters from the outside (Mishbahul et al., 2013). Leachate is a group of waste with the B3 category which mostly contains heavy metals, such as Fe, Hg, Cd, Pb, and Cr as well as essential metals such as Zn, Cu, Fe, Co, and Mn (Pandia et al., 2017; Sari, 2017; Bakis & Tuncan, 2011; Weyens et al., 2009).

The entry of chemical substances contained in leachate into the ecosystem can pollute water and soil which in turn can affect the biota in the environment. Therefore, it is necessary to treat the waste before it is released into the environment. Heavy metal contamination can be carried by soil particles swept away by wind and rain from the starting point of the pollution area. Once these soil particles settle, heavy metals can diffuse into the environment, contaminating new areas (Ogundiran & Afolabi, 2008; Kharlamova et al., 2016).

Pollution cleaning technology (remediation) to reduce the harmful effects in the locations contaminated with heavy metals can be done by several methods, including excavation (physical transfer of contaminated material), stabilizing metals in the soil (stabilization of metals in the soil), and using plants (phytoremediation) (Lambert et al., 2000). In more heavily contaminated soils, phytostabilization with tolerant plants can be used to stabilize contaminated sites and reduce the risk of erosion and leaching of pollutants into water bodies. Metal or metalloid hyperaccumulation is important for the phytoextraction strategy (Zhao & Mcgrath, 2009). Cleaning metal contamination using the principle of phytoremediation can be considered in counteracting the major impacts caused by the open dumping method of waste disposal. One of the phytoremediation techniques that has been studied is using the Water Bamboo plant (*Equisetum hyemale*), with zeolite growing media (Mishbahul et al., 2013)

Phytoremediation with different plant species that can accumulate or degrade contaminants, migrate, and retain heavy metal loads during the complete growth cycle (Cristaldi et al., 2017). Such plants are known as hyperaccumulators (Zhao & Mcgrath, 2009). The plants that naturally have the ability to absorb and convert metal elements become more benign and reduce or prevent contamination infiltration into groundwater (Trapp & Christiansen, 2003).

The concept of phytoremediation is a concept that has been studied for a long time in the treatment of reducing metal contamination (Trapp & Christiansen, 2003; Kra, 2005; Xie et al., 2016; Padmavathiamma & Li, 2007; Prasad, 2003; Gupta et al., 2012; Kamusoko et al., 2017; Ukhopadhyay & Maiti, 2010; Bakis & Tuncan, 2011). Each plant has a different ability to bind metals and depends on the type of heavy metal. Phytoremediation is an environmentally friendly concept that is recommended in metal management in modern times, because it uses an environmentally friendly concept (Ukhopadhyay & Maiti, 2010). Phytoremediation has many advantages over traditional methods. It uses plant mechanisms to remodel a contaminated environment (Gupta et al., 2012; Reichenauer & Germida, 2008). These technologies include phytoextraction, rhizofiltration, phytostabilization, phytodegradation, and phytovolatization. The above-mentioned approaches differ in their aims and objectives, which may include remediation, detoxification, water movement management, and contaminant leaching, containment, and stabilization (Kamusoko et al., 2017).

The application of the phytoremediation concept is a combination of the concept of in situ waste management with processing or purification of contamination at the locations where the soil is polluted (Trapp & Christiansen, 2003; Kra, 2005; Xie et al., 2016; Padmavathiamma & Li, 2007; Prasad, 2003).The application of phytoremediation cannot be carried out at an open damping landfill that is still operating. Phytoremediation is a technique that has proven to be effective in reducing metal contamination, its application is inexpensive, aesthetically pleasing, and effective (Kamusoko et al., 2017). Phytoremediation is one of the cleaning metal contamination studies that have been carried out in processing taken with various considerations that have the potential to be developed into new innovations in the leachate waste treatment process. Therefore, other alternatives are needed in processing the impact of waste generated from open damping landfill activities, including the placement of a barrier at the location boundary before the waste is distributed to the environment, so that the leachate flowing downstream to or to the environment is safe for the environment.

METHOD

Research design

This type of research is descriptive-analytic. The design of this study was carried out to analyze the distribution pattern of heavy metals from landfill leachate in peatland areas for Hg, Pb, and Cd metal parameters as well as analyze the ability of ferns as phytoremediation to inhibit the distribution of heavy metals to the environment by the activities of the open landfill dumping.

