

Uptake of Heavy Metals in Landfill Leachate by Vetiver Grass

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ABSTRACT

Many waste disposal sites in Thailand are sources of environmental pollution because waste is still largely disposed of at these places without effective and proper management control. Landfill leachate usually contains high concentrations of heavy metals that are seriously harmful to the environment and human health. The study was conducted using vetiver for phyto-remedying soil contaminated with landfill leachate. Surat Thani ecotype vetiver plants planted in pots were treated with landfill leachate at the strength of 0, 50, 70 and 100 %. Data on growth and heavy metal uptake analyzed by X-ray fluorescence technique were recorded. The results indicated that the growth of vetiver was reduced as the landfill leachate strength increased. The vetiver grass treated with 100 % leachate could not survive at 80-85 days after planting. Vetiver grass uptook more heavy metals as the strength of leachate increased and these heavy metals were evenly distributed in shoot and root. Heavy metals derived from leachate remained more in soil as the leachate strength was higher and could reach the toxic level for plants. The results of a field trial at the landfill site also indicated that vetiver technology could be useful for rehabilitating landfills and nearby areas. Practically, vetiver plants should be contour-planted on the side slopes of old landfills or at the leachate site. For young landfills, this green technology could be used with a limited leachate strength. The shoot part should be harvested periodically in order to remove the heavy metals from the contaminated soil and stimulate new growth for more uptake.

Key words: vetiver, landfill, leachate, heavy metal

INTRODUCTION

In Thailand, the environmental pollution problem from solid waste has seriously increased due to increasing amount of solid waste, especially in Bangkok, the capital city of Thailand. The average daily solid waste generated in Bangkok doubled from 3,260 tons in 1985 to 6,633 tons in 1995 and reached 9,173 tons in 2001 (The United Nations Environment Programme, 2001). A waste minimization project has been introduced urging

people to reduce and separate wastes before disposal as well as to recycle. However, there is no effective implementation so far as shown by the elevated amount of solid waste every year. This increase is due to various factors such as increasing population, consumption pattern and changing life style. In Bangkok, household garbage is collected and then unloaded at the landfills. Most landfill sites are open dump type without proper leachate or gas collection and treating system. The leachate from landfills usually has high content of pollutants,

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especially heavy metals and other harmful substances which became contamination in the area around the landfill sites and in ground water.

The technology of using plants for *in situ* remedying treatment of contaminated soils, sediments and water has been developed and widely accepted (Chaney *et al.*, 1997; Cunningham *et al.*, 1995). Plants used for this technology must have the capacity to withstand a relatively high concentration of pollutants. Vetiver grass (*Vetiveria zizanioides* (L.) Nash.) has been successfully used for erosion and sediment control as well as soil and water conservation. Due to its unique morphological, physiological and ecological characters, vetiver grass is now being used in over 40 countries for various environment protection purposes (Truong and Hart, 2001). Many experiments and observations have confirmed that vetiver grass grows well in soil contaminated with heavy metals (Roongtanakiat and Chairaj, 2001; Truong and Baker, 1998; Zheng *et al.*, 1998). The absorbed heavy metals in plant shoot and root also indicated the high tolerance of vetiver to heavy metals. The research presented here aimed at using vetiver grass for absorption of heavy metals from leachate and reducing leachate discharge on the landfill site. X-ray fluorescence technique was used for heavy metal analysis while multi elements in samples could be conveniently analyzed in a short time without using any digestion processes. The use of this green technology for rehabilitation of landfill sites in Thailand is anticipated.

MATERIALS AND METHODS

A pot experiment using CRD with four replications was used for studying the effect of four leachate strength levels applied to vetiver grass. Two seedlings of Surat Thani vetiver ecotype were planted in each pot containing 7 kg of contaminated soil collected from the landfill site at Kamphaeng Saen, Nakhon Pathom province. The

raw leachate was diluted to 0, 50, 75, 100 % strength levels and the pH was adjusted to 7. Each leachate strength solution was applied to the vetiver plants at 200 ml daily. Plant height was measured at 30, 60 and 90 days. After harvesting, shoot and root were separated for dry matter measurement, and soil samples from individual pot were air dried. Heavy metal was analyzed using the Wavelength Dispersive X-ray Fluorescence Spectrometer, Model PW 2400 of Phillips Company. The grinding and briquetting method was used for soil and plant specimen preparation, and the standard addition and dilution method was done for matrix correction. (Jenkins *et al.*, 1995)

A preliminary field trial was also carried out at the landfill site. Five rows of Surat Thani vetiver ecotype were planted at the landfill side slope. The vetiver planting rows were 20 m long with 50 × 10 cm plant spacing. The experimental area was irrigated weekly during the first month of growth. After that, plants were left at field condition without irrigation for observation of plant growth.

