



ASSESSMENT OF *GLOSSOSTIGMA ELATINOIDES* AND
BACOPA CAROLINIANA TO REMEDIATE LANDFILL
LEACHATE THROUGH LANDSCAPE ECOLOGY
MODEL SYSTEM

BY

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ABSTRACT

The environmental pollution resulting from solid waste disposal at landfills is a severe problem. Many landfills in Malaysia have increased waste generation without proper disposal procedures. Heavy metals or inorganic contaminants exhibited in landfill sites in the form of dust, gas and leachate due to anthropogenic activities may result in serious environmental problems when they transport into the atmosphere, soil, surface water and groundwater without filtration or treatment system. Thus, this study assesses heavy metals sequestration rate of *Glossostigma elatinoides* and *Bacopa caroliniana* at different concentrations and different types of heavy metal in single element and hybrid elements at four different periods (week 1 until week 4) through an in vitro model system. This study also identifies heavy metals concentration in landfill soil. The concentration of several heavy metals contaminants (Al, Mn, Mg, Fe, Cu, Cr, Cd, Zn, Ni and Pb) in landfill soil and level of toxicity in the soil were evaluated from seven different localities. Factors influencing the concentration of heavy metal contaminants in landfill soil were the composition and compound of waste, degree of waste compaction, types of soil, evapotranspiration, landfill class and age, landfill area, climate and other environmental factors. The analysis of variance established significant to highly significant differences ($P < 0.001$) between landfill soil and heavy metal concentration. From the findings, Cu, Zn, Cd and Pb concentration were found in landfill soil of Sungai Sabai landfill which exceeded the standard limit of natural soil. The four highest metals detected in all landfill sites were Al, Fe, Mn and Mg can cause soil contamination. The experimental in vitro model system established that the sequestration rate for single metals experiment by *G.elatinoides* and *B.caroliniana* individually showed (0.81 ± 0.006189 mg/L) and (0.36 ± 0.004 mg/L) efficiency of Iron. Whereas the sequestration rates for hybrid metals experiment revealed that *G.elatinoides* presented (0.43 ± 0.0074 mg/L) and *B.caroliniana* (0.3220 ± 0.0063 mg/L) efficiency of Magnesium. Both single and hybrid experiments were conducted in different concentration ranges at different incubation periods. Interestingly, both *G.elatinoides* and *B.caroliniana* have the ability to sequester all four types of heavy metals at same trends which $Fe > Mg > Mn > Al$ for single model system and $Mg > Mn > Fe > Al$ for hybrid model system. The hybrid results showed that the interactive pattern was antagonistic when all metals were combined as Mg has reduced the sequestration rate of Al, Fe and Mn. The combination of Al, Fe and Mn without Mg showed that the interactive effects between Al, Fe and Mn were synergistic. The plants were able to sequester all heavy metals in a linear relationship with the incubation period, as the sequestration rates were increased with increased concentrations and periods for Al which decreased after long exposure. The result showed that certain metal removal efficiencies were increased initially by increasing of time and concentration. Thus, in this study both *G.elatinoides* and *B.caroliniana* are a good and potential bio-sequester agent to clean-up heavy metals contaminant in landfill soil and groundwater. In order to use these plants on a large scale, some factors need to be highlighted such as plant capabilities and tolerance towards level of heavy metal contaminants, plant species sequestration rate as well as type of contaminants. All factors may assist in achieving the effectiveness of plant sequestration rate.

