UNIVERSITI PUTRA MALAYSIA

HEAVY METALS IN SURFACE SOILS OF KOTA BHARU LANDFILL SITE AND ITS RELATIONS TO THE GROWTH AND MACRONUTRIENTS UPTAKE OF *ACACIA MANGIUM*

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CONTENTS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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By

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Faculty: Science and Environmental Studies

A study of heavy metals distribution in landfill surface soil, surface water and landfill leachate and its relations to *Acacia mangium* growth and macronutrients uptake was conducted in a landfill in Kota Bharu, Kelantan. Five heavy metals, particularly Fe, Cr, Zn, Cu and Cd was analyzed in this study and results shows elevated heavy metals concentration level compared to the control surface soil. The distribution of the heavy metals in the surface soil from the landfill varies throughout the study site. The concentration decreased prominently in the river sediment adjacent to the landfill. The concentration of Fe was the highest that ranged between 1993.4 – 2404.6μg/g, followed by Zn, 18.08 – 54.10 μg/g; Cr, 2.67 – 62.10 μg/g; Cu, 5.21 – 18.60 μg/g and Cd, 0.70 – 1.52 μg/g of soil dry weight. However, compared to DOE soil threshold concentration, this landfill was only slightly contaminated with Cd that exceeds the threshold with an average of 0.94 μg/g. Heavy metals speciation by sequential extraction of

landfill surface soil shows that the surface soil was not yet contaminated with heavy metals as the anthropogenic fraction is less than 30% of the total concentration of heavy metals of the surface soil and mainly attached to the organic matter. Concentration of heavy metals in landfill leachate shows higher level than the surface water. However, the levels of heavy metals in both water samples were still considered as low compared to other landfills due to dilution by rain and river nearby. Cu concentrations in water samples were generally higher than other heavy metals that ranged between 0.03 – 6.14 mg/L whereas Cd and Cr were generally very low, below detectable limits. The level of accumulation in *A. mangium* leaves was highest for Fe that ranged between 139.5 – 537.6 μg/g, followed by Cr 45.54 – 357.3 μg/g, Zn 29.36 - 57.23μg/g, Cu 6.88 - 15.61μg/g and Cd 1.63 - 3.48μg/g. However, Fe shows no significant difference in the level of accumulation between landfill and control plants. Heavy metals accumulation level in *A. mangium* leaves have very wide range dependent on the leaves sampled. However, from the soil-plant concentration ratio, heavy metals uptakes by *A. mangium* in landfill site were found higher than control plants especially for Cr and Cd. Generally the concentration of heavy metals was found so much higher in the plants tissues rather than in the landfill surface soil and landfill leachate or surface water. Relation between heavy metals accumulation in *A. mangium* and growth and macronutrient uptake was not demonstrated this study as the N, P, K level in control and landfill site do not show any significant correlation with heavy metals concentrations. Uptakes of N and P in landfill *A. mangium* were found higher than control but on the contrary, K was found higher in control plants. Growth of *A.mangium* in landfill was slightly different with control plants as there are tendency of *A. mangium* in landfill site to produce many branches, leaves and incisive increase of trunk diameter whereas, control plants tends to gained heights very quick. This is due to different soil type and climatic factors influence rather than heavy metals level in the plants' tissue. This study also proposed *A. mangium* is tolerant to Cd and Cr however the use of *A. mangium* as general bioindicator for heavy metals was not probable as only Cd and Cr was highly accumulated. *A. mangium* can be used for phytoremediation of low contaminated soil as shown in his study. Furthermore, landfill site is this study found it suitable to be used as A*. mangium* culture site.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KANDUNGAN LOGAM BERAT DIPERMUKAAN TANAH KAWASAN PELUPUSAN SAMPAH DI KOTA BHARU DAN KAITANNYA TERHADAP PERTUMBUHAN SERTA KANDUNGAN MAKRONUTRIEN *ACACIA MANGIUM*

oleh

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Kajian kandungan logam berat di permukaan tanah, air di permukaan dan air dari sampah serta kaitannya terhadap pertumbuhan dan kandungan makronutrien *Acacia mangium* telah di jalankan di tapak pelupusan sampah di Kota Bharu, Kelantan. Lima logam berat yang dikaji iaitu Fe, Zn, Cr, Cu dan Cd menunjukkan kandungan logam berat lebih tinggi di permukaan tanah di tapak pelupusan sampah berbanding dalam tanah kawalan. Tahap kandungan logam berat di permukaan tanah pelupusan sampah juga didapati sangat berbeza-beza untuk setiap sampel dari seluruh kawasan kajian. Namun, kandungan logam berat dalam sedimen sungai yang bersebelahan kawasan kajian ini didapati lebih rendah dari permukaan tanah tapak pelupusan yang dikaji. Kandungan Fe di permukaan tanah tapak pelupusan adalah yang tertinggi, berjulat antara 1993.4 – 2404.4 μg/g diikuti oleh Zn;18.08 – 54.10 μg/g, Cr; 2.67

