Potential of *Cordyline* sp Plant for Remediation of Metal-Leachate Contaminated Soil

B. Jayanthi, C. U. Emenike, P. Agamuthu, and S. H. Fauziah

***Abstract*—Heavy metals are extremely persistent in the environment and cannot degrade through chemical process, hence the long term accumulation cause induce to the environment. Soil is one of the major sink to heavy metal contamination due human activities associated to the development of global economies. Metals from waste stream, especially landfill leachate impact the soil and there is need to develop remedial option for the environmental safety of soil core. Various plants have been used to remedy polluted soil, yet metal interaction with plant differ with respect to medium or source of metal pollution. Phytoremediation technology is an alternative and cheaper approach for remediation of metal contaminated soil. Plant-based remediation is one of the most significant sustainable techniques to cope with overwhelming consequences of pollutants. Therefore this study aimed to study the potential of *Cordyline* sp plant and *Durianta* variegated for the phytoremediation of heavy metals (Pb, As, Mn, Ni, and Cr) from the leachate contaminated soil. The results showed that *Cordyline* sp plants tends to accumulate high amounts of this metals compared to *Durianta* variegated and control. *Cordyline* sp was able to remove 63 % of Pb, 90 % of As, 78.8 % of Mn, 88.9 % of Ni and 75 % of Cr from the metal polluted soil. The removal of heavy metal from the contaminated soil was significantly higher compared to control at P > 0.05. The highest heavy metal removal rate constant was obtained for As and Ni at same rate of 0.018 mg/kg day^{-1} when *Cordyline* sp plants were used. Therefore we can conclude that, *Cordyline* sp have a potential to remediate heavy metal contaminated soil at a significant level.**

***Index Terms*—Heavy metal, landfill soil, leachate, phytoremediation.**

I. Introduction

Heavy metal contamination in the environment is a worldwide phenomenon that requires serious attention [1]. This is mainly due to geologic and anthropogenic activities. Landfilling is identified as one of major contributor to heavy metal contamination to the environment [2]. The high waste generation pattern in especially in developing generation leads to high generation of landfill leachate. Landfill leachate is highly concentrated complex effluents which contains organics: alkenes, aromatic hydrocarbons, acids, esters, alcohols, hydroxyl benzene, amides, and others, ammonia, nitrogen and heavy metals such as cadmium, chromium, copper, lead, zinc, and nickel [3]. The industrialization and urbanization that has progressively developed over time without any regard for environmental consequences. The indiscriminate release of heavy metals into the soil is major health concern globally, as the heavy metal cannot be broken down or transform to non-toxic form easily. Most of the heavy metal are human carcinogenic even at low concentration [4]. Due to the high degree of toxicity, As, Cd, Cr, Pb and Hg rank among the most toxic metals that are of public health significance. Heavy metals are systemic toxicants that are known to cause multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer. Most of the Asian countries are surrounded by water bodies and expanse of fertile land that serve as serene environment for aquatic organisms [5]. Phytoremediation is an aspects that uses plant for treatment of heavy metal contaminated soil. An effective phytoremediation occurs when the pollutants is within the root zone of the plant [6] and [7]. About 420 species from 45 plants have been were identified as hyper accumulators of heavy metals [8]. This study evaluated potential of two selected plants in towards uptake of heavy metals from leachate contaminated soil.

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II. Materials And Methodology

A. Soil and Leachate Characterization

Soil samples were collected from Taman Beringin (TBL) (30 13.78 N; 1010 39.72 E; non-operational) landfills at 30cm depth in accordance with the 2014 ASTME–1197 [9], [10], and [11]. The sample were analyzed for pH using a multiprobe meter (YSI Professional Plus, USA), while the soil total nitrogen, total potassium, and total phosphorus were analyzed by adopting ASTM E778-87, ASTM E96-94, and ASTM D5198-92 methods, respectively. Meta concentrations were analyzed based on the USEPA 3050B guidelines except for mercury (Hg), which was analyzed based on the USEPA 3052 method. Leachate samples were also collected from the landfill and analyzed for parameters similar to the soil samples. Physico-chemical properties of the leachate samples determined in the laboratory were BOD_5, COD, total N, P, and K. The analysis was conducted based on APHA (1998) standards [10].