The landfill site at Kamphaeng Saen, Nakhon Pathom Province was opened in 1990 covering an area of approximately 128 hectares. About 5,000 tons per day of municipal solid waste from Bangkok was dumped and layered at this landfill. The new waste layers were deposited on top of old waste layers where the lower parts of landfill would have progressed much further than the top with respect to stabilization. Each waste layer was 2.0-2.5 m thick and covered with 30-50 cm clayey soil. The leachate was discharged from the top of the landfill and overflowed to the ground area where the sample was taken. Leachate quality was investigated by using the dilution method, open reflux method and Macro Kjeldahl for BOD, COD and total N, respectively, while the heavy metal contents in leachate were analyzed with X-ray fluorescence.

RESULTS AND DISCUSSION

Landfill leachate composition

It had the pH of 9.2 and very high content of organic pollutants with COD of 13,160 mg/l, BOD of 6,607 mg/l and total N of 3,566 mg/l which very far exceeded the industrial effluent standard values of 120-400 mg/l COD, 20-60 mg/l BOD and 100-200 mg/l total N (Pollution Control Department, 2003). The contents of heavy metals in leachate and soil, namely Pb, Zn, Cu, Ni, and Cr were shown in Table 1.

Vetiver growth

The average heights of vetiver plants treated with various strength levels of leachate at 30, 60 and 90 days of growth are shown in Figure 2. In the early-middle (30-60 days) of growth periods, vetiver treated with 0, 50, and 75 % of leachate strength levels showed increasing height and a similar growth pattern while 100 % treatment plants had the lowest plant height. At a more mature stage, plant height distinctively decreased with increasing given leachate strength. Plants were greatly affected in the 100 % treatment and did not survive at 80-85 days after planting. The influence of leachate strength on plant height obviously showed at 90 days after of growth as shown by statistically significant differences in height among treatments.

The average weights of dry shoot and root were not statistically different among plants treated with 0, 50 and 70 % leachate strength levels.

However, they were significantly higher than those treated with 100 % leachate as shown in Figure 3.

The death of vetiver grass in the 100 % leachate treatment was probably due to the very high contents of organic pollutants as indicated by the high values of COD (13,160 mg/l) and BOD (6,607 mg/l). It is obvious that the leachate from this landfill is highly toxic and harmful to plants. From a hydroponic culture experiment, Xia *et al.* (2000) found that vetiver was capable of surviving in leachate with COD of 1120.1 mg/l and BOD of 120.8 mg/l. Yet, we have found that vetiver could still survive in the 70 % treatment in which the COD and BOD values were 9,200 and 4,600 mg/l, respectively, which were extremely high. It has been proven here that vetiver is an excellent pollution resistant plant and could be used to alleviate the problem of contaminated soil.



Figure 1 Leachate runoff on the ground of the landfill site, where the leachate samples were collected.

Table 1 Heavy metal contents in the leachate and soil used in the experiment, in comparison to the industrial effluent standard value.

Item	Heavy metal content (mg/l or mg/kg)				
	Pb	Zn	Cu	Ni	Cr
Leachate	25.05	234.46	53.30	51.77	79.53
Soil	26.23	22.47	16.58	18.58	25.44
Industrial effluent standard	<0.2	<5.0	<2.0	<1.0	<0.25