– 64.10 μg/g, Cu; 5.21 – 18.60 μg/g dan Cd; 0.70 – 1.52 μg/g berat kering tanah. Walaubagaimanapun, secara umumnya tahap kandungan logam berat di kawasan kajian adalah di bawah piawaian tahap kritikal tanah tercemar yang digunapakai oleh Jabatan Alam Sekitar Malaysia. Hanya Cd didapati melebihi aras tercemar dengan purata kandungan sebanyak 0.94 μg/g. Kandungan logam berat yang diekstrak secara bersekuen dari permukaan tanah tapak pelupusan sampah menunjukkan bahawa sekitar 30% sahaja logam berat berpunca dari punca antropogenik dan kebanyakannya bergabung dengan bahan organik. Sampel air dari sampah mempunyai kandungan logam berat yang tinggi berbanding sampel air di permukaan tanah. Walaupun begitu, kandungan ini boleh dianggap rendah berbanding sampel dari tapak pelupusan lain kerana telah berlaku pencairan oleh air hujan dan sungai berdekatan. Kepekatan Cu di dalam sampel air didapati tinggi berbanding logam berat yang lain dengan julat antara 0.03 – 6.14 mg/L, manakala kepekatan Cd dan Cr adalah amat rendah dan biasanya tidak dapat dikesan. Tahap pengumpulan logam berat dalam daun *A. mangium* menunjukkan Fe yang tertinggi kandungannya dengan julat antara 139.5 – 537.6 μg/g, diikuti oleh Cr; 45.54 – 357.3 μg/g, Zn; 29.36 – 57.23 μg/g, Cu; 6.88 – 15.61 μg/g, dan Cd 1.63 – 3.48 μg/g. Walaubagaimanapun, kandungan Fe tidak menunjukkan perbezaaan yang bererti antara daun dari pokok yang ditanam di kawasan tapak pelupusan sampah dan kawalan. Namun, hasil dari pengamatan nisbah kandungan logam berat antara tanah dan daun *A. mangium*, pengambilan logam berat didapati tinggi pada pokok yang ditanam di kawasan kawalan, terutamanya untuk logam

Cd dan Cr. Julat kandungan pengumpulan logam berat amat luas di dalam daun *A. mangium* di mana kandungannya dipengaruhi oleh keadaan daun semasa sampel diambil. Kandungan logam berat lebih tinggi dalam tisu tumbuhan berbanding dari kandungannya dalam tanah dan air di persekitaran. Kaitan antara logam berat dan kandungan makronutrien dalam daun dan pertumbuhan *A. mangium* tidak kelihatan di mana tiada kaitan yang bererti dapat diperolehi antara kandungan N, P, K dan kandungan logam berat. Namun begitu, secara umumnya, kandungan N dan P di dalam daun *A. mangium* di kawasan pelupusan sampah didapati lebih tinggi dari kawalan tetapi sebaliknya bagi K. Pertumbuhan *A. mangium* di tapak pelupusan sampah berbeza sedikit dari pertumbuhan pokok di tapak kawalan kerana dipengaruhi oleh faktor cuaca dan jenis tanah yang berbeza bukannya akibat kandungan logam berat dalam yang terkumpul dalam tisu. *A.mangium* di tapak pelupusan sampah lebih cenderung mengeluarkan banyak daun dan dahan serta menambah diameter batang manakala pokok di tapak kawalan lebih cepat menambah ketinggian. Hasil kajian ini mencadangkan penggunaan *A. mangium* sebagai agen pemulihan tanah yang sederhana tercemar tetapi penggunaan tumbuhan ini sebagai penunjuk biologi umum adalah tidak sesuai kerana tumbuhan ini menimbun Cd dan Cr yang terlalu tinggi. Tapak pelupusan sampah dari kajian ini sesuai dijadikan kawasan penanaman pokok *A. mangium*.