ملخص البحث

يعد التلوث البيئي الناتج عن تراكم النفايات الصلبة المدفونة من أكبر المشاكل التي تهدد البيئة في العالم أجمع. في الأونة الأخيرة ازدادت عمليات دفن النفايات في ماليزيا دون مراعاة الطرق العلمية التي يجب أن تتبع من أجل التخلص منها. من أهم أنواع هذه النفايات، هي: المعادن الثقيلة أو مايسمى بالملوثات غير العضوية التي توجد في البيئة المحيطة بها في شكل أغبرة، غازات ومواد ناتجة عن فلترة مواد أخرى سامة. نتيجة لذلك يُعد النشاط السكاني من أهم أسباب التلوث البيئي بما ينجم عنه من ازدياد مضطرد من حيث انتاج المزيد من النفايات التي يتم دفنها في سطح الأرض وتسربها في المياه الجوفية بعد ذلك دون مراعاة ترشيحها أو معالجتها من المعادن السامة، كل هذه العوامل مجتمعة يمكنها أن تسبب مشاكل بيئية خطيرة. لذلك أُجريت هذه الدراسة بغرض تقييم معدل عزل المعادن الثقيلة باستخدام نباتي قلوستتيقما إلتينويد، ونبات الباكوبا كارولينيتا (*Glossostigma elatinoides* and *Bacopa caroliniana*) ، بتحضير تراكيز وأنواع مختلفة للمعادن الثقيلة في شكل عنصر أحادي، وفي شكل هجين أو مزيج من العناصر. وذلك لفترات زمنية مختلفة تتراوح ما بين الأسبوع الأول وحتى الأسبوع الرابع من خلال تطبيقها في أنموذج حيوي داخل المختبر. أيضاً، هذه الدراسة أُجريت لتقدير تركيز المعادن الملوثة الموجودة في سبعة مناطق مختلفة لدفن النفايات ومدى سميتها، علماً بأن المعادن الثقيلة التي تم تحديدها في التجربة، شملت: الألمونيوم، المانجنيز، الماغنزيوم، الحديد، النحاس، الكريتون، الكادميوم، الخارصين، النيكل وأخيراً الرصاص. ومن المهم جداً معرفة العوامل المؤثرة على تركيز المعادن الثقيلة المتراكمة في مناطق دفن النفايات لمعرفة كيفية التعامل معها وهي تمثلت في التركيب الكيميائي للنفايات، ودرجة تجميعها، ونوع التربة وعمرها، تبخر الماء من التربة والنباتات، بالإضافة إلى المناخ والعوامل البيئية الأخرى. أوضحت نتائج الدراسة بأن هنالك فروقات كبيرة عند مستوى معنوية ($P \leq 0.001$) بين مناطق دفن النفايات، والمعادن الثقيلة الموجودة فيها، حيث وجد أن تركيز عناصر النحاس، الخارصين، الكادميوم والرصاص في منطقة سنجاي ساي قد تجاوزت الحد المسموح به للتربة الطبيعية. ذكرت نتائج الدراسة أيضاً أن عناصر الأمونيوم، الحديد، المنجنيز، والماغنزيوم وهي العناصر الأكثر أهمية من حيث حدوث تلوث مناطق دفن النفايات على الإطلاق في كل مناطق دفن النفايات التي شملتها الدراسة. حيث أن التجارب المعملية أشارت إلى أن معدل فصل المعادن الثقيلة الأحادية باستخدام نباتي قلوستتيقما إلتينويد، و نبات الباكوبا ، أعطت تراكيز (0.81 ± 0.006189 ملغرام/لتر) و (0.36 ± 0.004 ملغرام/لتر) من حيث فعالية فصل عنصر الحديد على

التوالى. بينما معدل عزل عنصر الهجين باستخدام نبات قلوستتيقما أعطى تركيز (0.43±0.0074 ملغرام/لتر) ونبات الباكوبا (0.3220±0.0063) من حيث كفاءة فصل عنصر الماغنزيوم. أوضحت النتائج أن استخدام الاثنين معا قلوستتيقما إلتينويد و نبات الباكوبا لديهما القدرة على عزل أربعة أنواع من المعادن السامة فى الوقت نفسة التى تمثلت فى الحديد < الماغنزيوم < المنجنيز < الألمونيوم بالنسبة للنظام الأحادى . أما بالنسبة لنظام الهجين كانت كفاءة ترتيب عزل عناصر الماغنزيوم < المنجنيز < الحديد < الألمونيوم على التوالى. أخيراً، تبين أن نتائج الهجين أظهرت نمطاً تفاعلياً مضاداً عندما تم استخدام كل العناصر الثقيلة مجتمعة بما فيها المغنزيوم هذا أدى إلى خفض كفاءة نسبة عزل عناصر الألمونيوم ، الحديد والمنجنيز. بينما ظهر العكس تماماً عندما تم عزل الماغنزيوم من التجربة. النباتات المستخدمة فى الدراسة قادرة على عزل العناصر السامة كلما زادت مدة الحضانة والتركيز. يمكن أن يستنتج من هذه الدراسة أن كلتا النباتين قلوستتيقما إلتينويد، والباكوبا تعدان من النباتات الجيدة فى عزل المعادن الثقيلة الملوثة إذ يمكن من المهم جدا استخدامها على نطاق واسع من أجل بيئة نظيفة خالية من الملوثات الخطرة كالمعادن الثقيلة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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TABLE OF CONTENTS

