STUDY ON LANDFILL SPATIAL CONTAMINANT DISTRIBUTION AND POTENTIAL TERRESTRIAL FERN SPECIES AS PHYTOREMEDIATION AGENT

BY

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ABSTRACT

As a developing country, Malaysia is facing a problem with waste management issues. Even though landfilling is preferable due to its low cost, availability of land and environmentally friendly method, the problem caused by the dumping sites is not adequately treated. During rainy season, leachate may accelerate heavy metals toxicity at the landfill areas into ground surface. Therefore, this research aimed to study pattern distribution of landfill contaminants as well as to explore the capabilities of fern species as phytoremediation agent. In order to achieve the goal, there are two objectives that need to be fulfilled. Firstly is to study spatial distribution and potential of landfill contaminant at active and closed landfills at different depths (0 cm to 30 cm, 30 cm to 60 cm and 60 cm to 90 cm) and radiuses (5 m to 10 m, 10 m to 15 m, and 15 m to 20 m). Secondly, to assess type of fern species ability and stability as phytoremediation agent. By using hand auger, samples were taken from three (3) different localities in Perak, Selangor and Johor in order to investigate their massive metal sequestration rate stability and pattern distribution in this highly weathered soil. Nine landfill sites located in the state of Selangor comprising of a variety of active and closed landfills chosen. Phytoremediation technology that uses living plant is adopted to accumulate and remove various heavy metals toxicity. This is because phytoremediation activity in plant system functions to degrade, extract or inactivate potentially hazardous compounds in the contaminated soil. Four terrestrial fern species namely; *Dicranopteris linearis*, *Nephrolepis bifurcata*, *Stenochlaena palustris* and *Acrostichum aureum* were chosen to sequester heavy metal contaminants from laterite soil. Samples that taken from vegetative parts, soils and roots of the plant, were then taken to the laboratory for cleaning and drying purposes before the analysing process. Soils and plants sampling were measured using ICP-MS (Perkin Elmer NexION 300X) for ten heavy metals element (Al, Fe, Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb). Both results showed Al and Fe were detected with the highest concentrations. Al and Fe concentration for landfill soils were detected highest at every radiuses and depths of the landfill sites regardless other heavy metals were detected low due to leach out to the groundwater level. The analysis of variance (ANOVA) output has shown a statistically significant difference (P<0.0001), in the mean of heavy metal concentrations between different radiuses and different depths at all interactions. While the age pattern of landfill shows that the concentration of heavy metals is increasing as the radiuses and depth of soil increase. In order to certify the potential of fern species as a phytoremediation agent to remediate heavy metals toxicity in the landfill soil, the evaluation of bio-concentration factor (BCFs) and translocator factor (TFs) were implemented. The ANOVA output has shown a statistically significant difference (P<0.0001), in the mean of concentrations of heavy metals between vegetative part, root and soil at all interactions. Therefore, it is indicated that all four terrestrial fern species are potential as phytoremediation agents to sequester Cr, Mn, Co, Ni, Cu, Zn, Cd and Pb from landfill sites. Since there are many factors that contributed to the heavy metal accumulation, fern species are suggested to be one of the alternative measures to remediate the soil and remove heavy metals toxicity. In addition to its potential as a green technology, ferns can also be commercialised as an inexpensive alternative method to clean areas that contaminated with heavy metals toxicity.

