

**Research Article**

**Lead and chromium removal from leachate using horsetail  
(*Equisetum hyemale*)**

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**Abstract:** Phytoremediation has been widely used for wastewater treatment technology. Horsetail was investigated for its capacity to remediate lead and chromium in leachate. This plant seemed to be an effective choice for phytoremediation due to its survival in extreme to moderate conditions, the availability of annual or perennial varieties and a deep root system. Conducted in a greenhouse, this research used leachate from final disposal. The leachate was exposed to six treated plants with three multiplications using activated natural zeolite media for one month. The treatments were flow system i.e. batch and continue, and living plants weight that is 0, 153 and 306 g planted in 20 cm diameter and 30 cm deep pots. The leachate pH, temperature, lead, and chromium concentration were observed and also the surrounding temperature and humidity. Results showed that 82.2% of lead can be removed by 153 gram horsetail on batch system as well as 61.2% chromium removal by 153 gram horsetail on continue system. Horsetail seemed to have future to be applied in phytoremediation of artisanal and small scale mining waste.

**Keywords:** chromium, horsetail, lead, phytoremediation

**Introduction**

In case of municipal solid waste disposal, leachate comes from waste decomposition process of solid wastes. Since it contains various materials, so, the leachate contains extracts of various waste substances as well. Leachate at Supit Urang solid waste landfill of Malang, Indonesia, processes by using sedimentation and filtration technology in five units in series (Fauzan, 2009). Landfill leachate may contain heavy metals contaminant such as lead, chromium, copper, mercury and others depend on the wastes source. Using the simple process, leachate quality were often below the standard quality of effluent and consequently the receiving water body was polluted (Sarudji, 2007). Once the effluent discharged into water body such as river, it can spread to multiple environmental media, for example soil. These also can enter food chain through consumed fish and plant and causing health risk for human.

Heavy metal contaminations were resulted from industrial activities, and mining was one of them. They were found in increasing of environmental stress. The most common heavy metal contaminants are lead (Pb), chromium (Cr), cadmium (Cd), copper (Cu), mercury (Hg) and zinc (Zn) which were in general form for a group of elements with density higher than 6 g/cm<sup>3</sup> (Jankaite and Vasarevisius, 2007). Based on the material density, heavy metals were Lead has ability to disperse across environmental multimedia, so they were noted as primary contaminant (Alloway and Ayres, 1997). Chromium presents in nature usually in form of hexavalent chromium. Since it is non-biodegradable and toxic, so it removal on wastewater treatment is essential and important (Wittbrodt and Palmer, 1995). In this research, leachate contains 2.29 mg/L lead and 0.39 mg/L chromium which is exceeding the allowable

standard (0.1 mg/L). Waste water from mining activity also contains heavy metals. According to Untung and Achmad (1999), wastewater from gold mining usually acidic (pH 1.99-2.06) with heavy metals concentration such as copper (2.49-3.17 mg/L), zinc (39.21-98.20 mg/L) and lead (0.16-1.25 mg/L). Sumual (2009) also found mercury (9.03 mg/L), arsenic (0.09 mg/L) and lead (0.06 mg/L) in wastewater from small scale gold mining at North Minahasa, North Sulawesi. These amount exceeds quality standard from Indonesia's Ministry of Environment (2004).

The use of plant to remediate pollutant from nature is called phytoremediation. Phytoremediation represent as economically opportunity for pollutant removal based on plant's ability to extract, filter, absorb, stabilize, accumulate and volatilize pollutant (Gosh and Singh, 2005a).

Investigation on the ability of plants in removing heavy metals from soil has been intensified using *Polygonum hydropiper* L., *Rumex acetosa* L. (Wang *et al.*, 2003), *Lolium perenne* (O'Connor *et al.*, 2003), *Brassica juncea* (Bennet *et al.*, 2003), *Helianthus annuus* and *Brassica napus* (Solhi *et al.*, 2005), *Streptanthus polygaloides*, *Sebertia acuminata*, *Armeria maritima*, *Aeollanthus biformifolius*, grass, water hyacinth and sun flower (Ghosh and Singh, 2005b). *Equisetum ramosissimum* (Vaunch) has been observed as plant that can grow well at the Pb-Zn mine tailings of Tan Long, Dong Hy district, Thai Nguyen province, Vietnam and accumulated Pb and Zn much more than 0.3% in their roots (Bui *et al.*, 2011).