B. Phytoremediation Experimental Design

The leachate contaminated soil from Taman Beringin

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Landfill was collected for the phytoremediation study and the heavy metal concentration was predetermined before the set up. The phytoremediation potential of two plant were tested in this study (Table I). Plants were obtained from University of Malaya Nursery, Kuala Lumpur, Malaysia. Each plant was placed in polybag containing 2.25 kg of leachate contaminated soil with predetermined heavy metal concentration. Experiment was conducted for 120 days. Soil microcosm without any plant served as the control experiment. The initial and final concentration of metals were respectively analyzed before and after the experiments for the plants and soil.

TABLE I: DESCRIPTION OF TREATMENT

Treatment	Details of treatment	No of Samples
A	2.25 Kg of TB Soil + Cordyline	3
B	2.25 Kg of TB Soil + Durianta variegated	3
C	2.25kg of TB Soil (Control)	3

C. Heavy Metal Analysis

Soil and plant heavy metal concentration was analysed for all the treatment using ICP-OES according to USEPA 3050B guidelines [10].

D. Rate Constant of Heavy Metal Removal

Rate of metal uptake in a day was calculated using first order kinetic models

$$K=-\frac{1}{t}\left(\ln\frac{c}{c_0}\right) \tag{1}$$

K = first-order rate constant for metal uptake per day
t = time in days
C = concentration of residual metal in the soil (mg kg^{-1})
C_0= initial concentration of metal in the soil (mg kg^{-1})

E. Uptake Modelling of Heavy Metal

The uptake of heavy metals by plant from soil was calculated with bioaccumulation factor (BAF) and translocation factor (TF),

$$\text{BAF} = \frac{\text{Heavy mental in plant}}{\text{Heavy mental in soil}} \tag{2}$$

BAF= Bioaccumulation factor
Heavy metal in plant= Concentration of heavy metal in harvested part of plant (mg/kg)
Heavy metal in soil = Concentration of heavy metal in soil (mg/kg)

$$\text{TFshoot} = \frac{\text{Mental in shoot}}{\text{Mental in root}} \tag{3}$$

TF= Translocation factor
Metal in shoot = Concentration of heavy metal in shoot of plant (mg/kg)
Metal in root = Concentration of heavy metal in root of plant (mg/kg)

III. RESULTS AND DISCUSSION

Taman Beringin Landfill is a closed non-sanitary landfill. The operation of the landfill ended in 2005 and was receiving about 1800 to 2000 tonnes of MSW daily. Leachate and soil characterization is tabulated in Table II and Table III. Landfill leachate of Taman Beringin landfill contained heavy metals above the discharge limit from the standard of Environmental Quality Regulations 2009, Malaysia. Similarly the soil characterization also showed that heavy metal concentration in Taman Beringin Landfill is above the prescribed limit [12]. The concentration of heavy metal in soil followed the order of Al (49600 mg/L) > Fe (42900 mg/L) > Mn (281 mg/L) > As (141 mg/L) > Cu (59 mg/L) > Zn (49 mg/L) > Cr (46 mg/L) > Ni (21 mg/L) > Pb (18 mg/L) > Hg (0.02 mg/L) > Cd (0.01 mg/L). The metal distributions among the specific forms differs based on their chemical properties and characteristics of the soil [11], [13].