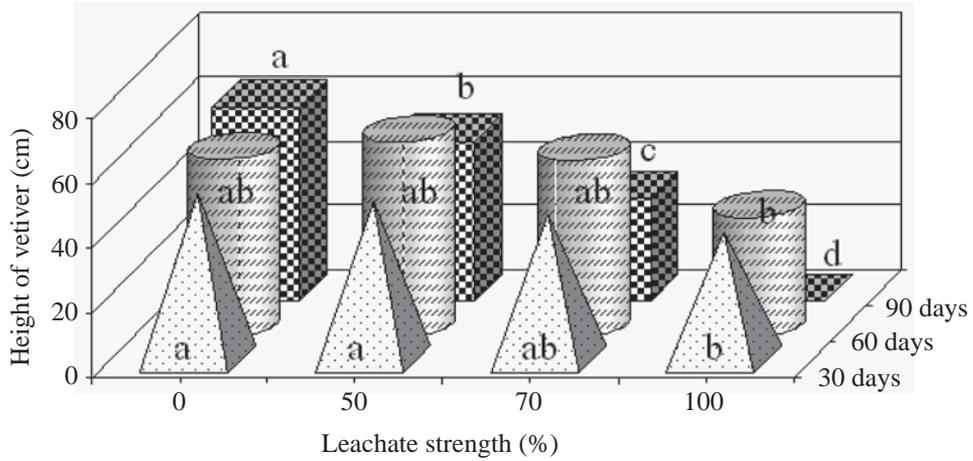


Figure 2 Average heights (cm) of vetiver plants treated with 0, 50, 70 and 100 % leachate strength at 30, 60 and 90 days after planting.

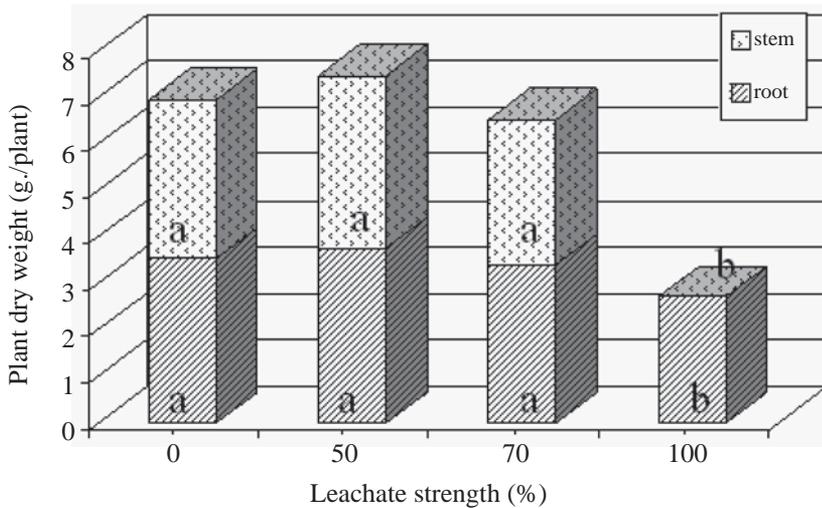


Figure 3 Average dry weights of vetiver shoot and root treated with 0, 50, 70 and 100 % leachate strength.

Concentration of heavy metals in vetiver

The heavy metals analyzed in vetiver shoot and root were Zn, Cu, Ni, Cr and Pb. The concentrations of Pb in plant specimens from all treatments were extremely low and could not be detected by X-ray fluorescence spectrometer. Figure 4 showed the concentrations of heavy metals in both vetiver shoot and root. Vetiver was capable

of taking up more amounts of Zn, Cu, Ni, and Cr as it received leachate of higher strengths. The highest concentrations of heavy metals were found in vetiver shoot and root treated with 100 % leachate and these were significantly higher than those in the 0 and 50 % treatments. Comparing to the 70 % leachate treatment, the concentrations of heavy metals in vetiver from the 100 % leachate

