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Study on Phytoremediation Performance and Heavy Metals Uptake in Leachate by Reed Beds Plant

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Abstract. The principal concern subjected to this research is focused on the pollution potential due to migration of the leachate generated from the landfill sites into groundwater, surface water or the sea. In this study, phytoremediation treatment has being used to examine the heavy metals removal. Two basic parameters tested were zinc (Zn) and chromium hexavalent (Cr^{6+}), which were found to be critical compounds in leachate sample from selected landfill. The amounts of both heavy metals were measured in initial monitoring and compared after being retained by the native plant, called as Reed Beds. The final results indicated that this method is better applied to reduce zinc concentrations with highest removal efficiency almost 70%. Chromium concentrations however still reduced around 18.6 to 31.2%, but still do not complied with the required standard.

Keywords: Heavy Metals Uptake, Untreated Leachate, Reed Beds

1. Introduction

According to Chaudhry et al. (2001) and Schröder (2006), there are thousands of sites all around the world especially from industrialized countries are being polluted with organic chemicals due to industrial processes, spills, and accidents or due to improper use of chemicals. In this study, the concern on the pollution potential has been purposeful due to migration of the leachate generated from the landfill sites into the groundwater, the surface water, or the sea. Kumar and Alappat (2005) have conducted a study on the potentials of leachate contaminant from two active and two closed landfills sites in Hong Kong. The study evidenced that the leachate generated from the closed landfills can have equal or more contamination potential in comparison to the active landfills sites. Leachate in closed landfill normally is characterized by high concentration of organic matter (biodegradable and non-biodegradable), ammonia nitrogen, heavy metals, and chlorinated organic and inorganic salts (Umar et al., 2010).

Various efforts also being used in order to eliminate those surplus chemicals from keep leaching into the surrounding sites, especially from landfill trashes. Engineering and chemical methods such as dig-and-dump, forced aeration, solvent use, and incineration has been used in extensive ways to achieve the goal (Schröder et al., 2008). Lately, more environmentally friendly approaches is preferably, comprises of bioremediation and phytoremediation. This is due to the facts that they are more economical, require not or less chemicals, harmless, and uncomplicated to maintain. Phytoremediation has been widely known as an emerging technology which uses plants and their associated rhizospheric microorganisms to remove, degrade contain chemical contaminants located in the soil, sediments, groundwater, surface water and even the atmosphere (Raskin and Ensley, 2000). Applying phytoremediation to landfill associated with leachate treatment has several potential advantages including (1) providing a water and nutrient source for enhanced plant performance, (2) reduction of leachate volume and consequently mitigation of the migration of groundwater containing elevated levels of contaminants and the (3) removal of the contaminants in the leachate and hence improvement of the quality of leachate (Kim and Owens, 2010).

2. Methodology

2.1. Experiment Set Up

In this study, the leachate sample was collected in Teflon containers from the leachate collection point in closed landfill at Kuala Perlis, Perlis. The represent sample of perennial plant used for this method is Reed Beds that was taken from Ampang Jajar closed landfill in Penang and planted into medium-sized garden pot immediately. Reed is a generic polyphyletic botanical term used to describe numerous tall, coarse grass-like plants of wet places. According to Oo (2010), a reed beds system containing gravels and local plants has been found to be an effective, long-term, and cheaper way to treat domestic wastewater. The base of garden pot was put on a tray to collect the dripping of treated leachate from the above pot. The plants were then let for acclimatization to the environment for two weeks, and then were thrived. Acclimatization is achieved when the plant illustrated healthy leaves and stem and also by the growth of new leaves and inflorescence (Ain Nihla et al., 2011). Experiment started by filling the Reed Beds pot with 1.2 L of leachate, which was added once in a week for four times. After seven days of leachate retention in each week, the effluent trapped in the tray will be collected and tested for heavy metals concentration using HACH Spectrophotometer DR2800. Heavy metal components that been tested including Chromium (Cr^{6+}) by 1,5-Diphenylcarbohydrazide Method (Method 8023, Powder Pillow, 0.01-0.70 mg/l Cr^{6+}), and Zinc (Zn) by Zinco Method (Method 8009, 0.01- 3.00 mg/l). All parameter analyses were carried out according to the recommendation of the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Prior testing, the leachate sample was filtered to remove the content of high-suspended solid. The effectiveness of the phytoremediation will be examined through the percentage reduction of heavy metal concentrations of the plant and soil medium, by comparing with the previous condition (untreated leachate).

3. Result and Discussion

3.1. Untreated Leachate Monitoring

At the first stage of this study, untreated leachate concentrations of heavy metals were monitored from four different points of leachate collection pipe in three weeks. There points included Environmental Site Assessment (ESA): ESA 8, ESA 12 and ESA 13, and mainhole point. Environmental Site Assessment was used as a leachate collection point to monitor the groundwater leachate, while mainhole was used as a leachate collection system on the site.

Table 1: Leachate Collection Points

Point of Leachate Collection	Point Function
P1	Mainhole Point
P2	ESA 8
P3	ESA 12
P4	ESA 13

Due to the location of landfill near to the sea, results obtained were compared with the Standard B in Third Schedule of the Environmental Quality Act, 1974, lies under the Malaysian Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979. The average values of zinc concentration for all the points in three weeks ranged from 0.43 to 1.56 mg/l. Results indicated highest value of Zn came from P1, which is the leachate drainage system on the site during first week of monitoring. This might be influenced by its local position, combined with the rainfall infiltration and waste on the landfill's surface. Also, concentration of heavy metal is generally higher at earlier stages because of higher metal solubility as a result of low pH caused by production of organic acids (Kulikowska and Klimiuk, 2008).

