HEAVY METALS REMOVAL FROM LANDFILL LEACHATE USING *VERTIVERIA ZIZANIOIDES* AND ARTIFICIAL ROOTS

MOHAMMAD SAFWAN BIN MOHD YANI

A thesis submitted in fulfilment of the
requirement for the award of the degree of
Master of Engineering (Environmental Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUN 2015

Special thanks to my beloved parents, Mohammad Yani bin Hj Suramin and Shamsuriah binti Hj Mansor and my family,Mohammad Aiman, Najiah Syahirah, Amirah Afiqah and Amirul Haqkim,

Hasbullah bin Abdul Aziz, Azri Johari, Izuan Ismail, Bahiah Binti Mazalan, Ungku Mariam Ungku Omar,

Ahmad Sobri, Izamuddin (Condeng), Hafizzuddin (Boter), Syahmi (Crouch), Shahrul (Jidin), Shahrul Azri (Talaha), Elly Norisya,

Alif Ridzuan,Akram Bahtiar (Katok) , Izzul (Ijol 2),

Adilah Mahabob (Deqn), Nur Ikhma (Ima), Anis Amalina, Najiba Ramly, Siti Khadijah, Mamat, Fiq, Ayam, Fatin Sara, Nurul Amirah Mohd Noor and for their support and encouragement.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Graceful. With His blessing and permission, finally this Master's thesis has been accomplished successfully in the given time frame

First of all, I would like to extend my gratitude to everyone who has been helping me directly or indirectly from the beginning until the final stage of this project. All the help and cooperation from various parties had been a motivation factor for me to complete this project. I would like to express my utmost gratitude and appreciation to the thesis supervisor Prof. Dr. Mohd Razman bin Salim, for his cooperation, guidance, facilitation and advice for me to finish this project. I am particular grateful to Pn.Normala Hashim, who guides me throughout the project.

All staff in the Environmental Engineering Laboratory, Faculty of Civil Engineering UTM, who has been helping me in providing the equipment for data collection in this project, to all of you I extend my gratitude. Thank you for your cooperation and assistance. Not to forget, thank you very much to my fellow friends who have been helping me during the data collection process and provided support to the completion of the project.

My hearteous gratitude to my beloved family and close friends for always being there for me. Your endless support has always been my inspiration. Last but not least I would like to extent my special thanks to my fellow friends. I sincerely appreciate their views and comments. Their enthusiasm has kept me going till the end of this project report. Wassalam

Thank you.

ABSTRACT

High concentrations of heavy metals and ammonia in landfill leachate can bring hazard to water bodies if it is not treated properly before discharge. Pure water has become the most precious and valuable resource for today generations as its supply become limited and is easily being polluted by industrial wastewater. Nowadays, methods of treatment have become expensive and certainly uneconomical for smaller communities and small medium industries. Biological treatment plays an important role in processing and treating solid waste disposed in a sanitary landfill. Leachate generation is one of the main issues of concerned in a sanitary landfill, due to the existence of high concentrations of heavy metals and ammonia. A combined wetland system utilizing a free floating plant attached with artificial roots was constructed to treat landfill leachate. The aim of the study was to investigate the effectiveness of leachate treatment using floating island wetland system. A free floating plant (*Vertiveria zizanioides*) and artificial roots were used. The wetland systems were arranged in series and operated until the result obtained was in stable state for 50%, 75% and 100% leachate concentrations, respectively. The performances in these series were evaluated with comparison to Set D (control system). The result demonstrated that the removal efficiency of pollutants in leachate using a wetland combination of Set B (*Vertiveria zizanioides* and artificial roots) was achieved for 50% leachate concentration compared to 75% and 100% leachate concentrations. At 100% leachate concentration removal for ammoniacal nitrogen for Set B was 100% compared to set A and Set C which were 89% and 79%, respectively. Besides that, Set B also achieved high metal removal for Cr, Cu, Mn, Fe, Zn at 50% leachate concentration which are 95%, 88%, 93%, 98% and 96% respectively. Set A (*Vertiveria zizanioides*) had higher capacity of metals uptake (Fe, Zn and Mn) in leachate constituents compared to Set C (artificial roots). From the study, it shows that Fe, Zn and Mn uptake were more significant in roots compared to leaves. This study concluded that combination of free floating plants and artificial roots can increase the performances of nutrients and metal uptake and also enhance treatment of leachate.

ABSTRAK

Kepekatan logam berat dan ammonia yang tinggi dalam air larut lesap boleh membawa bahaya kepada jasad air jika tidak diolah dengan betul sebelum dialirkan keluar. Air tulen telah menjadi sumber yang paling bernilai dan terhad kepada generasi kini kerana ia mudah dicemari oleh air sisa industri. Perkembangan teknologi di dalam kaedah olahan air sisa telah menjadi mahal dan tidak ekonomik untuk penempatan komuniti yang kecil dan industri kecil dan sederhana. Kaedah olahan biologi memainkan peranan yang penting dalam pemprosesan dan mengolah sisa pepejal yang telah dilupuskan di tapak kambus tanah sanitari. Penjanaan air larut lesap adalah salah satu isu utama di tapak kambus tanah sampah, kerana mengandungi kepekatan logam berat dan ammonia yang tinggi. Kajian ini bertujuan untuk menguji keberkesanan olahan air larut lesap menggunakan sistem tanah bencah pulau terapung. Dalam kajian ini, tumbuhan terapung bebas (*Vertiveria zizanioides*) dan akar tiruan telah digunakan. Sistem tanah bencah disusun secara bersiri dan dikendalikan sehingga keputusan yang diperolehi adalah dalam keadaan stabil untuk 50%, 75% dan 100% kepekatan air larut resap. Prestasi siri olahan ini telah dinilai dengan membuat perbandingan kepada Set D (sistem kawalan). Keputusan yang diperolehi menunjukkan bahawa kecekapan penyingkiran bahan cemar dalam air larut lesap menggunakan gabungan tanah bencah set B (*Vertiveria zizanioides* dan akar tiruan) tercapai untuk kepekatan 50% air larut lesap berbanding dengan kepekatan 75% dan 100% air larut lesap. Untuk 100% kepekatan air larut lesap, kecekapan penyingkiran nitrogen ammonia bagi Set B adalah 100% berbanding dengan Set A dan Set C pada 89% dan 79%. Selain daripada itu, Set B juga mencapai kadar penyingkiran logam yang tinggi untuk Cr, Cu, Mn, Fe, Zn bagi kepekatan air larut lesap 50% pada 95%, 88%, 93%, 98% dan 96%,masing-masing. Set A (*Vertiveria zizanioides*) mempunyai kapasiti yang lebih tinggi untuk pengambilan logam (Fe, Zn dan Mn) dalam juzuk air larut resap berbanding dengan Set C (akar tiruan). Berdasarkan pada kajian ini, keputusan menunjukkan bahawa penyingkiran bahan logam berat seperti Fe, Zn dan Mn adalah melalui akar berbanding daun. Kesimpulan kajian ini menunjukkan bahawa gabungan tumbuhan terapung bebas dan akar tiruan boleh meningkatkan prestasi pengambilan nutrien dan logam serta meningkatkan olahan air larut lesap.