Abstract.....	ii
Approval Page.....	v
Declaration Page.....	vi
Copyright Page.....	vii
Acknowledgements.....	viii
List of Tables.....	xiii
List of Figures.....	xvi
List of Abbreviations.....	xix
CHAPTER 1: INTRODUCTION.....	1
1.1 Research Background.....	1
1.2 Issues.....	4
1.3 Problem Statement.....	6
1.4 Research Aim.....	7
1.5 Research Objectives.....	7
1.6 Research Significance.....	7
1.7 Research Scope.....	9
CHAPTER 2: LITERATURE REVIEW.....	10
2.1 Municipal Solid Waste.....	10
2.2 Type of Municipal Solid Waste.....	11
2.3 Municipal Solid Waste Generation in Malaysia.....	11
2.4 Municipal Solid Waste Management.....	13
2.5 Landfill.....	17
2.6 Leachate Contamination.....	20
2.7 Soil Contamination.....	22
2.8 Effects of Contamination.....	23
2.9 Landscape Ecological Approach.....	24
2.10 Phytotechnology.....	25
2.11 Phytoremediation.....	26
2.12 Aquatic Plants as Bio-Sequester Agent.....	28
2.13 Capability of <i>Glossostigma elatinoides</i> and <i>Bacopa caroliniana</i>	33
2.14 Factor Affecting Accumulation of Heavy Metal by Aquatic Plants..	34
2.14.1 Rhizofiltration.....	34
2.14.2 Plant Character.....	36
2.14.3 Heavy Metal Character.....	36
2.14.4 pH.....	38
2.14.5 Soil Character.....	38
2.14.6 Cation Exchange Capacity.....	39
2.14.7 Metal Ion.....	39
2.14.8 Toxicology Interaction.....	40
2.14.9 Environmental Factor.....	40
2.15 Ecological Benefit to Plants in Polluted Environment.....	41

CHAPTER 3: MATERIALS AND METHODS	42
3.1 Site Selection	42
3.1.1 Sungai Sabai Landfill, Hulu Selangor, Selangor	43
3.1.2 Sungai Wangi Landfill, Setiawan, Perak	45
3.1.3 Kampung Sungai Kertas Dumpsite, Gombak, Selangor.....	46
3.1.4 Taman Beringin Landfill, Jinjang, Selangor	47
3.1.5 Krubong Landfill, Ayer Keroh, Melaka.....	49
3.1.6 Dengkil Inert Waste Landfill, Sepang, Selangor	50
3.1.7 Jeram Sanitary Landfill, Kuala Selangor, Selangor.....	52
3.2 Soil Sampling.....	53
3.2.1 Acid Digestion	54
3.2.2 Heavy Metals Analysis	57
3.3 Concentration of Heavy Metal in Landfill Leachate.....	62
3.4 In Vitro Culture of <i>Glossostigma elatinoides</i> and <i>Bacopa</i>	66
<i>caroliniana</i>	67
3.4.1 Medium Preparation.....	68
3.4.2 Aquatic Plants Propagation.....	70
3.5 Development of Model System	70
3.5.1 Heavy Metal Solution Preparation.....	71
3.5.3 Sample Harvesting	72
3.6 Statistical Analysis by ANOVA.....	73
CHAPTER 4: ANALYSIS OF HEAVY METAL TOXICITY IN OPEN	74
DUMPING AND SANITARY LANDFILL SOIL	74
4.1 Introduction.....	74
4.2 Results	78
4.3 Discussion.....	
4.3.1 Factors Affecting Heavy Metals Concentration in Landfill	78
Soil	
CHAPTER 5: ASSESSMENT OF Al, Fe, Mn AND Mg	
SEQUESTRATION RATE OF <i>Glossostigma elatinoides</i> AND <i>Bacopa</i>	
<i>caroliniana</i> TOWARDS IN SINGLE AND HYBRID VITRO MODEL	
SYSTEM	85
5.1 Assessment of <i>Glossostigma Elatinoides</i> Sequestration Rate	
Towards Single In Vitro Model System at Three Difference	
Concentrations and Four Different Periods of Time.....	85
5.1.1 Analysis of Al sequestration rate by <i>G. elatinoides</i> at three	
different concentrations and four different periods.....	86
5.1.2 Analysis of Fe sequestration rate by <i>G. elatinoides</i> at three	
different concentrations and four different periods.....	88
5.1.3 Analysis of Mn sequestration rate by <i>G. elatinoides</i> at three	
different concentrations and four different periods.....	90
5.1.4 Analysis of Mg sequestration rate by <i>G. elatinoides</i> at three	
different concentrations and four different periods.....	92
5.2 Assessment of <i>Glossostigma Elatinoides</i> Sequestration Rate	
Towards Hybrid In Vitro Model System at Three Difference	
Concentrations and Four Different Periods of Time.	96