The similar genus, horsetail (*Equisetum hyemale*) might have similar capability to be used in phytoremediation heavy metal from leachate. This plant seemed to be an effective choice for phytoremediation due to its survival in extreme to moderate conditions, the availability of annual or perennial varieties and a deep root system.

This study was aimed to assess the effectiveness of Horsetail (*Equisetum hyemale*) in removing lead and chromium from leachate. This study was only to observe the capacity of system to remove pollutant, so it focused only to the system and no specific observation for the plants. The effectiveness was expressed as percentage and half time removal.

## Material and Method

A greenhouse study was conducted at Brawijaya University during dry season in 2011. Horsetail plants were collected from local ornamental plants shop. The plants were adapted under greenhouse

condition. Healthy plants were chosen from its green and strong appearance. Plants were released from the previous medium carefully for not to damage the roots then cleaned with clean water until no material left on the roots. Plants were endeavored not to damage the roots so was easy to replant on test pots. Those plants then placed in a plastic box with leachate containing as acclimatization process for three days. The amount of leachate on acclimatization process was just enough to soak the plant roots. Total weight of tested plants in one pot is the treatment of this research i.e. 153 and 306 gram.

Media used in this research is 2-3 mesh sterile zeolites placed in plastic pot with 20 cm diameter and 20 cm deep which has 3 kg medium on each pot. No specific purpose underlies the choosing media material except for the use as upholder of the tested plants. The leachate volume for each pot is 2700 ml. The leachate was taken from first pond of five ponds series at Supit Urang municipal solid waste landfill in Malang, East Java, Indonesia.

Each of the test plant was grown in test pot as observed treatment i.e. pot contains 153 gram, 306 gram living plants, and control pot with no plant. Each pot has surface area 314.29 cm<sup>2</sup>. Experiments were carried out with three replicates. Leachate flow was conducted continuously and intermittently. Continuous loading was conducted using 15 ml/s flow rate for daily during 21 days to observe the trend volumetric loading. Intermittent loading was conducted at intervals of three days, which was considered a resting period or detention time. Lead and chromium concentration on leachate were observed weekly for three weeks using Cold Vapor Atomic Absorption Spectrophotometer (Standard Method, 2005). Additionally, surroundings temperature and humidity were observed and also leachate's pH and temperature. The efficiency of lead and chromium removal was measured using common efficiency (E) formula, which was defined as follows:

$$E = [(C_i - C_e) / C_i] * 100\%$$

Where  $C_i$  was influent concentration and  $C_e$  was effluent concentration.

Obtained data of lead and chromium removal from leachate were then analyze statistically using Least Significance Difference (LSD) analysis to know the significant different of each treatment. While, the interaction was analyze using Honestly Significance Difference (HSD) with level of confidence ( $\alpha$ ) 0.05.

## Results and Discussion

The leachate in this research contains 2.2923 mg/L lead and 0.3892 mg/L chromium. Both of them exceed the quality standard effluent that is 0.1 mg/L for lead and 0.05 mg/l for chromium (Indonesian Government law No. 82/2001; Governor of East Java law No. 45/2002). Temperature and humidity on surrounding system were observed daily during research in order to find its possibility impact to the system. Temperature inside greenhouse was fluctuated from 26°C to 36°C while, humidity ranged from 63% to 75%. Leachate temperature and pH was remaining stable at around 22°C and ranged from 7.2 to 7.8 respectively in both system. No significant correlation was found between these two parameter with lead and chromium removal. These values were not limiting for phytoremediation process (Jeyasingh and Philip, 2005). Least Significance Difference (LSD) test for the treatment group for lead and chromium

removal from leachate was calculated on weekly data (Table 1). Lead and chromium removal from leachate as a combination between flow method (intermittent and continuous) and plants (153 and 306 g/pot) can be seen at Table 2. It was then followed by HSD analysis to find the significance of the treatment capability to remove pollutant.

Table 1 showed that the amount of plant in the system is significantly affect the lead and chromium removal from leachate. While the flow method only showed significant respond on the lead removal at week I. The presence of horsetail can significantly remove lead from leachate comparing to control. It can also significantly remove chromium from leachate. Honestly Significance Difference (HSD) analysis on Table 2 showed that combination between intermittent flow and 306 gram horsetail plant can remove the most amount of lead from leachate at the end of the observation (week III) as combination between continuous flow and 306 gram horsetail plant did for chromium removal.