.

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		ii
	DEDICATION		iii
	ACKNOWLEDGEMENTS		iv
	ABSTRACT		v
	ABSTRAK		vi
	TABLE OF CONTENT		vii
	LIST OF TABLE		x
	LIST OF FIGURES		xv
	LIST OF ABBREVIATIONS		xvii
1	**INTRODUCTION**		1
	1.1	Background Of Study	1
	1.2	Problems Statement	4
	1.3	Objectives	5
	1.4	Significance Of Study	5
	1.5	Scope Of Study	6

2	**LITERATURE REVIEW**		8
	2.1	Introduction	8
	2.2	An Overview Of Leachate	8
	2.2.1	Leachate Generation	10
	2.2.2	Leachate Characteristic	12
	2.2.2.1	Composition Of Waste	13
	2.2.2.2	Landfill Age	13
	2.2.2.3	Climate Variation	14
	2.2.3	Leachate Composition	15
	2.2.3.1	Ph	18
	2.2.3.2	Chemical Oxygen Demand	18
	2.2.3.3	Total Dissolved Solid	18
	2.2.3.4	Nitrogen	18
	2.2.3.5	Heavy Metal	19
	2.3	Leachate Treatment	19
	2.3.1	Biological Treatment Process	22
	2.3.1.1	Aerobic Treatment	22
	2.3.1.2	Activated Sludge Process	23
	2.3.1.3	Aerated Lagoons	24
	2.3.1.4	Anaerobic Treatment	24
	2.3.2	Physical – Chemical Treatment	25
	2.3.2.1	Precipitation	25
	2.3.2.2	Carbon Adsorption	26
	2.3.2.3	Chemical Oxidation	27
	2.3.2.4	Reverse Osmosis	27
	2.4	Wetland	31
	2.4.1	Natural Wetland	32
	2.4.2	Constructed Wetland	33
	2.4.3	Types Of Constructed Wetland	33

	2.4.3.1	Free Surface Wetland	36
	2.4.3.2	Horizontol Subsurface	37
	2.4.3.3	Vertical Subsurface Flow	38
	2.4.3.4	Free Floating Leaved Plants	40
	2.4.3.5	Free Floating Plant Treatment	40
	2.4.4	Pollutant Removal Process	42
	2.4.5	Wetland Plants	45
	2.4.6	Vetiveria Zizanioides	48
	2.4.7	Phytoremediation	50
	2.4.8	Factors For Wetland Performance	51
	2.5	Role Of Wetland Treatment	53
	2.6	Artificial Roots	53
	2.7	Application Of Constructed Wetland	55
	2.8	Conclusion	55
3	**METHODOLOGY**		59
	3.1	Introduction	59
	3.2	Research And Operational Structure	59
	3.3	Leachate Sample Collection	62
	3.4	Experiment Design	63
	3.5	Vetiveria Zizanioides	68
	3.6	Artificial Roots	68
	3.7	Sampling And Analysis	70
	3.8	Analysis Process	70
	3.8.1	Observation of Plant Growth	72
	3.8.2	Analysis of Heavy Metal in Plant Tissue	72
	3.9	Performance Assessment	73
4	**ANALYSIS AND DISCUSSION**		74
	4.1	Introduction	74
	4.2	Nutrients Removal	76
	4.2.1	Ammonia Nitrogen	76

	4.3	Chemical Oxygen Demand	79
	4.4	Heavy Metal Removal	85
	4.4.1	Chromium Hexavalent	81
	4.4.2	Copper	85
	4.4.3	Manganese	88
	4.4.4	Iron	92
	4.4.5	Zinc	96
	4.5	Heavy Metal In Plant Tissue	99
	4.5.1	Heavy Metal Uptake	100
	4.6	Effect Of Leachate Concentration	110
	4.6.1	Physical Appearance Of Plants	110
5	**CONCLUSION**		115
	5.1	Conclusion	115
	5.2	Recommendation	117
REFERENCES			118

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Leachate Concentration vs. Landfill Age	14
2.2	Composition of Landfill Leachate	17
2.3	Comparative performance of various treatments Processes for leachate treatment	21
2.4	Physical – chemical and biological treatment Processes applicable to process trains for Leachate treatment	28
2.5	Advantages and disadvantages of Free Surface, Horizontal Subsurface and Vertical Subsurface Wetlands	39
2.6	Pollutant Removal Mechanism in Constructed Wetland	43
3.1	Table 100 % Landfill leachate dilution and retention time	61
3.2	Table 75% Landfill leachate dilution and retention time.	61
3.3	Table 50 % Landfill leachate dilution and retention time.	61
3.4	Table of method removal of floating island	66
4.1	Comparison between initial and effluent quality Of leachate on 50% leachate dilution	75
4.2	Comparison between initial and effluent quality Of leachate on 75% leachate dilution	75
4.3	Comparison between initial and effluent quality Of leachate on 100% leachate	76
4.4	Length of *Vetiveria Zizanioides* shoots and roots in Different leachate concentration wetlands	110