5.2.1 Analysis of Al x Fe sequestration rate by <i>G. elatinoides</i> at three different concentrations and four different periods.....	96
5.2.2 Analysis of Al x Mn sequestration rate by <i>G. elatinoides</i> at three different concentrations and four different periods.....	98
5.2.3 Analysis of Fe x Mn sequestration rate <i>G. elatinoides</i> at three different concentrations and four different periods.....	99
5.2.4 Analysis of Al x Fe x Mn sequestration rate by <i>G. elatinoides</i> at three different concentrations and four different periods.....	101
5.2.5 Analysis of Al x Fe x Mn x Mg sequestration rate by <i>G. elatinoides</i> at three different concentrations and four different periods.....	102
5.3 Assessment of <i>Bacopa Caroliniana</i> Sequestration Rate Towards Single In Vitro Model System at Three Difference Concentrations and Four Different Periods of Time.....	104
5.3.1 Analysis of Al sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	105
5.3.2 Analysis of Fe sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	107
5.3.3 Analysis of Mn sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	109
5.3.4 Analysis of Mg sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	110
5.4 Assessment of <i>B. caroliniana</i> Sequestration Rate Towards Hybrid In Vitro Model System at Three Difference Concentrations and Four Different Periods of Time.....	115
5.4.1 Analysis of Al x Fe sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	115
5.4.2 Analysis of Al x Mn sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	117
5.4.3 Analysis of Fe x Mn sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	118
5.4.4 Analysis of Al x Fe x Mn sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	120
5.4.5 Analysis of Al x Fe x Mn x Mg sequestration rate by <i>B. caroliniana</i> at three different concentrations and four different periods.....	121
5.5 Discussion.....	124
5.5.1 Mechanism Affecting Sequestration Rate of <i>Glossostigma elatinoides</i> and <i>Bacopa caroliniana</i> in Single and Hybrid Model System.....	124
CHAPTER 6: GENERAL DISCUSSIONS AND CONCLUSIONS.....	130
6.1 Research Aim and Objectives.....	130
6.2 Heavy Metal in Landfill Soil.....	131
6.3 Assessment of <i>Glossostigma elatinoides</i> and <i>Bacopa caroliniana</i> as Bio Sequestration Agent for Landfill Soil Contaminant.....	131
6.4 Conclusion and Recommendation.....	132
BIBLIOGRAPHY.....	134

APPENDIX A.....	149
APPENDIX B.....	150
APPENDIX C.....	151
APPENDIX D.....	152
APPENDIX E.....	153
APPENDIX F.....	154
APPENDIX G.....	155

LIST OF TABLES

<u>Table No.</u>		<u>Pages No.</u>
1.1	Waste generated by region	5
2.1	Classification of Rubbish	11
2.2	Municipal Solid Waste generation in Peninsular Malaysia	12
2.3	Method of Municipal Solid Waste Disposal in Malaysia	13
2.4	Capacity of waste to be process using incinerator in Malaysia	16
2.5	Classes of landfill sites in Malaysia	18
2.6	Classification of non-sanitary landfills in Malaysia	19
2.7	Parameter for leachate pollution index	22
2.8	List of Aquatic plants used for heavy metal remediation from industrial effluents	31
2.9	List of aquatic plant species which has capability to accumulate specific heavy metals	32
3.1	Selected Landfill Areas with Their Classes of Level, Scale, Capacity and Operation Period of Time	42
3.2	Classes of Landfill Sites in Malaysia	43
3.3	Calculation for Calibration and QC Solution Preparation	60
3.4	Analysis Parameter set in ICP-MS method software	61
3.5	Concentration of Leachate at Bukit Tagar Landfill, Taman Beringin Landfill and Jeram Sanitary Landfill	63
3.6	Leachate characteristics at Kunadang Landfill, Sungai Sedu Landfill and Panchang Bedena Landfill	64
3.7	Leachate contamination at Pulau Burung Landfill, Kulim Landfill, Ampang Jajar Landfill and Kuala Sepetang landfill.	64