Meanwhile, the average values of chromium concentration levels were observed in the range 0.2 to 0.31 mg/l, which legally exceeds the Standard B criteria of 0.05 mg/l. This is consistent with solubility and mobility of metals, which increased in the presence of natural and synthetic humid substances (Jones et al., 2006). Furthermore, colloids have great affinity for heavy metals and a significant but highly variable fraction of heavy metals when associated with colloidal matter. The solubility of the metals might also increase because of the reducing condition of the leachate that changes the ionic state of the metals (Li et al., 2007).

3.2 Performance of Phytoremediation Treatment

Table 2: Treatment Performance on Zn and Cr^{6+}

Cycle	Zn Concentrations			Cr^{6+} Concentrations		
	Raw (mg/L)	Treated (mg/L)	Removal Efficiency (%)	Raw (mg/L)	Treated (mg/L)	Removal Efficiency (%)
1	0.43	0.4	6.98	0.70	0.51	27.1
2	0.67	0.5	25.4	0.70	0.57	18.6
3	2.1	0.67	68.1	0.56	0.43	23.2
4	2.1	0.63	70.0	0.48	0.33	31.2

After four weeks of retention of the leachate, a significant reduction was indicated in Zn concentrations by the Reed Beds particularly after three and four cycles of treatment done. The accumulation of leachate's volume and its concentration gradually increased the ability of the plant uptake on heavy metals. As being discussed by Schröder (2008), reed metabolism can be affected by pollutants and their detoxification capacity may adapt to the pollution situation. The removal percentage therefore has complied with the parameter limits of effluent for Standard B in Environmental Quality (Sewage and Industrial Effluents) Regulation 1979, where the concentration of zinc must be at maximum 1.0 mg/L. While for Cr^{6+} concentrations, the results still exceeded the Standard B criteria of 0.05 mg/L. However, in another way the treated leachate concentrations were still decreased compared to the raw leachate after the treatment process. The results revealed the effectiveness of the phytoremediation approach in treating leachate.

For plants successfully undergone phytoremediation, its ability to adapt quickly to pollution scenarios is really important. This is because rapid detoxification of pollutants has to be achieved right after the uptake process, to prevent damage to living tissue (Schröder, 2006). The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found. In this kind of treatment process, the immobilizing contaminants in the soil will be adsorbed onto roots or precipitated within root zone of plants (Ralinda, 1996).

As can be observed through Fig. 1, the root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth along with other non-essential contaminants. Plant roots will cause changes at the soil-root interface as they release organic and inorganic exudates in the rhizosphere. This root exudation affects the number and activity of microorganisms, the aggregation, and stability of the soil particles around the root, and the availability of the contaminants. Root exudates by themselves can increase or decrease (immobilize) the availability of the contaminants in the root zone of the plants through changes in soil characteristics, release of organic substances, changes in chemical composition and/or increase in plant assisted microbial activity (Jones et al., 2006). As reported by Krishnan (2002), the high accumulation of heavy metal in the Reed Beds tissues were influenced by the plant's many shorter roots. This condition helps to create aeration zones for heavy metal uptake. In addition, the use of tree-based phytoremediation to treat and dispose leachate allows it to stimulate bioremediation at the root level and to accelerate evaporation due to leaf evapotranspiration (Alkorta and Garbisu, 2001).

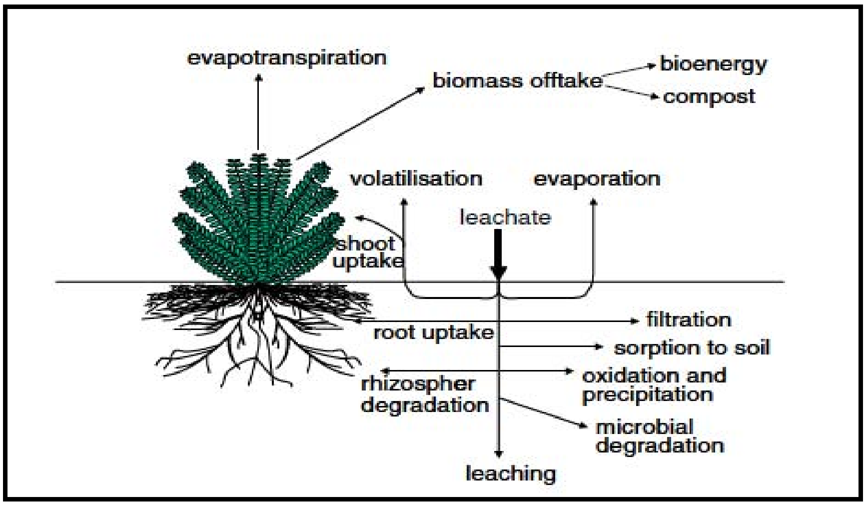

Fig. 1: Schematic Representation of the Soil-plant Bioreactor (Jones et al., 2006)

4. Conclusion

Based on the results depicted from this study, it can be concluded that phytoremediation treatment is a promising remediation option for leachate (Haarstad and Maehlum, 1999). Reed Beds proved an excellent tolerant to a month treatment of leachate irrigation. The results obtained supported by Abbas et al. (2009) whom found that leachate irrigation to land can provide an opportunity for closing the nutrient cycling loop and simultaneously producing effluent of a suitable quality for discharge. Therefore this study will lead to a more economical measure in future for eliminating heavy metals in highly polluted soil, by using combination between phytostabilization and rhyzofiltration processes, based on the potential of selected plants. This research in other way evidenced that plants can be directly assimilating and degrading toxic contaminants.

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