TABLE II: LEACHATE CHARACTERIZATION OF TAMAN BERINGIN LANDFILL

Test Parameters	**Method**	**Range values (mg/L)**	**Standard (Environmental Quality Regulations 2009, Malaysia)**
pH	Probe insertion	7.57 ± 0.8*	6.0-9.0
BOD	APHA 5210 B	127 ± 45	20
COD	APHA 5220	482 ± 103	400
Total N	ASTM E778-87	0.25 ± 0.08*	5
Total K	ASTM E926-94	11.6 ± 2.1	N.A
Total P	ASTM D5198-92	24.3 ± 0.7	N.A
As	USEPA 3050 B	0.01	0.05
Ca	USEPA 3050 B	242.1 ± 42	N.A
Fe	USEPA 3050 B	134.6 ± 16	5.0
Mn	USEPA 3050 B	3.1 ± 0.32	0.2
Mg	USEPA 3050 B	52.2 ±8.7	N.A
Na	USEPA 3050 B	29.7 ± 5.1	N.A
Cu	USEPA 3050 B	0.5 ± 0.1	0.2
Zn	USEPA 3050 B	24.3 ± 3	2.0
Pb	USEPA 3050 B	<0.01	0.10
Cd	USEPA 3050 B	0.4 ± 0.1	0.01
Hg	USEPA 3052	0.03	0.005
Cr	USEPA 3050 B	6.2 ± 1.4	0.20
Ni	USEPA 3050 B	0.85 ±0.1	0.20
Al	USEPA 3050 B	5.47 ± 1.2	N.A

(Mean values n = 3) *All parameters are in mg/L except pH and Total N (%)

TABLE III: SOIL CHARACTERIZATION OF TAMAN BERINGIN LANDFILL

Test parameter	Units	Test method	Taman Beringin landfill
			Mean[a]
pH		Probe Insertion	7.57
Total N	%	ASTM E778-87	0.62
Total K	mg/kg	ASTM E926-94	396.9
Total P	mg/kg	ASTM D5198-92	568
As	mg/kg	USEPA 3050 B	141
Ca	mg/kg	USEPA 3050 B	1608
Fe	mg/kg	USEPA 3050 B	42900
Mn	mg/kg	USEPA 3050 B	281
Mg	mg/kg	USEPA 3050 B	127.2
Na	mg/kg	USEPA 3050 B	4.54
Cu	mg/kg	USEPA 3050 B	59
Zn	mg/kg	USEPA 3050 B	49
Pb	mg/kg	USEPA 3050 B	18
Cd	mg/kg	USEPA 3050 B	<0.01
Hg	mg/kg	USEPA 3052	<0.02
Cr	mg/kg	USEPA 3050 B	46
Ni	mg/kg	USEPA 3050 B	21
Al	mg/kg	USEPA 3050 B	49600

Mean[a] =3

Table IV shows the soil initial and residual concentration of heavy metals from the phytoremediation experiment on the contaminated soil. For As, highest removal was observed with Treatment A. Initial As concentration was 141 mg/kg and residual concentration after 120 days experiment is 15.67 mg/kg. Statistical analysis shows a significant difference between Treatment A and the control at $p > 0.05$. Similar trends were observed for almost all the metals studied, whereby Treatment A, *Cordyline* sp showed highest heavy metal removal activity compared to Treatment B (*Durianta* variegated) as well as the control. The differences in the removal activity of the phytoextraction may have been due to the different plant species, solubility, and plant uptake [14]. The degree of Pb reduction after 120 days was highest with Treatment A, whereby it reduced or removed 63% of Pb from the contaminated soil (18 mg/kg it reduce to 6.67 mg/kg), whereas Treatment B and control recorded 55.5% and 53% removal, respectively. The potential of *Cordyline* sp to remove the Pb metal in soil showed its ecological importance [8] and supported by another findings by Perumal [15] reported that the *Cyperus rotundus* and *Ludwigea* sp able to removed 60% of Cr from a contaminated soil without supplements of organic wastes. Treatment A shows an significant removal of Mn from the contaminated soil. It was removed 78.8% of Mn from the soil whereas Treatment B was only able to remove 69% and control 65%. The rate of metal uptake with Treatment A was higher than Treatment B and could be due to differences in physiology of the plants or growth rate and higher biomass of the plant. An effective bioremediation of metal is when the metal is removed at more than 65% [16]. The removal of Ni from the leachate contaminated soil again revealed that higher removal was recorded when Treatment A plant was used in this study. The initial Ni concentration was 21 mg/kg and after 120 days of phytoremediation the Ni concentration reduced to 2.33 mg/kg and percentage of Ni removal was 88.9 %. In the case of Cr, Treatment A was able to remove 75 % of Cr from the initial of 46 mg/kg and control only removed 67 % only.