3.8	Landfill Leachate contamination at Lat Krabang, Kampang Sein, San Sai and Leuwigadja Landfill.	65
3.9	Summary Profile of <i>Glossostigma elatinooides</i> and <i>Bacopa caroliniana</i>	66
3.10	Set of single element and hybrid element treatments	70
3.11	Description of acid digestion method for samples	72
4.1	Result of heavy metal analysis of seven landfill sites in Peninsular Malaysia (mg/kg)	76
4.2	Analysis of variance (ANOVA) for total of ten heavy metals concentration in seven selected landfill sites.	77
4.3	Analysis of variance (ANOVA) for total heavy metals concentration by individual selected landfill sites.	77
5.1	Analysis of variance (ANOVA) of Al sequestration rate by <i>Glossostigma elatinooides</i> at three different concentrations in 4 weeks	86
5.2	Analysis of variance (ANOVA) of Fe sequestration rate by <i>Glossostigma elatinooides</i> at three different concentrations in 4 weeks	88
5.3	Analysis of variance (ANOVA) of Mn sequestration rate by <i>Glossostigma elatinooides</i> at three difference concentration in 4 weeks	90
5.4	Analysis of variance (ANOVA) of Mg sequestration rate by <i>Glossostigma elatinooides</i> at three difference concentration in 4 weeks	92
5.5	Analysis of variance (ANOVA) for hybrid element of Al x Fe heavy metals sequestration rate by <i>Glossostigma elatinooides</i> at three different concentrations in 4 weeks	96
5.6	Analysis of variance (ANOVA) for hybrid element of Al x Mn heavy metals sequestration rate by <i>Glossostigma elatinooides</i> at three different concentrations in 4 weeks	98
5.7	Analysis of variance (ANOVA) for hybrid element of Fe x Mn heavy metals sequestration rate by <i>Glossostigma elatinooides</i> at three different concentrations in 4 weeks	99

5.8	Analysis of variance (ANOVA) for hybrid element of Al x Fe x Mn heavy metals sequestration rate by <i>Glossostigma elantinooides</i> at three difference concentration in 4 weeks	101
5.9	Analysis of variance (ANOVA) for hybrid element of Al x Fe x Mn x Mg heavy metals sequestration rate by <i>Glossostigma elantinooides</i> at three different concentrations in 4 weeks	103
5.10	Analysis of variance (ANOVA) for Al sequestration rate by <i>Bacopa caroliniana</i> at three different concentrations in 4 weeks	105
5.11	Analysis of variance (ANOVA) for Fe sequestration rate by <i>Bacopacaroliniana</i> at three different concentrations in 4 weeks	107
5.12	Analysis of variance (ANOVA) for Mn sequestration rate by <i>Bacopa caroliniana</i> at three different concentrations in 4 weeks	109
5.13	Analysis of variance (ANOVA) for Mg sequestration rate by <i>Bacopa caroliniana</i> at three different concentrations in 4 weeks	111
5.14	Analysis of variance (ANOVA) of Al x Fe heavy metals sequestration rate by <i>Bacopa carolinina</i> at three different concentrations in 4 weeks	115
5.15	Analysis of variance (ANOVA) of Al x Mn heavy metals sequestration rate by <i>Bacopa carolinina</i> at three different concentrations in 4 weeks	117
5.16	Analysis of variance (ANOVA) of Fe x Mn heavy metals sequestration rate by <i>Bacopa carolinina</i> at three different concentrations in 4 weeks	118
5.17	Analysis of variance (ANOVA) of Al x Fe x Mn heavy metals sequestration rate by <i>Bacopa carolinina</i> at three different concentrations in 4 weeks	120
5.18	Analysis of variance (ANOVA) of Al x Fe x Mn x Mg heavy metals sequestration rate by <i>Bacopa carolinina</i> at three different concentrations in 4 weeks	121
5.19	Quantities of element (kg/ha) removed by continuous culture aquatic plants per year	126