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Conceptual Leachate and Infiltration Process	9
2.2	Distribution of flow in particle consolidation phase	11
2.3	Movement of external water in the leachate	12
2.4	Variation in COD and rainfall in Thailand	15
2.5	Generalized Diagram of the Activated Sludge Process	24
2.6	Categorization of constructed wetland systems for Wastewater treatment	34
2.7	Classification of Constructed Wetland System for Wastewater Treatment.	35
2.8	Types of Horizontal Sub Surface Constructed Wetland	37
2.9	Types of Vertical Sub Surface Constructed Wetland	38
2.10	Free Floating Plant in Constructed Wetland	41
2.11	Contaminated uptake and release pathway in Wetland treatment system	42
2.12	Nitrogen transformation in wetland treatment system	44
2.13	*Vetiveria Zizanioides* Plants	49
3.1	Sequence of the Investigation Method	60
3.2	Leachate Collection Activities	63
3.3	Diagram of floating island from side view for Set A	64
3.4	Diagram of floating island from side view for Set B	64
3.5	Diagram of floating island from side view for Set C	65
3.6	Diagram of floating island from side view for Set D	65
3.7	Pilot scale of Constructed Wetland for Floating Island	66

3.8	Wetland System Components for Set A	66
3.9	Wetland System Components for Set B	66
3.10	Wetland System Components for Set C	67
3.11	Short description of *Vetiveria Zizanioides*	69
3.12	Sample of Artificial Roots Used in the Wetland System	70
3.13	Sample for Analyzed using DR5000	71
3.14	Plants digestion for root, vascular and leaves using Behr TRS300	72
4.1	Percentage of Ammonia Nitrogen (NH_4-N) removal Efficiency with difference concentrations of leachate	77
4.2	Percentage of Chemical Oxygen Demands (COD) Removal efficiency with difference concentration of leachate	79
4.3	Percentage of Chromium Hexavalent (Cr) removal efficiency With Difference concentration of leachate with exposure to Natural environmental condition and aerated throughout The experiment	82
4.4	Percentage of Chromium Hexavalent (Cr) removal efficiency of 50% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9997, 0.9878, 0.9987 and 0.9797 respectively.	82
4.5	Percentage Chromium Hexavalent (Cr) removal efficiency of 75% leachate concentration with exposure to natural Environmental condition and aerated throughout the Experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9657, 0.9443, 0.9598 and 0.9689 respectively.	83
4.6	Percentage of Chromium Hexavalent (Cr) removal efficiency of 100% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9598, 0.9542, 0.9704 and 0.9414 respectively.	84

4.7	Percentage of Copper (Cu) removal efficiency with Difference concentration of leachate with exposure to Natural environmental condition and aerated throughout The experiment.	86
4.8	Percentage of Copper (Cu) removal efficiency of 50% Leachate concentration with exposure to natural Environmental condition and aerated throughout the Experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9639, 0.9821, 0.9907 and 0.9830 respectively.	86
4.9	Percentage Copper (Cu) removal efficiency of 75% Leachate concentration with exposure to natural Environmental condition and aerated throughout the Experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9838, 0.9878, 0.9563, and 0.9362 respectively	87
4.10	Percentage of Copper (Cu) removal efficiency of 100% Leachate concentration with exposure to natural Environmental condition and aerated throughout the Experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9934, 0.9910, 0.9930 and 0.9871 respectively	87
4.11	Percentage of Manganese (Mn) removal efficiency with Difference concentration of leachate with exposure to Natural environmental condition and aerated throughout The experiment	89
4.12	Percentage of Manganese (Mn) removal efficiency of 50% Leachate concentration with exposure to natural Environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9224, 0.9763, 0.9959 and 0.9903 respectively	90

4.13	Percentage Manganese (Mn) removal efficiency of 75% Leachate concentration with exposure to natural Environmental condition and aerated throughout the Experiment. Based on the fit graph the value of regression Coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9482, 0.9785, 0.9544 and 0.9518 respectively.	90
4.14	Percentage of Manganese (Mn) removal efficiency of 100% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9783, 0.9918, 0.9821 and 0.9728 respectively.	91
4.15	Percentage of Iron (Fe) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment.	93
4.16	Percentage of Iron (Fe) removal efficiency of 50% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9849, 0.9857, 0.9799 and 0.9659 respectively.	93
4.17	Percentage Iron (Fe) removal efficiency of 75% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9896, 0.9801, 0.9959 and 0.9782 respectively.	94

4.18	Percentage of Iron (Fe) removal efficiency of 100% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9596, 0.9969, 0.9913 and 0.9974 respectively.	94
4.19	Percentage of Zinc (Zn) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment.	96
4.20	Percentage of Zinc (Zn) removal efficiency of 50% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9965, 0.9868, 0.9974 and 0.9578 respectively.	97
4.21	Percentage Zinc (Zn) removal efficiency of 75% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9683, 0.9680, 0.95180 and 0.9594 respectively.	97
4.22	Percentage of Zinc (Zn) removal efficiency of 100% leachate concentration with exposure to natural environmental condition and aerated throughout the experiment. Based on the fit graph the value of regression coefficient (r^2) for Set A, Set B, Set C and Set D is 0.9949, 0.9999, 0.9969 and 0.9984 respectively.	98
4.23	Chromium (Cr) with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set A.	100

4.24	Percentage of Copper (Cu) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set A.	101
4.25	Percentage of Manganese (Mn) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set A.	102
4.26	Percentage of Iron (Fe) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set A.	103
4.27	Percentage of Zinc (Zn) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set A.	104
4.28	Percentage of Chromium (Cr) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set B	105
4.29	Percentage of Copper (Cu) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set B	116
4.30	Percentage of Manganese (Mn) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set B	107
4.31	Percentage of Iron (Fe) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set B	107

4.32	Percentage of Zinc (Zn) removal efficiency with difference concentration of leachate with exposure to natural environmental condition and aerated throughout the experiment in Set B	109
4.33	Physical appearance of *Vetiveria Zizanioides* in 50% at the ends of experiments for 20 days in (a) roots Set A (b) shoots Set A (c) roots Set B (d) shoots Set B.	111
4.34	Physical appearance of *Vetiveria Zizanioides* in 75% at the ends of experiments 35 days in (a) roots Set A (b) shoots Set A (c) roots Set B (d) shoots Set B.	112
4.35	Physical appearance of *Vetiveria Zizanioides* in 100% at the ends of experiments for 43 days in (a) roots Set A (b) shoots Set A (c) roots Set B (d) shoots Set B.	113