BCF is the measurement of the metal accumulation efficiency and indicates the capacity of metal accumulation in relation to plant biomass [17]. The bioconcentration factor was higher in Treatment A for all the five metal tested compared to Treatment B (Table V). The differences in the results might be due to the use of different plants which indicates that Treatment A showed more effective accumulation of metals in the plant tissue compared to Treatment B. However the Translocation factor of shoot in Treatment B shows higher factor compared to Treatment A for Pb and Cr and while TF of root was higher in Treatment B for As, Mn and Ni. This indicates that the shoot of Treatment B accumulated higher amount of metals compared to Treatment A.

TABLE IV: INITIAL AND RESIDUAL CONCENTRATIONS OF HEAVY METALS FROM THE PHYTOREMEDIATION OF TAMAN BERINGIN LANDFILL LEACHATE CONTAMINATED SOIL

Heavy metals	Initial Concentrations (mg/kg)	Mean Residuals Concentrations(mg/kg)		
		Treatment A	Treatment B	Treatment C
As	141	15.67	19	28
Mn	281	59.33	83	96.33
Pb	18	6.67	8	8.33
Cr	46	11.67	12.67	15
Ni	21	2.33	3	3.67

TABLE V: BIOACCUMULATION AND TRANSLOCATION FACTOR OF METALS UPTAKES DURING PHYTOREMEDIATION

Heavy metals	Treatment A			Treatment B		
	BAF	TF_{Shoot}	TF_{Root}	BAF	TF_{Shoot}	TF_{Root}
As	2.03	0.523	1.90	2.01	0.35	2.81
Mn	0.927	0.586	1.70	0.38	0.54	1.82
Pb	0.848	0.30	3.25	0.366	0.479	2.08
Cr	0.51	0.28	3.56	0.19	0.66	1.5
Ni	1.40	0.40	2.47	1.20	0.36	2.73

Treatments with plants as metal accumulator have higher heavy metal removal potential than the control experiment. The reduction of metals in Treatment C, which act as control in this experiment can be due to the natural bio attenuation activity in the soil [10]. The heavy metal removal rate is shown in Table VI. First order kinetic model was used to calculate the removal rate of metal by the plant. Comparison between the different treatments across different metals, revealed that the highest removal rate was found in Treatment

A for As and Ni. The removal rate was at 0.018 mg/kg day^{-1}. Also, Treatment A recorded the highest removal rate for all other three metals as well. For Mn (0.013 mg/kg day^{-1}), Pb (0.008 mg/kg day^{-1}) and Cr (0.011 mg/kg day^{-1}). The results showed that an optimum metal uptake rate was with Treatment A.

TABLE VI: HEAVY METAL REMOVAL RATE FOR DIFFERENT TREATMENT (MG/KG DAY^{-1})

Metal	Treatment A	Treatment B	Treatment C
As	0.018	0.016	0.013
Mn	0.013	0.010	0.009
Pb	0.008	0.006	0.006
Cr	0.011	0.010	0.009
Ni	0.018	0.016	0.014

IV. CONCLUSION

Metal contamination is widespread in soil exposed to leachate from non-sanitary landfills or open dump. The metal concentrations was above the recommended limit. However, certain hyper accumulator plant shows an survival and uptake the metals from the contaminated soil at significant rate. *Cordyline* sp demonstrated as a potential plant for remediation of leachate contaminated soil.

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