LIST OF FIGURES

<u>Figure No.</u>		<u>Pages No.</u>
2.1	Percentage of average waste composition disposed to landfills in Malaysia	20
3.1	Location map of Sungai Sabai Landfill	44
3.2	View towards surrounding of Sungai Sabai Landfill	44
3.3	Location map of Sungai Wangi Landfill	45
3.4	View towards surrounding of Sungai Wangi Landfill	45
3.5	Location map of Kampung Sungai Kertas Dumpsite	46
3.6	View towards surrounding of Kampung Sungai Kertas Dumpsite	47
3.7	Location map of Taman Beringin Landfill	48
3.8	View towards Taman Beringin Landfill	48
3.9	Location map of Krubong Landfill	49
3.10	View towards Krubong Landfill	50
3.11	Location map of Dengkil Inert Waste Landfill	51
3.12	View towards Dengkil Inert Waste Landfill	51
3.13	Location map of Jeram Sanitary Landfill	52
3.14	View towards Jeram Sanitary Landfill	53
3.15	Soil Sampling Preparation	55
3.16	Acid Digestion Preparation	56
3.17	Samples Preparation for Heavy Metal Analysis using ICP-MS	59
3.18	ICP-MS daily optimization check	61
3.19	Workflow for analytical performance, Method 6020B	62

3.20	Preparation of MS Medium for plant sub cultured	68
3.21	a)Plant sub cultured b) Sub cultured Plant in Incubator Room	69
3.22	Subcultured of a) <i>Bacopa caroliniana</i> b) <i>Glossostigma elatinoides</i>	69
3.23	<i>Glossostigma elatinoides</i> and <i>Bacopa caroliniana</i> plantlets were transplanted into treatment media	71
3.24	Samples were harvested and digested for further analysis	72
5.1	Sequestration rate of Al by <i>Glossostigma elantinoïdes</i> at three different concentrations for four difference periods	87
5.2	Sequestration rate of Fe by <i>Glossostigma elantinoïdes</i> at three different concentrations for four different periods	89
5.3	Sequestration rate of Mn by <i>Glossostigma elantinoïdes</i> at three different concentrations for four different periods	91
5.4	Sequestration rate of Mg by <i>Glossostigma elantinoïdes</i> at three different concentrations for four different periods	93
5.5	Sequestration rate of Al, Fe, Mn and Mg by <i>Glossostigma elantinoïdes</i> at three different concentrations for four different periods	94
5.6	Sequestration rate of Al, Fe, Mn and Mg by <i>Glossostigma elantinoïdes</i> at three different concentrations for four different periods	95
5.7	Sequestration rate of 2 combinations of heavy metals (Al x Fe) by <i>Glossostigma elantinoïdes</i> at three different concentrations in four different periods	97
5.8	Sequestration rate of 2 combinations of heavy metals (Al x Mn) by <i>Glossostigma elantinoïdes</i> at three different concentrations in four different periods	98
5.9	Sequestration rate of 2 combinations of heavy metals (Fe x Mn) by <i>Glossostigma elantinoïdes</i> at three different concentrations in four different periods	100
5.10	Sequestration rate of 3 combinations of heavy metals (Al x Fe x Mn) by <i>Glossostigma elantinoïdes</i> at three different concentrations in four different periods	101