خلاصة البحث

تواجه ماليزيا –كدولة نامية – مشكلة في قضايا إدارة النفايات. على الرغم من أن الطمر ظل هو الطريقة المفضلة بسبب كلفته المنخفضة وتوافر الأرض والطريقة الصديقة للبيئة ، فإن المشكلة الناتجة عن مواقع الطمر لا يتم معالجتها بشكل صحيح. خلال موسم الأمطار، قد تُسرع المادة المرتشحة سمية الفلزات الثقيلة في مناطق المكب إلى سطح الأرض. لذلك ، يهدف هذا البحث إلى دراسة توزيع نمط ملوثات المكب وكذلك استكشاف قدرات الأنواع السرخس كعامل علاج نباتي. من أجل بيئة نظيفة، هناك هدفان يجب تحقيقهما. أولاً، دراسة التوزيع المكاني وإمكانات تلوث مدافن النفايات النشطة والمغلقة على أعماق مختلفة (0 سم إلى 30 سم، 30 سم إلى 60 سم، و60 سم إلى 90 سم) ونصف قطرها (5 م إلى 10 م، 10 م إلى 15 م، و 15 م إلى 20 م). ثانيا، تقييم قدرة أنواع السرخس واستقرارها باعتبارها وسيلة العلاج النباتي. تم أخذ عينات من ثلاث (3) مواقع مختلفة في بيراك وسيلانجور وجوهور من أجل التحقيق في استقرار معدل عزل المعادن الثقيلة وتوزيع الأنماط في هذه التربة متقلبة الطقس. تم اختيار تسعة مواقع لطمر النفايات في ولاية سيلانجور تضم مجموعة متنوعة من المكبات النشطة والمغلقة. تم اعتماد تقنية المعالجة النباتية التي تستخدم النباتات الحية لتجميع وإزالة سمية المعادن الثقيلة المختلفة. وذلك لأن نشاط المعالجة النباتية في نظام النبات يعمل على تحطيم أو استخلاص أو تعطيل المركبات التي يحتمل أن تكون خطرة في التربة الملوثة. تم اختيار أربعة أنواع سرخس برية وهي؛ Stenochlaena palustris و Nephrolepis bifurcataو Dicranopteris linearis و Acrostichum aureum لعزل ملوثات المعادن الثقيلة من التربة الخام. ثم أخذت العينات المأخوذة من الأجزاء النباتية والتربة وجذور النبات إلى المختبر لأغراض التنظيف والتجفيف قبل عملية التحليل. تم قياس عينات التربة والتربة ، Fe، Al) لعشرة عناصر من المعادن الثقيلة (ICP-MS (Perkin Elmer NexION 300X باستخدام أظهرت كلتا النتيجتين أنه تم اكتشاف الألمنيوم والحديد .(Cd and Pb، Zn، Cu، Ni، Co، Mn، Cr بأعلى التركيزات. كما تم اكتشاف تركيزهما لتربة المكب على أعلى مستوى في كل دائرة حسب نصف قطرها وعمق مواقع المكب بغض النظر عن المعادن الثقيلة الأخرى التي تم اكتشاف أنها منخفضة التركيز بسبب الترشيح إلى مستوى المياه ، في متوسط تركيزات المعادن ($P < 0.0001$) فرقًا ذو دلالة إحصائية (ANOVA) الجوفية. أظهر تحليل التباين الثقيلة حسب اختلاف نصف القطر وعمق المكب في جميع التفاعلات. بينما يوضح النمط العمري لطمر النفايات أن تركيز المعادن الثقيلة يزداد مع زيادة نصف القطر وعمق التربة. من أجل التصديق على إمكانات أنواع السرخس كعامل وعامل تحديد (BCFs) معالجة نباتية لعلاج سمية المعادن الثقيلة في تربة المكب، تم تنفيذ تقييم عامل التركيز الحيوي ، في ($P < 0.0001$) فرقًا ذو دلالة إحصائية ANOVA أظهرت نتائج تحليل مخرجات التباين .(TFs) الموقع متوسط تركيزات المعادن الثقيلة بين الجزء النباتي والجذر والتربة في جميع التفاعلات. لذلك ، فإنه يشير إلى أن جميع أنواع السرخس الأرضي الأربعة محتملة كعوامل علاجات نباتية لعزل المعادن الثقيلة الملوثة من مواقع المكب. ونظرًا لوجود العديد من العوامل التي تسهم في تراكم المعادن الثقيلة، يُقترح أن تكون أنواع السرخس واحدة من التدابير البديلة لعلاج التربة وإزالة سمية المعادن الثقيلة. بالإضافة إلى إمكاناتها كتقنية خضراء، يمكن أيضًا تسويق السرخس كوسيلة بديلة غير مكلفة لتنظيف المناطق الملوثة بسمية المعادن الثقيلة.

APPROVAL PAGE

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DECLARATION

I hereby declare that this dissertation 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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LIST OF ABBREVIATIONS

Al	aluminium
As	arsenic
ANZECC	Australian and New Zealand Environment and Conservation Council
B	Boron
BBT	butyl benzylphalate
BCF	Bioconcentration factor
BOD	Biochemical oxygen demand
cm	centimeter
Cr	chromium
Cd	cadmium
Co	cobalt
Cu	cuprum
CO2	carbon dioxide
COD	Chemical oxygen demand
EDTA	ethylenediamine tetraacetic acid
Fe	iron
ICP-MS	Inductive coupled plasma mass spectrometer
IWL	Inert waste landfill
km^2	square kilometer
kJ	kilo joule
kg	kilogram
l	liter
m	meter
MSW	Municipal solid waste
Mn	manganese
MUHLG	Ministry of Urban Wellbeing Housing and Local Government
m^3	cubic meter
mg	milligram
m^3/kg	cubic meter per kilogram
Ni	nickle
NTA	nitrilotriacetic acid
Pb	lead
PCBs	Polychlorobiphenyls
SL	Sanitary landfill
TF	Translocator factor
TOC	Total organic carbon
U	uranium
UNISEL	University of Selangor
WTE	waste-to-energy
WHB	Worldwide Holding Berhad
Zn	zinc
%	percent
ºC	Degree celsius

h	hour
ug/l	micrograms per liter

CHAPTER ONE
INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Municipal solid waste (MSW) is a category of diverse waste which generated from different sources (that is, residential, commercial, municipal services, agriculture), each of which is itself heterogeneous (Sharifah & Latifah, 2013). Waste generation become continues to increase in line with the economy and population growth. This suggests that the greatest challenge is to provide more waste disposal facilities such as landfill to treat the waste (Hassan *et al*., 2001).