Research sample

The research samples were the leachate waste from landfill activities, soil around the landfill and ferns as a phytoremediation barrier an the Batu Layang landfill in Pontianak City. Stratified sampling was carried out by taking into account aspects of the measurement of the parameters to be tested. The sampling area was divided into two parts: topographic factors and sources of pollution, namely the study area and the control area, namely the side of the landfill which contains ferns. The control area was selected on the side of the landfill, where there is no barrier from ferns.

Sampling procedure

In this study, the sampling point was determined based on the location of the Pontianak City final disposal site, West Kalimantan. The purposive sampling was performed, which is carried out by taking into account the conditions and circumstances of the research area, where the points taken are two sides of the final disposal site with 10 points on each side with a distance between 1 point and another adjacent point of 2 m.

Soil sampling

In order to avoid the uncontrolled influence of various surfaces, such as sewage and humus and to ensure the soil is naturally in place, the sampling depth chosen was from 10 to 15 cm below the surface to a depth of 25 cm. Sampling was carried out using a plastic spatula and the use of metal tools was avoided. The samples were collected in self-locking plastic bags and collected sealed in double bags.

Waste water sampling

The instrument used is the Atomic Absorption Spectrophotometer (AAS) Analyst 700 Perkin Elmer. To maintain sample quality, 500 ml sample bottles with glass material were washed using detergent and rinsed using 1:1 nitric acid (HNO_3), rinsed with analyte-free water 3 times and allowed to dry. The bottle was filled with the wastewater sample. The samples taken were immediately brought to the laboratory for analysis (SNI 6989.57:2008).

Plant sampling

The tumbungan tissue used as a sample as an indicator for measuring the ability to remediate heavy metals was taken from the roots and young stems at the ends. The plant samples were then inventoried by species names and analyzed for the potential accumulation of heavy metals in their tissues. Heavy metal analysis was carried out by AAS and spectrophotometry.

Data analysis design

The data that has been obtained were analyzed descriptively. Descriptive analysis provides an overview of the characteristics of all univariate variables studied, which are presented with tables, graphs and textual as well as describes the differences in the distribution of heavy metals in open dumping landfills using phytoremediation barriers and open dumping landfills without phytoremediation barriers.

RESULTS

Characteristics of leachate at the Batu Layang landfill

The quantity of leachate produced at the Batu Layang landfill is strongly influenced by rainfall and tidal activity. In addition, the quantity of leachate is also influenced by operational aspects applied at the landfill such as the application of overburden, surface slope, climatic conditions, and so on so that it varies and fluctuates (Englehardt, 2006). Leachate collection is carried out in leachate drainage channels that are not covered with concrete and directly adjacent to the soil surface, so it can be assumed that leachate will directly infiltrate into the ground and lead to groundwater flow (unsaturated zone).

Table 1. Characteristics of Batu Layang landfill leachate

No	Parameter	Unit	Analysis results
1	Temperature	°C	31.5
2	pH	-	8.6
3	Lead	mg/l	0.153
4	Mercury	mg/l	0.316
5	Cadmium	mg/l	signed

Table 1 shows the leachate characteristics of the Batu Layang landfill (Pontianak City) contains 0.153 mg·l^{-1} of Pb, 0.316 mg·l^{-1} of Hg and undetectable Cd.

Analysis of the Pb content in landfill soil

Figure 1 shows that the distribution of Pb from leachate to the soil in the area around the landfill on the side without a barrier from ferns at a distance of 10 m from the disposal site is higher than on the side of the landfill with a fern barrier, which is 0.0320 g/kg and 0.00313 g/kg.

Analysis of the Hg content in landfill soil

Figure 2 shows the distribution of Hg from leachate to the soil in the area around the landfill on the side without a barrier from ferns at a distance of 10 m from the disposal site, which is higher than on the side of the landfill with a fern barrier, which is 0.0104 g/kg and 0.0039 g/kg.

Analysis of metal content in the roots of ferns

Table 2 shows the ability of ferns used as a barrier on the landfill side to be able to bind heavy metals in the form of Pb and Hg at 2.5 points of 0.0692 mg/kg and 0.7064 mg/kg.