5.11	Sequestration rate of 4 combinations of heavy metals (Al x Fe x Mn x Mg) by <i>Glossostigma elantinoides</i> at three different concentrations in four different periods	103
5.12	Sequestration rate of Al by <i>Bacopa caroliniana</i> at three different concentrations for four different periods	106
5.13	Sequestration rate of Fe by <i>Bacopacaroliniana</i> at three difference concentrations for four difference period of times	108
5.14	Sequestration rate of Mn by <i>Bacopacaroliniana</i> at three different concentrations for four difference periods	110
5.15	Sequestration rate of Mg by <i>Bacopacaroliniana</i> at three different concentrations for four different periods	112
5.16	Sequestration rate of Al, Fe, Mn and Mg by <i>Bacopa caroliniana</i> at three different concentrations for four different periods	113
5.17	Sequestration rate of Al, Fe, Mn and Mg by <i>Bacopa caroliniana</i> at three difference concentrations for four difference period of times	114
5.18	Sequestration rate of 2 combinations of heavy metals (Al x Fe) by <i>Bacopa caroliniana</i> at three different concentrations in four different periods	116
5.19	Sequestration rate of 2 combinations of heavy metals (Al x Mn) by <i>Bacopa caroliniana</i> at three difference concentrations in four different periods of time	117
5.20	Sequestration rate of 2 combinations of heavy metals (Fe x Mn) by <i>Bacopa caroliniana</i> at three different concentrations in four different periods	119
5.21	Sequestration rate of 3 combinations of heavy metals (Al x Fe x Mn) by <i>Bacopa caroliniana</i> at three different concentrations in four different periods	120
5.22	Sequestration rate of 4 combinations of heavy metals (Al x Fe x Mn x Mg) by <i>Bacopa caroliniana</i> at three different concentrations in four different periods	122
6.1	Model designed to exhibit the application of both plants to remediate soil and leachate at contaminated landfill.	133

LIST OF ABBREVIATIONS

%	Percent	mL	Mililitre
<	Less than	ICP-MS	Inductively coupled plasma mass spectrometry
>	More than	IETC	International Environmental Technology Center
°C	Degree celcius	IUCN	International Union for the Conservation of Nature
MΩ	Mega-ohm	KED	Kinetic energy discrimination
3R	Reduce, Reuse, Recycle	Kg	Kilogram
Al	Aluminium	KOH	Potassium hydroxide
Al ₂ O ₁₂ S ₃	Aluminium sulfate	L	Liter
ANOVA	Analysis of Variance	mg/kg	Milligram perkilogram
BOD	Biochemical Oxygen Demand	mg/L	Miligram perliter
CCOHS	Canadian Centre for Occupational Health and Safety	Mg	Magnesium
Cd	Cadmium	MgO	Magnesium Oxide
CEC	Cation exchange capacity	MHLG	Ministry of House and Local Government
CO ₂	Carbon dioxide	Mn	Manganese
COD	Chemical Oxygen Demand	MnSO ₄	Manganese (II) Sulfate
Cr	Chromium	M ₁	Stock concentration
Cu	Copper	M ₂	Desired concentration
DI	Deionized	MS	Murashige and Skoog
DNA	DeoxyriboNucleic Acid	NEB	Nebulizer
DO	dissolved oxygen	NH ₃ -N	Ammoniacal Nitrogen
EPA	Environment Protection Agency	Ni	Nickel
Fe	Iron	NSWMD	National Solid Waste Management Department
FeSO ₄ .7H ₂ O	Ferrous sulfate heptahydrate	Pb	Lead
g	Gram	PFA	perfluoroalkoxy polymer
H ₂ O ₂	Hydrogen peroxides	pH	Potential of hydrogen
H ₂ O	Water	Ppb	Parts perbillion
HNO ₃	Nitric acid	Ppm	Parts permillion
H ⁺	Hydrogen ion	PPSPPA	Solid Waste Management and Public Cleansing Corporation
HCl	Hydrochloric acid	PSII	photosystem II

QC	Quality control	USEPA	United States Environmental Policy Agency
STD	Standard mode	UV	ultraviolet
TDS	Total dissolve solid	V ₁	Volume of stock needed
U	Uranium	V ₂	Final volume
$\mu\text{g/L}$	Microgram perliter	WWF	World Wide Fund For Nature
USD	United States Dollar	Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Environmental management is one of the significant efforts which are essential to achieve and become a successful developed country in the new millennium. Malaysia has managed to minimize most of the side effects of modern development on the environment as guided by the Environmental Quality Act 1974 (Sani, 1997). This situation can be seen where the country is able to control the impact of the project on the environment and analyse the risk for the projects that handling hazardous materials. However, carelessness in the past has result every unaware country to face the problems such as depletion of the ozone layer, climatic change, global warming, the loss of animal and plant species diversity, chemical abuse and destruction of the forest which has threaten all the mankind in the whole world (Brugmann, 1992).

