PHYTOREMEDIATION OF LANDFILL LEACHATE USING *HIBISCUS CANNABINUS* AND *ACACIA MANGIUM*

MEERA A/P MUNUSAMY

DISSERTATION SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE

INSTITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2013

UNIVERSITY MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Meera a/p Munusamy (I.C. No: 820626-10-5730)

Registration / Matric No: SGR090002

Name of Degree: Master of Science

Title of Project Paper/ Research Report / Dissertation / Thesis: Phytoremediation of Landfill Leachate using *Hibiscus cannabinus* and *Acacia mangium*

Field of Study: Environmental Technology

I do solemnly and sincerely declare that:

(1) I am the sole author / writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be the owner of the copy right in this Work and that any reproduction or use in any form or by any means what so ever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

……………………… ………………..

Candidate's Signature Date

Subscribed and solemnly declared before,

………………… ………………...

Witness's Signature Date
Name:
Designation:

ABSTRACT

Resource managers are challenged with waste disposal, leachate produced from its degradation and its impacts to the environment. Jeram landfill leachate contains high amount of Fe, As, CN and NH_3-N. Knowledge about the response of *Hibiscus cannabinus* (Kenaf) and *Acacia mangium* (Akasia) to landfill leachate irrigation is limited; therefore this study was initiated to investigate the effect of phytoremediation on Jeram landfill leachate.

During pot-culture research, Kenaf and Akasia were irrigated for a period of 120 days in a nursery. Also, hydroponic culture employing Kenaf and Akasia for uptake of pollutants from leachate was carried out in a constructed wetland for contaminant bioconcentration study. These results detail the extensive variation in treatments of leachate, plant responses to leachate irrigation, along with the need and efficacy of plant and growth medium selection to choose superior phytoremediator plant. Leachate which was pretreated with $FeCl_3$ (4g/L) recorded an optimum condition for highest phytoremediation rate at 25% (0.24% N-content) in Kenaf and Akasia in both the pot-culture and hydroponic-culture systems.

Evaluation consisted of testing for differences in plant growth and biomass of leaves, stems, and roots, along with total Fe, As, CN and NH_3-N concentration in control and harvest soil, wastewater and in leaf, stems and root tissue. Accumulation of Fe, As, CN and NH_3-N was assessed based on mathematical models: Bioconcentration Factor (BCF), Translocation Factor (TF) and Bioaccumulation Kinetics. Kenaf sequestered 0.1–0.7 mg As, 18.5-51.7 mg Fe, 0.1-0.6 mg CN and 2.4-10.5mg NH_3-N /g dry weight, which implies that Kenaf can be a bioavailable sink for toxic metals. Akasia, being a leguminous plant recorded higher BCF than Kenaf for Fe (9.1-14.3), NH_3-N (4.2-8.8), CN (1.1-4.3) and As (1.5-2.9). In hydroponic culture, Akasia marked a

24% increase in contaminant uptake efficiency compared to Kenaf through rhizofiltration mechanism.

The ability of Kenaf and Akasia to tolerate these metals and avoid phytotoxicity could be attributed to the phytostabilisation of the metals in the plant roots and hence reduction of toxic metal mobility (translocation factor < 1). During irrigation with leachate, Kenaf and Akasia were also found to have higher biomass compared to control plants. Kenaf and Akasia recorded 49% and 53% higher bioaccumulation capacity, respectively indicating its suitability for phytoextraction of leachate contaminated sites. The bioaccumulation rate constant of the contaminants in Kenaf and Akasia were in the range of 0.01-0.03 and 0.02–0.04/day, respectively. Half-life of contaminants in Kenaf and Akasia were 35-60 and 25-68 days, respectively.

Development of e-Phytoremediation Modeling System (e-PMS) marked an integration of biological and artificial intelligence knowledge, thus serves as Decision Support System (DSS) platform for future research directions in phytoremediation. The user-friendly interphase and models applied determines the potential and performance of phytoremediator plants.

Overall, these results documented successful uptake of nutrients without detrimental impacts to plant health, which validated the use of landfill leachate as an irrigation and fertilization source for Kenaf and Akasia. In addition, these data will serve as a basis for researchers and resource managers making decisions about future leachate remediation projects.

ABSTRAK

Pengurus-pengurus sumber tercabar oleh masalah pelupusan sisa, air larut resap yang terhasil daripada degradasi dan impak negatif kepada alam sekitar. Air larut resap dari tapak pelupusan sisa Jeram mengandungi Fe, As, CN dan NH_3-N pada kepekatan tinggi. Pengetahuan mengenai tindakbalas *Hibiscus cannabinus* (Kenaf) dan *Acacia mangium* (Akasia) terhadap air larut resap adalah terhad, walhal, kajian ini telah dilaksanakan untuk mengkaji kesan fitoremediasi terhadap rawatan air larut resap.

Kenaf dan Akasia telah difertigasi dengan air larut resap bagi tempoh 120 hari di tapak semaian dalam kajian kultur-pot. Selain itu, kultur hidroponik menggunakan Kenaf dan Akasia untuk penyerapan bahan pencemar daripada air larut resap dijalankan di tanah benceh buatan untuk kajian perbandingan bioakumulasi. Kajian ini memperincikan variasi yang luas dalam rawatan air larut resap, tindakbalas tumbuhan kepada rawatan air larut resap, termasuk keperluan dan keberkesanan tumbuhan dan pemilihan medium pertumbuhan dalam penentuan tumbuhan “phytoremediator” yang unggul. Air larut resap yang diprarawat dengan $FeCl_3$ (4g/L) mencatatkan keadaan optimum untuk fitoremediasi kadar tertinggi pada 25% (0.24% kandungan-N) bagi Kenaf dan Akasia dalam kultur-pot dan kultur hidroponik.