LIST OF ABBREVIATIONS

BOD - Biochemical Oxygen Demand
cm/day - Centimeter per day
CAP - Consumers Association of Penang
Ca^{2-} - Calcium
$CaCO_3$ - Calcium carbonate
C/C_O - Present concentration over initial concentration
Cl - Clorine
Cl_2 - Chlorine gas
Cd - Cadmium
Cr - Chromium
COD - Chemical Oxygen Demand
CWs - Constructed wetland
Fe - Ferum
FWS - Free Water Surface
HCO_3^- - Bicarbonate
HF-SSF - Horizontal Subsurface
Flow HLR - Hydraulic Loading Rate
HRT - Hydraulic Retention Time
IUCN - International Union for the Conservation of Nature
kg - Kilogram
kg/m^3 - Kilogram per meter cube
m - Meter
mm - Millimeter
m/day - Meter per day
mg/g - Milligram per gram

mg/L	-	Milligram
per liter mL/s	-	Milliliter per
second Mg^{2+}	-	Magnesium
MLVSS	-	Mix liquor Volatile Suspended Solid
Mn	-	Manganese
N_2	-	Nitrogen
gas N_2O	-	Nitrogen Oxides
NH_4^+	-	Ammonia
NH_4-N	-	Ammonia Nitrogen
NO_2^-	-	Nitrite
NO_3^-	-	Nitrate
NO_2 -N	-	Nitrite Nitrogen NO_3
-N	-	Nitrate Nitrogen
P	-	Phosphorus
PO_4^{3-}	-	Orthophosphate
SO_4^-	-	Sulfate
SSF	-	Subsurface Flow
SSF-FWS	-	Combine Subsurface Flow and Free Water Surface System
SS	-	Suspended Solid
TIN	-	Total Inorganic
Carbon TKN	-	Total Kjeldahl
Nitrogen TN	-	Total Nitrogen
TP	-	Total Phosphorus
TOC	-	Total Organic Carbon
TSS	-	Total Suspended Solid
VF	-	Vertical Flow
VF-SSF	-	Vertical Subsurface Flow
VFA	-	Volatile Fatty Acid
VOC	-	Volatile Organic
Carbon RBC	-	Rotating Biological
Reactor Zn	-	Zinc
%	-	Percent

CHAPTER 1

INTRODUCTION

1.1 Background of study

Malaysia has become one of the greatest countries in the Southeast Asian Nations in engineering field, where rapid development in the industrial nation, the good health care, education and better employment opportunities in Malaysia have led to the increase in the population. The massive physical development and socioeconomic activities has produced a large mass of solid waste globally. In Malaysia, production rate of municipal solid waste (MSW) per capita is 0.5-0.8 kg/person/day and in specific high density population, this statistic has increased to 1.7 kg/person/day (Kalantarifard and Yang, 2011).

Generally, in Malaysia, sanitary landfill is the main option in solid waste management compare to incineration. On the other hand, due to the scarcity or limited land reserved, land space for MSW is now becoming critical, when the wastes produced are much higher as compare to the degrade mechanism production. Thus, land space for MSW becomes hard and costly to achieve. Installation of incineration system is acceptable but it is expensive and hazardous to human health.

Sanitary landfill is an isolation of municipal solid waste from the environment until the wastes are non hazardous through the chemical, physical and

biological processes of nature. Sanitary landfill involves two basic conditions; 1) compaction of the municipal solid wastes after spreading them into thin layer, and
2) Covering the wastes daily with soil to prevent negative impacts on human health and environment.

Sanitary landfill system causes formation of leachate (Ain Nihla, 2006) by precipitation percolating through waste layer deposited in a landfill. Combination of chemical, physical and microbial process in the residual transfer pollutants from the residual matter to the percolating water (Kjeldsen and Christophersen, 2014).

Highly polluted leachate move downwards into the base or impermeable layer from landfill into groundwater table by gravity force as a production of infiltrated precipitation. Once leachate reaches ground water table, over time, it will cause ground water pollution (Fetter, 2001; Nazaitulshila, 2006). Landfill leachate compositions depend on several factors such as pH, temperature, availability of moisture and oxygen, landfill age and operation system, climate, composition and depth of waste (Aderemi et al., 2011).

When a massive of solid waste is placed on the landfill sites, some reaction will occur due to the activity, such as biological decay of organic materials, chemical oxidation of waste materials or dissolving and leaching of organic and inorganic materials by water through the landfill. Those reactions produce gases, such as ammonia, carbon dioxide, hydrogen sulfide, oxygen, nitrogen, and methane

Organic matters are decomposed by microorganism and causes oxygen on surface water to deplete (Vymazal et al., 2008). In conjunction, the process brings harm to aquatic life. Therefore, leachate can be toxic and acidic which contain high concentration of heavy metal such iron, manganese and copper. Heavy metals are dangerous because they tend to bioaccumulation. Bioaccumulation is the uptake of organic compounds from water or food containing the chemical amd process by which chemical is taken up by an organism (Mark, 2008). Highly contaminated leachate can affect flora and fauna ecosystem, human health and environment, so landfills leachate treatment is required as a necessary part of solid waste management before being discharged into receiving water to prevent these occurrences (Chew, 2005).

Generally, wastewater in landfill leachate is difficult to be treated by itself due to the high strength of concentration. Thus, a biological treatment technology such as constructed wetlands can be adapted for this treatment. Constructed wetland treatment systems are engineered system that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils to assist in treating wastewater.

Usually, leachate treatment systems are made from steel and concrete construction (man-made) wetland treatment or employ naturally where it relies on intensive inputs of chemicals, that treat wastewater utilizing natural processes of sedimentation, precipitation, and adsorption, assimilation by plant tissue, microbial transformation and organic degradation (Alkassabeh et al., 2009).

In addition, wetlands have a higher rate of biological activity in ecosystem where they can transform many of the common pollutants that occur in conventional wastewater into harmless by product or essential nutrients that can be used for additional biological productivity. These transformations are accomplished by virtue of the wetland’s land area, with its inherit natural environmental energies of sun, wind, soil, plants and animals. These pollutant transformations can be obtained for relatively low cost of earthwork, piping, pumping, and few structures. Wetlands can be categorized as one of the least expensive treatment systems to operate and maintain, because of the natural environment energies at work in the wetland treatment system, with minimal fuel energy and chemical.