According to Brugmann (1992), urban areas or cities are integrated systems that facilitate the delivery of a wide range of services and activities. Increasing urbanization and industrialization has caused the environment to deflate. In addition, nowadays, the developments in various sectors such as the industrial, agricultural and services have caused to the decline of the environment quality as water, air and land has been polluted (Brugmann, 1992). WWF (2015) has reported that 80% of marine pollution comes from land based activities. The seen-able polluted materials such as plastic bags to the unseen pollution such as pesticides are commonly waste that generated on the land and then extended to water bodies such as river and stream through precipitation run off or direct dumping which end up at ocean (WWF, 2015).

From the waste generated, solid waste such as plastic bags, bottles, and packaging materials which the life span they used to decay is about 500 years may cause a lot of harm to the environment. For instance, the excessive of carbon dioxide emissions result from the decaying process may damage the natural ecosystems. The waste also cause hazardous to the animals in the sea as reported, many cases occurred where marine species such as turtles, whales, seals, dolphins, and others were died because of the plastic materials found in their stomach and some has blocking their breathing ways (WWF, 2015).

According to Conserve Energy Future (2009), air pollution occurred by the release of gases, dust and smoke to the atmosphere which may be hazardous to entire living things and the environment. The diminishing of ozone layer and global warming are known to be the biggest effects of air pollution and become threat to the world nowadays. These problems were caused by human activities such as:

- i. Fossil fuels burning – released of sulphur dioxide from the combustion of fossil fuels (e.g., petroleum, coal).
- ii. Agricultural activities – released of ammonia from the use of insecticides, pesticides and fertilizers.
- iii. Exhaust from industries, factories and vehicles – released of carbon monoxide, hydrocarbon, chemicals and organic materials.
- iv. Mining operation – emitted of chemicals and dust from earth during mining process.
- v. Indoor air pollution – emitted of toxic chemicals from wall finishing products such as paint.

- vi. Landfill – released up to 90% of methane gases and carbon dioxide and other gases including nitrogen, oxygen, ammonia, sulphides and hydrogen when bacteria break down the organic waste disposed at landfill.

As reported by Conserve Energy Future (2009), land pollution was defined as the degradation of earth's surface and soil which cause by the anthropogenic activities such as agriculture, deforestation, construction and so on. Conversely, land pollution is commonly emphasized after air and water pollution as the effects of air and water pollution are clearly seen in the environment rather than land pollution effects. Conserve Energy Future (2009) also has listed the sources of land pollution:

- i. Agricultural activities - highly toxic fertilizers and pesticides were used to produce fungi and bacteria free crops which the overuse may result soil contamination.
- i. Construction activities – rise of developing country led to the increase of construction activities which result large waste components such as metal, glass, wood, plastics and bricks to be disposed.
- ii. Industrialization – increase of population growth has led to increase the demand for food, house and other needs which result the industry to developed and produced more waste that need to be disposed.
- iii. Overcrowded landfill – the urbanization and population increase may result to the increase of waste generated and finally has been dump to the landfill which led to the soil contamination.

1.2 ISSUES

Landfills are critical sources of air, water and land pollution. Guerrero et al. (2013) relates such pollution to the rise of population, living standards and rapid urbanization causing increased municipal solid waste. Inappropriate waste management is

potentially one of the major contributors to environmental degradation (Fauziah et al., 2013). As referred to Table 1.1, Malaysia as one of developing countries is classified under upper middle income country which these countries produced 1.16 kg waste per capita in a day (Ismail and Manaf, 2013; Hoornweg et al., 2012). As a developing country, the challenge of the Malaysian government is to provide an efficient system to manage municipal solid waste (Guerrero et al., 2013). 95% of the almost 30,000 tonnes of daily solid waste generation in Malaysia is dumped in landfills (Fauziah et al., 2013).

Therefore, it is crucial to efficiently manage landfills to avoid being hazardous to life in the surrounding areas (Taylor and Allen, 2006). Fauziah et al. (2013) reported that non-sanitary landfills in Malaysia, also known as open dumpsites, have had a negative impact on the environment due to an improper lining system that causes leachate, which is the leakage of a large number of toxins into the nearest water bodies and infiltrates groundwater through contaminated soil. The generation of leachate is based on the composition and compound of waste, degree of waste compaction, types of soil, evapotranspiration, landfill class and age (Fauziah et al., 2013). Consequently, recognising the characteristics of leachate and its toxicity may help treat or eliminate leachate before it discharges into the water bodies.