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Approval

I certify that an Examination Committee met on 30st January 2004 to conduct the final examination of the Graduate Student on his Master of Science thesis entitled "Heavy metals in surface soils of landfill site and its relations to the growth of *Acacia mangium* and macronutrients uptake" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations that have been dully acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

NIK MOHD. SHIBLI BIN NIK JAAFAR

Date: 1st April 2004

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LIST OF ABREVIATION

AAS	Atomic Absorption Spectrophotometer
ATP	Adenosine Tri Phosphate
DNA	Deoxyribose Nucleic Acid
DO	Dissolved Oxygen
DOE	Department of Environment
DOM	Dissolved Organic Matters
EFLE	Easily, freely, leachable and exchangable
EIA	Environmental Impact Assessment
MMS	Malaysia Meteorological Services
MT	Metallothionein
PC	Phytochelatin
ppm	Part per million
TOC	Total Organic Contents
TSS	Total Suspended Solid
USEPA	United States Environmental Protection Agency
UV	Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 Importance Of Landfill

Landfill is a land disposal of waste that has been practiced for centuries. It is known that waste buried will eventually diminish thus enriching the soil with the most wanted nutrients for plants. Until now, in rural area where no proper waste collection services available, wastes are simply buried in a hole dug in the garden or dumped in any open space nearby. However, if larger volumes of wastes disposed in this manner, it has the potential to impose hazard to human well-being. Solid waste disposal becomes a concern especially in urbanized society, as waste produced daily cannot simply be buried in each own yard. Solid wastes have to be collected and disposed in a designated area selected for the purpose.

Malaysia nowadays has come so far to produce and consume so much in this ever-growing economy. Better education, entertainment and employment opportunities have also stimulated migration into urban areas, putting stress on the infrastructure and municipal services including sewage disposal and solid waste collection. In Kuala Lumpur, record shows that, the amount of waste generated is increasing each year (Table 1.1) with an average of 1.5kg of waste produced by each person. A total of more than 15,000 tonnes of waste are being produced daily by Malaysian and disposed in all of the 230 official landfills, which were already overflowing (Hassan *et al*., 1999).

Solid waste management is a major challenge for municipal and local authorities, constituting more than 40% of their operating budgets. For example, in 1998, Petaling Jaya Municipal Council spent RM1.8million a month for waste management, 40% of its operating budget. With the increasing volume, solid waste management merits urgent attention (Maseri, 2001).

Table 1.1: Generation of waste in Kuala Lumpur in two decades

Year	Amount of waste generated (Tonnes/day)
1980	700
1985	1350
1990	2000
1998	3510

Source: Hassan *et al*., 1999

1.2 Landfills In Peninsula Malaysia

By the end of 1970's, solid waste management in Malaysia was still primitive where municipal councils then could only managed to collect and dumped all the waste in a designated land. There were virtually no sanitary landfills ever existed in Malaysia and no respectable post-closure programs ever made to handle the pollution arise from landfill (Nakamura, 1999). There were a few documented reports on waste generation rates from urban and rural areas, as studies concentrate on waste collection rates rather than waste generation (Abdul *et al.*, 1996). However, by mid 1990's the public became more aware of the ever-growing magnitude of solid waste generated and risks associated with landfill. Hence, the government has implemented proper management programs to cope with the problems including venturing into privatization of landfill management.

From past records, the most common type of landfill was open dumping (Table 1.2) where wastes were dumped in a deserted open space. Most of the district councils in rural or sub urban areas with low population practiced open dumping. Wastes are spread on a land without any preparation of the site before landfilling and waste are seldom covered. Most of the landfill sites do not have adequate facilities and equipment for managing or to operate the landfills, and usually lack of supervision. These landfills are only able to support a minimal volume of wastes and reclamation of these sites was almost impossible as it takes a long period for the sites to stabilize. As for now this method was accepted by the authority and the locals, where vacant land is always available these dumpsites operate with minimal operating cost compared to others methods.

Table 1.2: Existing landfills condition in Peninsula Malaysia

Methods	Municipal councils		District councils	
	Count	(%)	Count	(%)
Sanitary landfill	4	(33)	1	(2)
Controlled tipping	4	(33)	19	(38.8)
Open dumping	3	(25)	29	(59.2)
Dumping into water body	1	(9)	0	(0)
Number of data	12 sites		49 sites	

Source: Hassan *et al*., 1999

Sanitary landfills usually operate under privatization scheme and the landfills located in urban areas This type has the most advanced landfill technology with monitoring and post-closure programs have been designed even before the landfill begins its operation. In developed countries this method of landfills are also known as bioreactor where waste decomposition is enhanced for faster stabilization of the site. This method needs big investment for setting up the operation but in long term, it is still considered as low cost practices due to fast site stabilization and minimum pollution problems arises. Hence, closed landfills can be developed in short period.