1.2 Problem Statement

Landfill leachate produced by MSW landfill sites contains highly contaminated heavy metals and complex wastewater that are very hard to deal with (Daud et al., 2009; Foul et al., 2009; Palaniandy et al., 2009; Mohajeri et al., 2010). Leachate contain high concentration of organic matters (biodegradable and non-biodegradable), ammonia nitrogen, chlorinated organics, inorganic salt, high concentration of Chemical Oxygen Demand (COD), and heavy metals (Aeslina, 2004; Renou et al., 2008). Leachate concentration may range over several orders of magnitude (Deng and Englehardt, 2007).

High concentration of contaminants in leachate (such as COD, ammonia and inorganic salts) can be hazardous to surface waters and ground water table, thus they need to be treated before being discharged to water resources (Bashir et al., 2010). In addition, lack of safety management in leachate collection and treatment also can contribute to harmful environment for flora and fauna. In Malaysia, 230 landfills have been recognized and most of them are not designed with proper leachate collection mechanism and do not come under sanitary leachate category because there are no facilities for collection and treatment leachate and landfill gas (Alkassabeh et al., 2009)

Operation and maintenance for landfill leachate treatment require high budget due to the sophisticated and advance technology that had ben used to treat all the heavy metals and hazardous component in the leachate before it been discharges to the nearer river . Plus, adequate skill labors are compulsory due to the management of the sophisticated system. An alternative eco-friendly and low cost technology with high sufficient natural treatment is therefore needed, such as constructed wetlands for secondary or tertiary treatment to treat treated leachate.

Constructed wetlands are built with such greater degree of control, thus allowing the establishment of experimental treatment facilities with a well-defined composition of substrate, type of vegetation, and flow pattern. In addition, constructed wetlands offer several additional advantages compared to natural wetlands, which include site selection, flexibility in sizing and most importantly control over the hydraulic pathways and retention time.

1.3 Objectives

The objectives of this research are as follows:

1. To investigate the removal efficiency performances of COD, Ammonia Nitrogen (NH_3-N), and heavy metal (Chromium Hexavalent, Copper, Manganese, Zinc, Iron) for different leachate concentrations (100%, 75%, and 50%) by *Vertiveria zizanioides* (Set A), *Vertiveria zizanioides* with artificial roots (Set B), Artificial roots (Set C) and Control system (Set D)
2. To evaluate the heavy metals uptake by *Vertiveria zizanioides* in roots, shoots with or without the combination of artificial roots.
3. To investigate the effect of leachate concentration in the capability growth of the *Vertiveria zizanioides*.

1.4 Significance of Study

Sophisticated leachate treatment technology usually is expensive in operation and maintenance and requires constant supervision, typical purification system consist of mechanical and chemical process which are required adequate skill staff, large amount of energy (non- renewable) resources.

Meanwhile, *Vetiveria zizanioides* is a biological purifier and renewable resources which can be used in others applications when no longer needed for phytoremediation purpose. New potential plants species with good climate condition in Malaysia can bring new ideas for natural environment as introduced in constructed wetlands to treat leachate. Thus, in this context, variation of expanding new ideas generate large concept beyond the common treatment of wastewaters.

This research is to evaluate the efficiency of the floating island system to treat the leachate from the landfills. Floating island plants will remove the pollutants from the leachate naturally without harming other flora and fauna lives before being discharged into the mainstream water base. Due to the eco-friendly characteristic, this method is potential to be used in landfill site to improve the quality of water. Floating islands are innovative variant of constructed wetland and pond technologies that can treat wastewater. Floating island employ rooted, emergent macrophytes on a mat floating on the surface of the water rather than a rooted in the sediments. Floating islands are hybrid between a pond and a wetland, which behave similarly to detention pond. The plant roots hang beneath the floating amt and provide a large surface area for biofilm growth which forms an important part of the treatment.

The research study can determine the suitable leachate concentration for optimum removal of pollutants through analysis of the parameters and criteria. Leachate concentration plays the vital role to ensure that the leachate concentration is neither too high nor too low to influence the effectiveness of treatment in constructed wetlands. In addition, the research also provides the information carried by the floating island system such as the heavy metal removals.

1.5 Scope of Study

The research was carried out in lab-scaled wetland system to treat leachate. Leachate will be collected from landfill and initial characteristics of the leachate were analyzed. Then, experiments were conducted separately in constructed wetlands, where leachate is only used as control, 100% leachate, 75% leachate and

50% leachate. All the experiments in the constructed wetlands were aerated and the total amount of leachate in each pair of tanks is 247.5 liters.

Evaluation of treatment efficiency for different leachate concentrations is determined for the following parameters (Temperature, DO percentage, DO, Conductivity, Total Dissolved Solid, pH, NH_4-N, NO_3^-N, COD) and heavy metals such as Chromium Hexavalent, Copper, Manganese, Zinc and Iron. The heavy metal removals evaluation will be determined on the leaves, rhizomes and roots of the floating plants (*Vetiveria Zizanioides*) and identify the function of artificial roots. The effects of leachate concentration are determined based on the length and physical appearance of the leaves throughout the experiment conducted.

REFERENCE

Aderemi, A.O., Orlaku, A.V., Adewumi, G.A. and Otitoloju, A.A. 2011. Assessment of groundwater contimation by leachate near a municipal solid waste landfill. Afican Jounal of Enivironemtal Science and Technology Vol5(11), pp. 933-940.

Adeyemi, O., Oloyede. O.B. and Oladiji, A.T. 2007. Effect of leachate contaminated groundwater on the growth and blood of albino of rats. *Journal of Hematology* 3:1-6.

Aeslina Abdul Khadir, 2004. *Landfill Leachate Treatment Performance in SSF Constructed Wetlands using Safety Flow System*. Master in Civil Engineering University Technology Malaysia.

Ain Nihla Binti Kamarudzaman, 2006. *Leachate Treatment Using Subsurface Flow and Free Water Surface Constructed Wetland Systems*. Master of Civil Engineering, University Technology Malaysia, Skudai.

Alkassabeh, J.Y.M., L. Y. Heng., and S.Surif., 2009. " Toxicity testing and the effect of landfill leachate in Malaysia on behavior of common carp (Cyprinus carpio L., 1758; Pisces, Cyprinidae)," *Waste Management* vol. 25, no. 10, pp. 1013-1020.