Malaysia is a South East Asia country where landfill is important and where the standard of waste management needs to be improved. It comprises thirteen states and three federal territories, with a total surface area of 329,700 km^2. Known as one of the rapidly developing economies in Asia, MSW generation is projected to increase from 292 kg/capita in 2000 to 511 kg/capita in 2025 (Aja & Al-Kayiem (2014). Currently, landfilling is the main waste disposal method (80% usage) and it is still expected to report for 65% of waste in 2020 (Waste Management Policy of Malaysia 10th Plan, 2010 to 2020). In other hand, recycling and intermediate processing are projected to take 20 and 15% of the waste in 2020. However, most landfills in the country are in a bad condition (Latifah *et al*., 2009). It operated without proper protective measures, such as lining systems, leachate treatment and gas venting. Despite the complexity of waste produced, the standards of landfills in

most developing countries are still poor; these include inadequate waste treatment facilities, inefficient collection and storage systems, co-disposal of municipal waste with hazardous waste, inefficient utilisation of disposal space, lack of environmental abatement measures and poor documentation (Hassan *et al*., 2000).

Planners face great difficulties in establishing the most suitable locations for landfilling due to rapid urbanisation process, the waste municipal face shortages of space and the increasing quantities of solid waste (Sharifah & Latifah, 2013). Hence, landfilling is the main waste disposal method in future. Thus, this study explores the suitable green technology to remediate the landfill area in Malaysia in term of their soil capability to absorb organic, inorganic and toxin caused by these domestic waste.

1.2. ISLAMIC PERSPECTIVE (SHARIAH COMPLIANCE) ON SUSTAINABILIY TOWARDS ENVIRONMENT

According to Islam, there is no such matter that can cause harm and uncomfort to the user and environment. The principle of '*La darar wa la dirar*' has been enhanced to remove all kind of harm (Mohammad Akram, 2006). Any actions (*Iilah*) with intention to improve, enhance and enrich the environment (*Tahsin al- ardh*) is considered as a part of environmental sustainability objectives as it ensure the ecological balance (*Mizan*) of earth. The whole universe has been created with wisdom (*Hikmah*) and none was created in vain by Allah. As a trustee (*Khalifah*) man cannot waste the resources in any case. It is the responsibility of a trustee to conserve the nature and protect the environment from any kind of harm or degradation. In fact, Allah has placed a measured quantity on the environmental

resources which matched with the demand of the resources on the earth. Therefore, human has to use them in a right ways. As stated in the Holy Quran, man are called to preserve this equilibrium, to be moderate in everything and to avoid any actions that would cause harm to nature, "*And the Firmament has He raised high, and He has set up the Balance [of Justice], in order that ye may not transgress [due] balance. So establish weight with justice and fall not short in the balance*" (Al-Rahman: 7-9).

1.3. STATEMENT OF THE PROBLEM

According to Aja & Al-Kayiem (2014), Malaysia waste management had difficulties in collection coverage of garbage. The low coverage is due to limited accessibility of vehicles in some areas, irregular collection services, inadequate equipment used for waste collection, crude open dumping and burning without air and water pollution control, inadequate legal provisions and resources constraints. These problems are caused by various factors which have an impact on the development of effective waste management systems in Malaysia. As most of the developing countries, Malaysia is facing an increase of the generation of waste and of accompanying problems with the disposal of this waste. Generating about 0.5 up to 1.9 kg per capita per day of Municipal Solid Waste (MSW), it is estimated that Malaysia is generating a total of about 25,000 tonnes of MSW per day and might been exceeded up to 30,000 tonnes per day by 2020. Characterised by 45% food waste, 24% plastic, 7% paper materials, 6% metal, 4% wood and 3% glass, it is approximately about 80-90% waste collections sent to landfill and 5% is recycled. Meanwhile, composting and energy recovery seems rarely practiced. Therefore, the

application of using metal-accumulating plants for environmental clean-up has been vigorously pursued to encounter the toxicity before it spread over to the environment (Vassilev *et al*., 2004). Using the bioaccumulation capacities of specialized group of plants may provide an effective way of removing heavy metals from contaminated soils (Khalid *et al*., 2017). As a consequence, a great deal of contamination, especially to surface water, soil and ground water, occurs, threatening the health of exposed populations and ecosystems (Zhang *et al*., 2010). Therefore, a cost effective and efficient treatment method are needed to cope with this future environmental problem.

1.4. RESEARCH AIM

This research aimed to study pattern distribution of landfill contaminant as well as to explore the capabilities of fern species as phytoremediation agent.

1.5. RESEARCH OBJECTIVES

The objectives has been construct to achieve the aim. The objectives are stated as below:

1. To study spatial distribution and potential of landfill contaminant at active and closed landfill at different depths (0 to 30cm, 30 to 60 cm and 60 to 90 cm) and radiuses (5 to 10 m, 10 to 15 m, and 15 to 20 m);
2. To assess type of fern species ability and stability as phytoremediation agent.