Kajian ini meliputi ujian pertumbuhan tumbuhan dan biomas daun, batang, dan akar. Kepekatan Fe, As, CN dan NH_3-N dalam set kawalan, tanah yang dituai, air kumbahan dan di dalam tisu daun, batang dan akar diselidik. Penyerapan Fe, As, CN dan NH_3-N dinilai berdasarkan model-model matematik: Faktor Bioakumulasi (BCF), Faktor Translokasi (TF) dan Kinetik Bioakumulasi. Kenaf menyerap 0.1-0.7 mg As, 18.5-51.7 mg Fe, 0.1-0.6 mg CN dan 2.4-10.5mg NH_3-N/g berat kering, menandakan potensi Kenaf sebagai takungan logam toksik. Akasia, sejenis tumbuhan kekacang mencatatkan BCF yang lebih tinggi daripada Kenaf bagi Fe (9.1-14.3), NH_3-N (4.2-8.8), CN (1.1-4.3) dan As (1.5-2.9). Dalam kultur hidroponik, Akasia mencatatkan

peningkatan sebanyak 24% dalam keberkesanan penyerapan beban pencemar berbanding Kenaf melalui mekanisme rizofiltrasi.

Keupayaan Kenaf dan Akasia untuk menyerap bahan pencemar dan mengelakkan “phytotoxicity” berkemungkinan disebabkan oleh fitostabilisasi logam dalam akar tumbuhan dan seterusnya pengurangan mobiliti logam toksik (Faktor Translokasi <1). Kenaf dan Akasia yang dirawat dengan air larut resap juga didapati mempunyai biomas yang lebih tinggi berbanding tumbuhan Kawalan. Kenaf dan Akasia mencatatkan 49% dan 53% keupayaan bioakumulasi yang tinggi, menunjukkan kesesuaian untuk “phytoextraction” tapak tercemar oleh bahan larut resap. Pemalar kadar bioakumulasi bebanan pencemar dalam Kenaf dan Akasia adalah dalam lingkungan 0.01-0.03 dan 0.02-0.04/hari, masing-masing. Separuh hayat bahan pencemar dalam Kenaf dan Akasia adalah 35-60 dan 25-68 hari.

Pembangunan e- Pemodelan Sistem Fitoremediasi (e-PMS) memperlihatkan integrasi pengetahuan biologi dan “artificial intelligence” dan justeru itu, berfungsi sebagai landasan Sistem Sokongan Keputusan (DSS) ke arah kemajuan halatuju penyelidikan dalam bidang teknologi persekitaran. Fasa mesra-pengguna dan model-model yang diaplikasi menentukan potensi dan prestasi tumbuhan “phytoremediator” yang dikaji.

Secara keseluruhannya, keputusan kajian ini mendokumenkan pengambilan nutrien yang berjaya tanpa kesan yang memudaratkan kesihatan tumbuhan kajian. Fenomena ini mengesahkan penggunaan air larut resap dari tapak pelupusan sisa sebagai sumber fertigasi untuk Kenaf dan Akasia. Di samping itu, data-data ini akan menjadi panduan bagi golongan penyelidik dan pengurus sumber yang berkecimpung dalam projek pemulihan dan rawatan bahan larut resap di masa akan datang.

ACKNOWLEDGEMENTS

In the process of meeting the requirements of the Master of Science degree, numerous individuals have been lending a helping hands and thoughts throughout the processes.

First and foremost thanks to God for His blessings upon completion of this Thesis. Next, I would like to express my thanks to my Supervisor, Prof. Dr. P. Agamuthu for his guidance and support in making this Thesis a reality and also collegues from Solid Waste Laboratory, Institute of Graduate Studies, University of Malaya for their assistance and advice.

I would also like to acknowledge National Hydraulics Research Institute of Malaysia and University of Malaya {IPPP /UPGP/Geran (RU/PPP)/2009B} for the financial assistance in carrying out the project.

Besides that, I would like to express gratitude to Water Quality Laboratory of National Hydraulics Research Institute of Malaysia for the laboratory facilities; Malaysian Tobacco Board and Forest Research Institute of Malaysia (FRIM) for providing the Kenaf and Akasia seeds used for the study.

Special thanks also to Worldwide Landfill Sdn. Bhd. to allow me to collect samples from Jeram Sanitary Landfill.

In addition, I would love to dedicate my sincere gratitude towards my parents, Mr. & Mrs. Munusamy and husband, Mr. A. Poovaneswaran for their continuous inspiration, moral energy and unwavering confidence.

Last but not least, I truly and sincerely appreciate those who have been helpful directly or indirectly in the process of accomplishing this Thesis.

TABLE OF CONTENTS

Contents	**Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

APHA	American Public Health Association
As	Arsenic
BCF	Bioconcentration Factor
BOD	Biological Oxygen Demand
CN	Cyanide
COD	Chemical Oxygen Demand
dH2O	Distilled water
DO	Dissolved Oxygen
DoE	Department of Environment
DSS	Decision Support System
e-PMS	e-Phytoremediation Modeling System
FAO	Food and Agriculture Organization
Fe	Ferum
FRTR	Federal Remediation Technologies Roundtable
GNP	Gross National Product
ICP-OES	Inductively Coupled Plasma - Optical Emission Spectrometer
IF	Inorganic fertiliser
MSW	Municipal solid waste
NH_3-N	Ammoniacal-Nitrogen
PDM	Plant dry matter
RGR	Relative growth rate
RL	Raw leachate
TF	Translocation Factor
TL	Treated leachate
TSS	Total suspended solid
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

LIST OF APPENDICES