DISCUSSION

Waste disposal activities using the open dumping method cause environmental pollution. Pollution occurs due to the release of heavy metals into

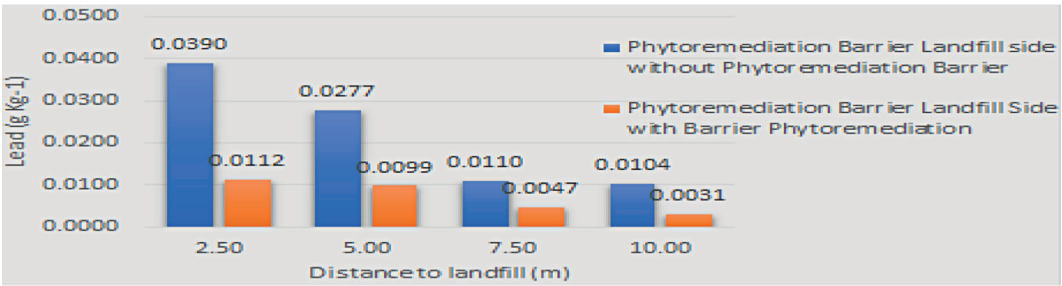

Figure 1. Distribution of Pb on soil in open dumping landfill

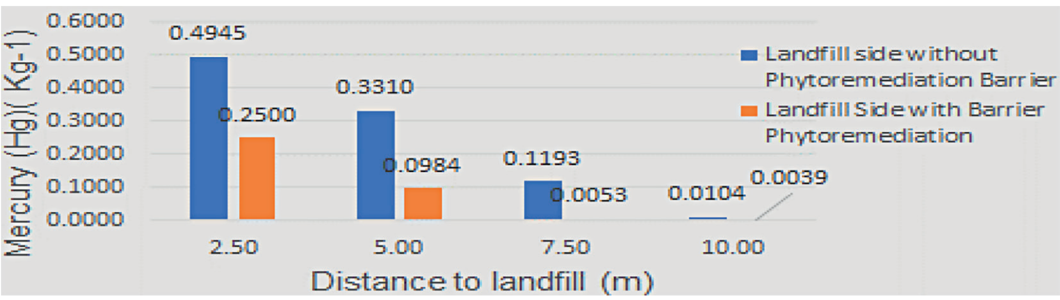

Figure 2. Distribution of Hg on soil in open dumping landfill

Table 2. Heavy metal content in fern roots as a barrier at the Batu Layang landfill

No	Pick up point to landfill	Average metal content (mg/kg)		
		Pb	Hg	CD
1	2.5 m	0.0692	0.7064	Signed
2	5 m	0.0455	0.3449	Signed
3	7.5 m	0.0394	0.1421	Signed
4	10 m	0.0397	0.1449	Signed

the environment as a result of waste disposal activities that are not properly controlled (Ali et al., 2014; Kanmani & Gandhimathi, 2013). The identified heavy metals released into the environment at the open dumping landfill at the Batu Layang in Pontinak City consist of mercury (Hg) and lead (Pb), while Cd was not detected from the resulting contamination. The level of pollution that occurs is strongly influenced by the tropical climate of West Kalimantan and is located at the equator, where rainfall is high and occurs throughout the year. The heavy metals that are produced from the waste disposal activities in landfills cause metals to be distributed in the environment which have an impact on soil, surface water and underground water pollution (Alam et al., 2020).

Soil characteristics in the West Kalimantan region are peat soils with a low acidity level of 4–6 anarat with high porosity which can affect the rate of distribution of heavy metals in the soil environment. On the soil located at the open dumping landfill location at the sampling point at a distance of 10 m from the landfill location, the Pb (0.0390 g/kg) and Hg (0.4945 g/kg) heavy metals were still identified. The level of heavy metal contamination at a point 10 m from the waste disposal site indicates that the heavy metals produced from open dumping activities cause pollution to the environment around the landfill.

The area of West Kalimantan with peat land indices is very suitable for the growth of ferns and becomes the dominant plant in the area. The ferns growing in the locations around the landfill were analyzed for the heavy metal content according to the soil. Ferns are bioindicators of environmental pollution at landfill sites and function as phytoremediation of metal contamination(Asif et al., 2018). The identified ferns contained Pb and Hg. At the point of collection 2.5 from the landfill location for ferns contained Pb (0.0692 mg/kg) and Hg (0.7064 mg/kg). At the landfill side location with a fern garden, the level of heavy metal contamination in the soil tends to be lower than at the landfill side without ferns. Ferns have the ability to absorb heavy metals in the soil and prevent the distribution of metal contamination in a wider environment.

CONCLUSIONS

The ferns grown in the area around the landfill were able to eliminate the heavy metal contamination (Pb and Hg) from the open dumping landfill. The ability of ferns can minimize the distribution of heavy metals to the surrounding environment such as soil, ground water and surface water around the landfill and ferns can be a bioindicator of environmental pollution around the landfill.

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