Al-Maliky Salam J. 2002. Performance of trickling filter with scrap (PVC) fills in a Vegetable Oils Industry Factory. *Proceeding of Jordanian Chemical Engineering Conference IV,Vol.2*

Andrii Butkovskvi, 2009. Leachate Treatment at Filnorna Landfill with Focus on Nitrogen Removal. Master Thesis. Water and Environmental Engineering, Department of Chemical Engineering. Lund University.

APHA (2002). *Standard Methods for Examination of Water amd Wastewater.* 21th Edition. Washinton: American Public Health Association.

Ashley Blauvelt., 2009. Removal of Ammonia from Landfill Leachate. Worcester Polytechnic Insititute. Degree Bachelor of Science Thesis.

Ayo, A., Abdulkareem, A. and Mokoana, B. 2011. Leachate Generation Characterization Due to the Disposal of Liquid and High Moisture Content Waste: A Case Study of Rietfontein, South Africa. International Conference on Chemical, Ecology and Environmental Sciences (ICCEES 2011) Pattaya. pp 374-379.

Aziz, H.A., Alias, S., Adlan, M. N. and Hung, Y-T. 2009. "Application of combined filtration and coagulation of semi-aerobic leachate treatment*," International Journal of Environment and Waste Management,* vol. 4, no.3-4, pp. 457-469.

Aziz S.Q., Aziz H.A., Yusoff M.S., Bashir M.J. K. and M. Umar, M. 2010. Leachate Characaterization in semi –aerobic and anaerobic sanitary landfills: A comparative study, Journal of Environmental Managament, **9**(**12**), 2608-2614.

Bashir, M. J. K., H. A. Aziz., M. S. Yusoff, and M. N. Adlan., 2010. "Application of response surface methodology (RSM) for optimization of ammoniacal nitrogen removal from semi-aerobic landfill leachate using ion exchange resin,"*Desalination*, vol. 254, no. 1-3, pp. 154-161.

Benson, C. H., Barlaz, M.A., Lane, D.T. and Rawe, J.M. B.E., 2007. Practice review of five bioreactor/ recirculation landiflls. *Waste Management*, **27**, 13-29.

Bilgili, M.S., Demir, A., and Ozkaya, B., B.E., 2007a. Influence of leachate recirculation on aerobic and anaerobic decomposition of solid wastes. Journal of Hazardous Materials, **143**, 177-183.

Bilgili, M.S., Demir, A., and Ozkaya, B., B.E., 2007b. Metal concentrations of simulated aerobic and anaerobic pilot scale landfill reactors. Journal of Hazardous Materials, **145**, 186-194.

Bohdziewicz, J. and Kwarciak, A. 2008. "The application of hybrid system UASB reactor-RO in landfill leachate treatment," *Desalination*, vol. 222, no.1-3, pp. 128-134.

Boni, M.R., Chiavola, A. and Sbaffoni, S. 2006. Pre-treated waste land filling: Relationship between leachate characteristic and mechanical behavior, *Waste Management* 26, pp 1156-1165.

Boni, M.R., Leoni, S. and Sbaffoni, S. 2007. Co-land filling of pre- treated waste: Disposal and management starategies at lab scale. J. *Hazardous Materials* 147, pp 37-47.

Cervantes, C., Garcia, J.C., Devars, S., Corona, F.G., Tavera, H.L. and Torres-Guzman, J. 2001. Interaction of Chromium with microorganisms and plants, FEMS Microbiol Rev 2001: 25:335-471.

Chen, K.F., Yeh, T.Y. and Lin, C.F. 2011. Phytoextraction of Cu,Zn, and Pb Enhanced by Chelators with Vetiver (*Vetiveria Zizanioides*) : Hydroponic and Pot Experiments.International Scholarly Research Network. ISRN Ecology. 729693: 1-12.

Chew Ai Ling, 2005. *Nutrient Removal From Leachate Using Horizontal Subsurface Constructed Wetlands*. Master of Civil Engineering, University Technology Malaysia, Skudai.

Crites, R.W., Middlebrooks, E.J. and Reed, S.C. 2006. Natural Wastewater Treatment Systems. Meyer M.D. (ed.) CRC Press Boca Raton, Florida.

Daud, Z., Aziz, H.A., Adlan, M.N. and Hung, Y-T. 2009. "Application of combined filtration and coagulation for semi –aerobic leachate treatment," *International Journal of Environment and Waste Management*, vol.4, no.3-4, pp.457-469.

Deng, Y. and Englehardt, J.D. 2007. "Electrochemical oxidation for landfill leachate treatment," Waste Management, vol. 27, no.3, pp. 380-388.

Ducic, T. and Polle, A. 2005. Transport and Detoxification of Manganese and Copper in Plants. Toxic in Plants. Braz. J. Physiol, 17(1): 103-112.

El-Gendy, Ahmed (2003). *Leachate Treatment using Natural System*. University of Windsor. PhD Thesis.

El-Nadi, M. and El- Hoseiny (2005). Wastewater Treatment Design Report, Task #4: Environmental Service for Improving Water Quality Management. Report No.*4. *International Resources Group in association with Epiq II Consortium.*

Foul, A.A., H.A. Aziz, M.H. Isa, and Y.T. Hung, 2009. "Primary treatment of aerobic landfill leachate using activated carbon and limestone: batch and column studies, " *International Journal of Environemnt and Waste Management*, vol.4, no. 3-4, pp. 282-298.

Galbrand, C.C. 2003. *Naturalized Treatment Wetlands for Contaminated Removal: A Case Study of the Burnside Engineered Wetland for Treatmetn of Landfill Leachate*. Dalhousie University: Master. Thesis.

Ghafari, S., Aziz H.A. and Bashir, M.J.K. 2005. The use of polu- aluminium chloride and ali\um for the treatment of partially stabilized: A comparative study, *Desalination*, **25**7(**1**), 110-116.

Ghafari, S., Aziz, H.A., Isa, M.H. and Zinatizadeh, A.A. 2009. "Application of response surface methodology (RSM) to optimize coagulation-flocculation treatment of leachate using poly-aluminium chloride (PAC) and alum," *Journal of Hazardous Materials*, vol. 163, no.2-3, pp. 650-656.

Hafeez, B., Khanif, Y. and Saleem, M. 2013. Role of Zinc in Plant Nutrification – A Review. American Journal of Experimental Agriculture 3(2): 374-391.