Table 1. Least Significance Difference test for lead and chromium removal from leachate

Parameter	Lead (mg/L)			Chromium (mg/L)		
Time (week)	I	II	III	I	II	III
Plant influence						
153 g plant	0.723 <sup>b</sup>	0.689 <sup>b</sup>	0.470 <sup>a</sup>	0.311 <sup>a</sup>	0.357 <sup>b</sup>	0.177 <sup>b</sup>
306 g plant	0.571 <sup>a</sup>	0.567 <sup>a</sup>	0.434 <sup>a</sup>	0.321 <sup>a</sup>	0.256 <sup>a</sup>	0.158 <sup>a</sup>
Control	0.810 <sup>b</sup>	0.764 <sup>c</sup>	0.592 <sup>b</sup>	0.404 <sup>b</sup>	0.329 <sup>b</sup>	0.204 <sup>c</sup>
LSD <sub>0.05</sub> value	0.087	0.048	0.053	0.079	0.068	0.017
Flow influence						
Intermittent	0.660 <sup>b</sup>	n.i	n.i	n.i	n.i	n.i
Continuous	0.743 <sup>ab</sup>					
LSD <sub>0.05</sub> value	0.087					

The same letter that follows numbers on the same column means not significantly different ( $\alpha=0.05$ ). n.i= no interaction

Table 2. Lead and chromium removal from leachate

Parameter	Lead (mg/L)			Chromium (mg/L)		
Time (week)	I	II	III	I	II	III
Intermittent flow						
153 g plant	0.677 <sup>ab</sup>	0.679 <sup>bc</sup>	0.466 <sup>ab</sup>	0.307 <sup>ab</sup>	0.309 <sup>ab</sup>	0.171 <sup>abc</sup>
306 g plant	0.501 <sup>a</sup>	0.550 <sup>a</sup>	0.409 <sup>a</sup>	0.370 <sup>ab</sup>	0.274 <sup>ab</sup>	0.165 <sup>ab</sup>
Control	0.802 <sup>b</sup>	0.746 <sup>c</sup>	0.575 <sup>bc</sup>	0.302 <sup>ab</sup>	0.312 <sup>ab</sup>	0.182 <sup>abc</sup>
Continuous flow						
153 g plant	0.770 <sup>b</sup>	0.699 <sup>c</sup>	0.473 <sup>ab</sup>	0.468 <sup>b</sup>	0.406 <sup>b</sup>	0.209 <sup>c</sup>
306 g plant	0.641 <sup>ab</sup>	0.579 <sup>ab</sup>	0.459 <sup>a</sup>	0.238 <sup>a</sup>	0.238 <sup>a</sup>	0.151 <sup>a</sup>
Control	0.817 <sup>b</sup>	0.783 <sup>c</sup>	0.609 <sup>c</sup>	0.388 <sup>ab</sup>	0.345 <sup>ab</sup>	0.209 <sup>c</sup>
HSD <sub>0.05</sub> value	0.192	0.107	0.116	0.174	0.149	0.037

The same letter that follows numbers on the same column means not significantly different ( $\alpha=0.05$ ).

Intermittent flow allows wastewater to have detention time in the system. This indicates that the resting period could enhance the lead removal

from leachate. This statement was supported by the previous research for BOD, COD and TN degradation from leachate (Samudro and

Mangkoedihardjo, 2011). Removal of chromium needed continuous flow to be removed from leachate. Continuous flow gives more opportunity of oxygen that can improve pollutant oxidation. By using equation 1, the efficiency of lead and chromium removal from leachate was as shown on Table 3. The highest removal efficiency for lead was reached by intermittent flow process that using of more amount horsetail plant. The highest removal for chromium was reached if the system use more horsetail plant combine with continuous flow system

Table 3. Process efficiency for lead and chromium removal from leachate

Parameter	Lead (mg/L)	Chromium (mg/L)
Intermittent flow		
153 g plant	79.67	56.05
306 g plant	82.16	57.61
Control	74.92	53.24
Continuous flow		
153 g plant	79.37	46.30
306 g plant	79.98	61.20
Control	73.43	46.30

## Conclusion

Horsetail seemed to be potential for phytoremediation of artisanal and small scale mining waste.

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