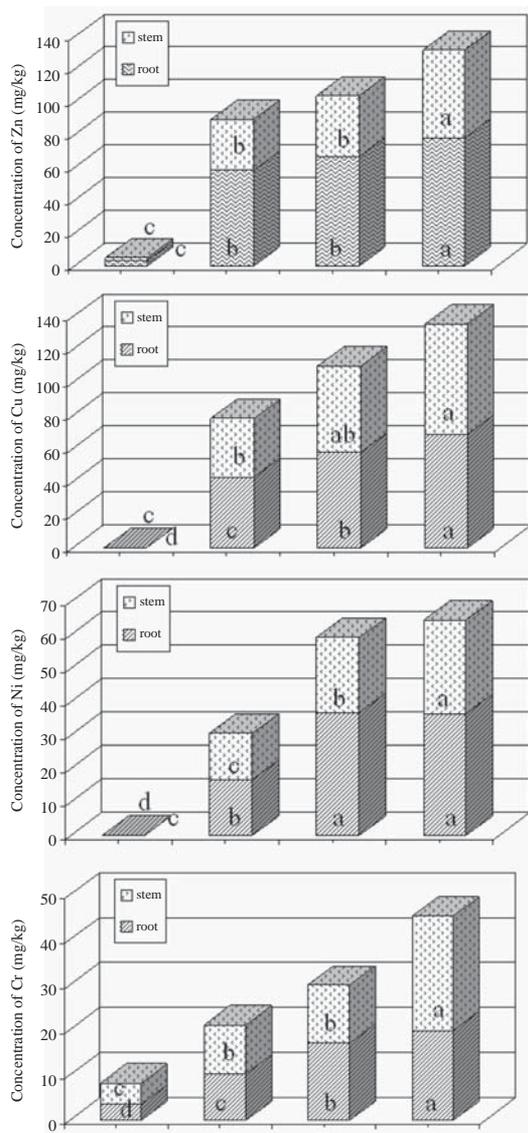


Figure 4 Heavy metal (Zn, Cu, Ni, and Cr) contents in shoot and root of vetiver plants treated with 0, 50, 70 and 100 % leachate strength.

treatment were significantly higher than those of the 70 % leachate treatment except for the concentrations of Cu in shoot and of Ni in root. The result showed a similar trend when the 50 to 70 % leachate treatments were compared. Vetiver plants grown in the 70 % leachate treatment had the

concentrations of Ni in both shoot and root, Cu and Cr in root higher than those in the 50 % leachate treatment.

Considering the heavy metals in vetiver shoot of the 100 % leachate treatment, Zn and Ni contents were 53.84 and 28.12 mg/kg, respectively. These values were below the levels toxic to vetiver growth of > 800 mg/kg and 347 mg/kg, respectively (Truong, 1999). However, the contents of Cu (68.9 mg/kg) and Cr (20.14 mg/kg) were above the levels toxic to vetiver as Truong (1999) reported that the Cu toxic threshold of vetiver was between 13 and 15 mg/kg and the Cr threshold was between 5 and 18 mg/kg. Therefore, one more evidence causing the death of vetiver in the 100 % leachate treatment may be toxicity of Cu and Cr. Concerning heavy metal distribution in the vetiver plant, the data showed that Zn, Cu, Ni and Cr were evenly distributed in shoot and root, similar to the report of Roontanakiat and Chairroj (2001) for the Zn and Cu distributions in the vetiver plant.

Heavy metal content in soil

The content of heavy metals in the soil of individual pots was analyzed after vetiver harvesting. The amounts of Zn, Cu, Ni, Cr and Pb remaining corresponded to the strength of leachate given to the vetiver (Figure 5). There were statistically significant differences among all treatments, except for the content of Cu in the 70 % treatment, which was higher than that in the 50 % treatment, but there was no statistical difference. Comparing the heavy metal contents in soil before and after the experiment, the data gave very interesting information about heavy metal pollution from the leachate. In the control treatment, in which plants were watered with the 0 % leachate (clean water), soil contents of all heavy metal decreased due to plant uptake. In the other treatments, in which soil was polluted with the leachate, there was an increase in heavy metal contents. Even though the plants absorbed some heavy metals, the amounts remaining in soil were