Headley, T.R. and Tanner, C.C. 2006. Application of Floating Wetlands for Enchaned Stormwater Treatment: A Review. Auckland regional Council. National Institute of Water and Atmospheric Research , Silverdale Road, Hamilton, New Zealand.

Helena Oliveira, 2012. Chromium as an Environmental Pollutant: Insights on Induced Plant Toxicity. Journal of Botany. Volume 2012. Department of Biology, CESAM, University of Aveiro, Portugal. 1-8.

Hoffmann, H., Platzer, C., Winker, M., Muench, E. and van, G.T.Z. 2011. Technology Review of Constructed Wetlands. Subsurface Flow Constructed Wetlands for Greywater and Domestic Wastewater Treatment. Eschborn. Sustainble Sanitation – ecosan program.

Hurst. C., Longhurst, P., Pollard, S., Smith, R., Jefferson, B. and Gronow, J. 2005. Assessment of municipal waste compost as a daily cover material for odour control at landfill sites. *Environment Pollution* 135, pp 171-177.

Jones, D.L., Williamson, K.L. and Owen, A.G. 2006. "Phytoremediation of landfill leachate," *Waste Management*, vol.26, no.8, pp.825-837.

Jun, D., Yongsheng, Z., Henry, K.R. and Mei, H. 2007. Impacts of aeration and active sludge addition on leachate recirculation bioreactor. *J. Hazardous Materials* 147, pp 240-248.

Kadlec, R.H. 2006. Integrated natural systems for landfill leachate treatment. In : Wetlands nutrients, Metals, and Mass Cycling, Vymazal J. (ed.) backhuys Publishers: Leiden, The Netherlands, pp. 1-33

Kadlec, R.H., Pries J.H. and Mustard. H. 2007. Muskrats (*Ondatrazibethicus*) in treatment wetlands. *Ecological Engineering* 29 (2): 143-153.

Kalantarifard, A. and Yang, G.S. 2011. Energy potential from municipal solid waste in tanjung langsat landfill, Johor, Malaysia. International Journal of Engineering Science and technology (IJEST).

Karnchanawong, S., and Yongpisalpop, P. 2009. Leachate Generation from Landfill Lysimeter using Different Types of Soil Cover. *International Journal of Civil and Environmental Engineering.*pp 126-130.

Kelly, J.R., Shearer, D.B., Kim, J., Goldsmith, D.C., Hater, G.R. and Novak, T.J. 2006. Relationship between analytical methods ultized as tool in evaluation of landfill waste stability. *Waste Management* 26, pp 1349-1356.

Keerti Raj, 2011. Anaerobic treatment of municipal solid waste landfill leachate. Master of Technology in Environment Science and Technology Thesis. Thapar Univerisity, Patiala.

Kjeldsen, P. and Christophersen, M. (2001). Composition of leachate from old landfills in Denmark, Waste Manag.Res., 19, 249-256.

Kobayashi, T. and Nishizawa, N.K. 2012. Iron Uptake , Translocation, and Regulation in Higher Plants. Annu. Rev. Plant Biol. 63:131-152.

Kulikowska, D. and Klimiuk, E. 2008. " The effect of landfill age in municipal leachate composition," *Bioresources Technology*, vol. 99, no, no.13, pp. 5981-5985.

Kumar, D. and Alappat, B.J. 2005. " Evaluating leachate contamination potential of landfill sites using leachate pollution index," *Clean technologies and Environmental Policy*, vol.7, no.3, pp. 190-197.

Kurniawan, T.A., Lo, W.H. and Chan, G.Y.S. 2006. " Physico-chemical treatments for removal of recalcitrant contaminants from landfill leachate," *Journal of Hazardous Materials B*, vol.129, no.1-3, pp. 80-100.

Lavrova, S. and Koumanova, B. 2011. Landfill Leachate Purification In a Vertical Flow Constructed Wetland With/Without Preliminary Aerobic Treatment. *Journal of the University Chemical Technology and Metallurgy*, **46**,3,299-304.

Lee, Y.F. 2004. Rainfall Effects to the Performance of Subsurface Flow Constructed Wetland in Leachate Treatment. Universiti Teknologi Malaysia. Master Thesis.

Li, R. 2009. Management of Landfill Leachate. Degree of Environmental Engineering. University of Applied Sciemces.

Madu Jude Ifeanyichukwu., 2009. New Leachate Treatment. Master Thesis.Water and Environmental Engineering Department of Chemical Engineering Lund Univeristy, Sweden.

Mark, A.G. 2008. The ability of Vetiver Grass to act as a primary purifier of waste water: An answer to low cost sanitation and fres water pollution. Unpublished.

Millaleo, R., Reyes-Diaz, M., Ivanov, A.G., Mora, M.L. and Alberdi, M. 2010. Manganese as Essential and Toxic Element for Plants: Transport, Accumulation and Resistance Mechanism. J.Soil Sci. Plant Nutr.v.10(4): 470-482.

Mohajeri, S., Aziz, H.A., Zahed, M. A. and Adlan, M.N. 2012. "Statistical optimization of process parameters for landfill leachate treatment using electron-

Fenton technique," *Journal of Hazaradous Materials*, vol. 176, no. 1-3, pp. 749-758.

Nagajyoti, P.C., Lee, K.D. and Sreekanth, T.V.M. 2010. Heavy Metals, Occurrence and Toxicity for Plants: A Review. Environ Chem Lett. 8: 199-216.

Nazaitulshila Binti Rasit, 2006. *Landfill Leachate Treatment Using Subsurface Flow Constructed Wetlands Enchaned With Magnetic Field*. Master of Civil Engineering, University Technology Malaysia, Skudai

Palaniandy, P., Adlan, M.N., Aziz, H.A. and Murshed, M.F. 2009. "Application of dissolved air floatation (DAF) in semi-aerobic leachate treatment," *Chemical Engineering Journal.*

Parades, D. (2003). *Landfill Leachate Treatment in Constructed Wetland: Removal of High Nitrogen Loads*. Center of Environment Research, Germany.Unpublised.

Peterson, J. and Petrie, J.G. 2000. Modelling and assessment of the long-term leachate generation potential in deposits of ferro-chromium slags. The Soult African Instute of Mining and Metallurgy, Cape Town, Rodebosch, South Africa.