Most landfills were located on a flat ground however, other landscapes such as swamps, riversides, mountain areas and canyons that are not suitable for development had been turned into landfills (Table 1.3). Location of landfills is usually determined by political needs. Land with low economic value has the highest priority to be converted into landfills. Nowadays, there are limitations for allocating land as landfills with certain technical criteria plus acceptance by the society has to be considered.

Table 1.3: Present siting of landfills in Peninsula Malaysia

	Municipal councils	District councils
River side	2	10
Swamp	5	8
Flat ground	1	19
Mountain area	3	9
Tin mine pool	2	3
Sea side	0	1
Others	1	3
Number of data	14 sites	53 sites

Source: Hassan *et al*., 1999

1.3 Problems In Solid Waste Management In Malaysia

The problems of environmental pollution and disposal of solid and liquid wastes are not new. Landfill sites, particularly those improperly managed have numerous impacts to the environment. Activities such as uncontrolled disposal of wastes, accidental spillage, use of herbicides and insecticides, and migration of contaminants in the form of vapor, dust or leachate through the soil from contaminated land into neighboring non-contaminated land contribute to contamination of our ecosystems. The two most significant impacts are leachate generation and the released of gas.

Landfill leachate is the main source of pollutants from landfills and affects groundwater quality. A number of researches have indicated that the groundwater is greatly affected by leachate. Among the contaminants that affect our underground water quality is heavy metals. Elevated heavy metals levels were observed in underground water receiving leachate from landfill sites (e.g.: Loizodou and Kapetanios, 1983, Puziah, 1999a). Groundwater pollution is the main concern of leachate effects since groundwater is our major sources of water supply. From Table 1.4, it is clear that groundwater pollution by landfill leachate is serious though moderately affecting the surface water.

Leachate has adverse effects on flora and fauna in the surrounding area. It is known that diversity of shrubs and other ground cover plants is low in landfills with high level of contamination and leachate production. Plant growth in landfills is affected with the quality of leachate (Saberi, 1999). Leachate contamination may result in high mortality rates of trees (Menser *et al*., 1983, Wong and Leung, 1989).

Fauna diversity in landfills varies while active and after ceased operation. In active landfills, fewer animals inhabit the site due to lack of vegetation. Landfill operation will result in the destruction of existing vegetation and natural balance between plants and animals within the habitat. Scavengers such as crows and dogs dominate fauna species in landfills while insects mainly dominated by flies. Closed landfills however attracted more animals. Animals inhabit the landfills are usually infested with parasites and viruses and act as vectors for causing disease to human (Jambari, 1999).

An additional problem that is significant to landfills is gas emission. Gases such as methane (CH_4), carbon dioxide (CO_2), hydrogen sulfite (H_2S) and other type of greenhouse gases are the products of decomposition processes in landfills. Landfill gas effected plant growth (Leone *et al*., 1983) but the main concern of landfill gas emission is methane, which is highly flammable that causes fire hazards in landfills (Abdullah and Awang, 1999). In countries like

United States and several others Europeans countries methane gas are recovered from the landfills has become an economical assets of landfills as it is used as fuel (Lisk, 1991). Landfills also have the potential to jeopardize human health by the release of toxic chemical substances and inorganic contaminants such as aromatic hydrocarbon and heavy metals that have carcinogenic effects or poisoning due to decomposition of toxic containing wastes (Puziah, 1999b).

Table 1.4: Problems reported in landfill sites (%)

	Serious		Not so serious		No problem	
	M	D	M	D	M	D
Ground water pollution	71.4	12	28.6	76	0	12
Leachate	57.2	7.2	42.8	78.5	0	14.3
Scavengers	50.0	8.6	37.5	74	12.5	17.4
Water pollution	37.5	12	50	72	12.5	16
Cover material	25	50	25	26.9	50	23.1
Littering	25	37.5	37.5	58.3	37.5	4.2
Open dumping	25	48	50	48	25	4.0
Odor	22.2	40	77.8	60	0	0
Fly	12.5	45.8	62.5	54.2	25	0
Air pollution	12.5	21.7	50	74	37.5	4.3
Crow	0	4.2	36.4	37.5	63.6	58.3
Noise	0	0	37.5	29.2	62.5	70.8

M= municipal councils: 9 councils　　Source: Hassan *et al*.,1999

D= district councils: 26 councils