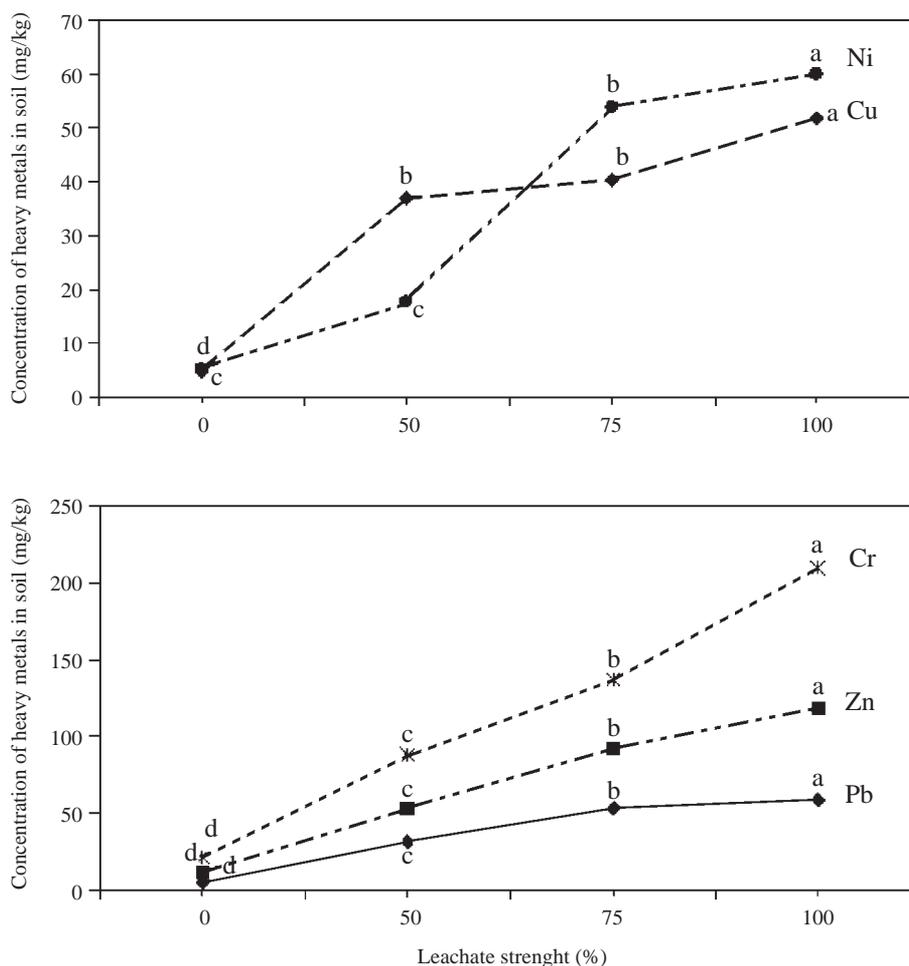


Figure 5 Heavy metal (Zn, Cu, Ni, and Cr) contents remained in soil after harvesting vetiver plants treated with 0, 50, 70 and 100 % leachate strength.

still very high, especially in the 100 % treatment. The maximum contents of Ni (60.07 mg/kg) and Cr (210.23 mg/kg) were above the standard values of 50 and 100 mg/kg, respectively (Pakpean *et al.*, 1998). The data indicated that the landfill leachate caused a problem of heavy metal contamination in soil. To remedy and rehabilitate the landfill site and nearby areas, vetiver could be grown and trimmed periodically to stimulate new growth and more heavy metal uptake.

Supporting data from the preliminary field trial

In the preliminary trial at the landfill site, vetiver plants grew well during the first 1-2 months after planting. They showed a good resistance to the poor environment of the garbage landfill. Twenty vetiver plants within each row along the side slope of the landfill were randomly measured for height at 3 months after planting. The average plant heights of the two top rows were (125 and 114 cm) higher than those in the three lower rows

(69, 71 and 69 cm) which received greater leachate strength. The toxicity of leachate was more serious or pronounced at the fourth month, especially in the lower rows, in which some vetiver plants gradually wilted and finally died as shown in Figure 6. The composition of leachate varies depending on many factors including the composition of waste, season, climate, hydrology, decomposition and age of the landfills (Reinhart and Grosh, 1998), it is suggested that, for a proper management, the quality of leachate should be determined before applying suitable vetiver technology to young landfills to control leachate runoff and seepage as well as to absorb organic pollutants and heavy metals. For old landfills in which leachate strength has decreased, vetiver is most suitable for use in rehabilitation of such a contaminated area. Vetiver will act as a pioneer plant to decontaminate and reduce surplus leachate on landfill sites and will help in improving the environment.



Figure 6 Five rows of Surat Thani vetiver ecotype were planted on the side slope of the landfill site at Kamphaeng Sean, Nakhon Pathom province. Vetiver growth at the top rows was better than that of the lower rows in which plants received more leachate.

CONCLUSION

Landfill is still one of the widely used approaches for treating and disposing solid waste globally in spite of its big environmental problem. One of the main environmental concerns associated with landfills is the generation of leachate from waste decomposition. This experiment showed that Surat Thani vetiver ecotype could grow and develop well when it was treated with landfill leachate. The concentration of heavy metals in plant parts increased as the strength of leachate increased. Because of extremely high content of organic pollutants and heavy metals, especially Ni and Cr, vetiver was killed by the 100 % leachate. Therefore, vetiver technology should appropriately be applied to old landfills for heavy metal decontamination and rehabilitation.

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