Renou, S., J.G. Givaudan, S. Poulain, F. Dirassouyan, and P. Moulin, 2008. "Landfill leachate treatment: review and opportunity," *Journal of Hazardous Materials*, vol.150, no.3, pp. 468-493.

Roongtanakiat, N. and Chairoj, P. 2001. Uptake potential of some heavy metals by vetiver grass. **Kasetsart J. (Nat.Sci.)** 35:46-50.

Roongtanakiat, N., Nirunrach, N., Chanyotha, S. and Hengchaovanich, D. 2003. Uptake potential of heavy metals in landfill leachate by vetiver grass. **Kasetsart J. (Nat.Sci.)** 37:168-175.

Roongtanakiat, N., Tangruangkiat, S. and Meesat, R. 2007. Utilization of Vetiver Grass (*Vetiveria Zizanioides*) for Removal of Heavy Metals from Industrial Wastewaters. ScienceAsia 33: 397-403.

Rui, L.M., Daud, Z. and Latif A.A.A. 2012. Treatment of leachate by Coagulation-Flocculation using different coagulants and polymer: A review, *International Journal on Advanced Science, Engineering and Information Technology*, **2**(**2**), 1-4.

Sanphoti, N., Towprayoon, S., Chaiprasert, P. and Nopharatana, A.B.E. 2006. The effects of leachate recirculation with supplemental water addition on methane production and waste decomposition in a simulated tropical landfill. *Journal of Environmental Management*, **81**, 27-35.

Shahid, M., Nayak, A.K., Shukla, A.K., Tripathi, R., Kumar, A., Mohanty, S., Bhattacharyya, P., Raja, R. and Panda, B.B. 2013. Long term effects of fertilizer and manure applications on soil quality and yields in sub-humid tropical rice-rice system. Soil Use and Management: 11 (2013) 1-11.

Shanker, A., Cervantes, C., Herminia Loza-Tavera, K. and Avudainayagam, S. 2005. Chromium Toxicity in Plants. Environmental International: 31 (2005) 739-753.

Shangping, Xu. and Peter, R.J. 2010. Effects of Plants on The Removal of Hexavalent Chromium in Wetland Sediments. Environmental International: 31 (2010) 1-24.

Siti Kamariah Md Sa'at., 2006. Subsurface Flow and Free Water Surface Flow Constructed Wetland with Magnetic Field for Leachate Treatment. University Teknologi Malaysia, Johor Bahru.

Spagni, A., Marsili-Libelli, S. and Lavagnolo, M.C. 2009. Nitrogen and COD Removal Optimisation from Leachate Generated in Old MSW Landfill. Bioresource Technol., 58(2): 337-243.

Swati, M. and Joseph, K. 2008. Settlement analysis of fresh and partially stabilized municipal solid waste in simulated controlled dumps and bioreactor landfills. *Waste Management* 28, pp 847-855.

Thian Siaw Hui, 2005. *Leachate Treatment by Floating Plants in Constructed Wetland*, Master of Civil Engineering, University Technology Malaysia, Skudai.

Tilley, E., Luethi, C., Morela, A., Zurbruegg, C. and Schertenleib, R. 2008. Compendium of Sanitation Systems and Technologies. Duebendorf and Geneva: Swiss Federal Institue of Aquatic Science and Technology (EAWAG).

Tizaoui, C., Bouselmi, L., Mansouri,. L. and Ghrabi. A. 2007. Landfill leachate treatment with ozone and ozone/hydrogen peroxide systems. *Journal Hazardous Mater* 140: 316-324.

Trankler, J., Visvanathan, C., Kuruparan, P. and Tubtimthai, O. 2005. Influence of tropical seasonal variation on landfill leachate characteristics. *Waste Management* 25. Pp 1013-1023

Truong, P. 1999. Vetiver Grass Technology for Flood and Stream Bank Erosion Control. *Proc. Intern.Vetiver Workshop,Nanchang,* China.

Truong, P. and Hart, B. 2001. Vetiver System for Waste treatment. Technique bulletin, No.2001/2, PRVN/ORDPB, Bnagkok. Thailand.

Truong, P. 2003. Information supply and experience in Vetiver techcnology. Report to DNR and Redland Shire Council, Queensland, Australia.

Tsonev, T and Lidon, F.J.C. 2012. Zinc in Plants – An Overview. Emer. J. Food Agric: 24(4): 322-333.

Ulrika Welander,1998. Characterization and Treatment of Municipal Landfill Leachate, Department of Biotechnology, Lund University. Page 7.

Umar, M., Aziz, H.A. and Yusoff, M.S. 2010. Variability of Parameters Involved in Leachate Pollution Index and Determination of LPI from Four Landfillsin Malaysia. *International Journal of Chemical Engineering, 1-6.*

UN-HABITAT, 2008. *Constructed Wetlands Manual*. UN-HABITAT Water for Asian Cities Programme Nepal, Kathmandu.

Vigneault, B. and Campbell, P.G.C. 2005. "Uptake of cadmium by freshwater green algae: effects of pH and aquatic humic substances," *Journal of Phycology,* vol.41, no.1, pp. 55-61.

Vymazal, J. and Kropfelova, L. 2008. Wastewater Treatment in Constructred Wetlands with Horizontal Subsurface Flow. *Environmental Pollution*. Volume 14.Czech Republic.

Wallace, S.D. and Kadlec, R.H. 2005. BTEX degradation in a cold-climate wetlands system. *Water Science and Technology* 51(9): 165-171.

Wetzel, R.G. 2001. *Limnology. Lake and River Ecosystem*, 3rd edition, Academic Press, San Diego, California.

William, P.T. 2005. Waste Treatment and Disposal. 2nd ed. United Kingdom. John Wiley & Son,Ltd. 171-244.

Xia, H.P., Liu, S.Z. and Ao, H.X. 2000. A study on purification and uptake by vetiver grass of garbage leachate. Proceedings of the Second International Conference on Vetiver. Office of the Royal Development Projects Board.Bangkok. 394-406.

Zainol, N. A., Aziz, H.A. and Ibrahim, N. 2013. Treatment of Kulim and Kuala Sepetang Landfills Leachates in Malaysia using Poly- Aluminium Chloride (PACI). School of Engineering, Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, Penang, Malaysia. *Research Journal of Chemical Sciences* Vol. **3** (**3**), 52-57.