PERFORMANCE OF VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLAND WITH LIMESTONE FILTER FOR LEACHATE TREATMENT

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ABSTRACT

Nowadays, the solid waste produced is increasing at high rate and known as global environmental issue as well as in Malaysia and the most common practice to reduce and dispose them is by using landfill method. However, landfill can causes generation of leachate. Leachate is highly contaminated since it contained high level of organic and inorganic matters. Before discharge to water body, leachate needs to be treated. This study was focused on the performance of constructed wetland and limestone filter in treating leachate. Constructed wetland and limestone filter emerged as one of the potential treatment to remove contaminants from leachate. In this study, limestone size from 2mm to 14mm was used for limestone filter and constructed wetland developed by using aggregate size from 5mm to 20mm, sand and planted with *Typha Latifolia (Cattails)* to treat landfill leachate. Leachate was collected from Jerangau-Jabor Landfill. Different flowrate (3LPM and 4LPM) was studied to compare the efficiencies of the treatment system in term of pollutants removal in leachate. The treated leachate was analyzed for BOD, COD, TSS, pH, oil and grease, and metals removal such as lead(Pb), copper(Cu), iron(Fe), zinc(Zn), manganese(Mn) and nickel(Ni). The treatment system with two variation flowrate showed effectiveness to remove the parameter but treatment with flowrate 3LPM showed more removal since the contact time taken was longer than 4LPM. Only TSS, COD andoil and grease succeed comply the standard after the treatment with 46mg/L and 1.63mg/L respectively. Parameter of BOD, NH3-N, Pb and Mn showed removal at the end of treatment but still not comply the standard. Metals such as Cu, Fe, Zn and Ni already comply standard and still have removal after treatment. The pH of leachate before and after treatment was satisfy the standard from 6-9. This is because the treatment does not affect the pH value in a leachate wastewater.

ABSTRAK

Masa kini, sisa pepejal yang dihasilkan semakin meningkat pada kadar yang tinggi dan menjadi salah satu isu global di dunia serta di Malaysia dan amalan yang paling biasa untuk mengurangkan dan melupuskan sisa pepejal adalah dengan menggunakan kaedah tapak pelupusan. Walau bagaimanapun, tapak pelupusan boleh menyebabkan penghasilan air larut lesap. Air larut lesap sangat tercemar kerana ia mengandungi tahap bahan organik dan bukan organik yang tinggi. Sebelum dilepaskan ke sumber air, air larut lesap perlu dirawat. Kajian ini memberi tumpuan kepada prestasi tanah bencah buatan dan penapis batu kapur dalam merawat air larut lesap. Tanah bencah buatan dan penapis batu kapur muncul sebagai salah satu rawatan yang berpotensi untuk menyingkirkan bahan cemar dari air larut resap. Dalam kajian ini, saiz batu kapur dari 2mm hingga 14mm digunakan untuk penapis batu kapur dan tanah bencah buatan dibangunkan dengan menggunakan saiz batu daripada 5mm hingga 20mm, pasir dan ditanam dengan Typha latifolia (Cattails) untuk merawat air larut lesap tapak pelupusan. Air larut lesap telah diambil dari tapak pelupusan Jerangau-Jabor. Kadar aliran yang berbeza (3LPM dan 4LPM) telah dikaji untuk membandingkan kecekapan sistem rawatan dari segi penyingkiran bahan pencemar dalam air larut resap. Keputusan menunjukkan penyingkiran yang lebih baik berlaku pada kadar aliran 3LPM kerana masa sentuhan yang diambil adalah lebih lama daripada 4LPM. Larut resapan dianalisis untuk penyingkiran BOD, COD, TSS, pH, minyak dan gris, dan logam seperti plumbum (Pb), tembaga (Cu), besi (Fe), zink (Zn), mangan (Mn) dan nikel (Ni). Sistem rawatan dengan dua kadar aliran berbeza menunjukkan keberkesanan untuk menyingkir bahan cemar tetapi rawatan dengan kadar aliran 3LPM menunjukkan penyingkiran yang lebih banyak daripada 4LPM. Hanya TSS dan minyak dan gris berjaya mematuhi standard selepas rawatan dengan masing-masing 46mg / L dan 1.63mg / L. BOD, COD, NH3-N, Pb dan Mn menunjukkan penyingkiran di akhir rawatan tetapi masih tidak mematuhi standard. Logam seperti Cu, Fe, Zn dan Ni sudah mematuhi standard dan masih mempunyai penyingkiran selepas rawatan. PH air larut lesap sebelum dan selepas rawatan adalah memenuhi standard dari 6-9. Ini adalah kerana rawatan ini tidak memberi kesan kepada nilai pH dalam air sisa larut resapan.

TABLE OF CONTENT

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

APHA	American Public Health Association
AOP	Advanced Oxidation Process
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CW	Constructed wetland
Cu	Copper
Cd	Cadmium
CO_2	Carbon Dioxide
$CaCO^3$	Calcium Carbonate
DO	Dissolved Oxygen
Fe	Ferum/Iron
GAC	Granular Activated Carbon
HCL	Hydrochloric Acid
H_2SO_4	Sulphuric Acid
HRT	Hydraulic Retention Time
Mn	Manganese
MAP	Magnesium Ammonium Phosphate
Ni	Nickel
N	Nitrogen
NH_3	Ammonia
NF	Nanofiltration
O_3	Ozone
O & G	Oil and Grease
P	Phosphorus
Pb	Lead
PAC	Powdered Activated Carbon
RO	Reverse Osmosis
SBR	Sequencing Batch Reactor
TOC	Total Organic Carbon

TSS	Total Suspended Solid
TDS	Total Dissolved Oxygen
TKN	Total Kjehdal Nitrogen
VF	Vertical Flow
VSS	Vertical Subsurface
Zn	Zinc

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The rapid population growth, urbanization and economic level in community generate tremendous rate of solid waste in Malaysia without proper management. Solid waste disposal cause much pollution to our environment such as water pollution and odor disturbance. Solid wastes are generated from municipal, industrial, agricultural and urban activities. The present statistic in Malaysia state that, Peninsular Malaysia generate about 17,000 tones of solid waste per day (6.2 million tones/year) in 2002 and the per capita varies between 0.5 to 0.85 kg/day and it continue to increase to 1.7 kg/day in big cities (Johari *et al.*, 2012). What need to be concern whether the rate can achieved 31, 000 tones per day in 2020.

Most of developing countries face the increase of generation of solid waste and problem associate with waste disposal. Many countries including Malaysia use landfill method to dispose all the solid waste. In 2001 for instance, there were 155 dumping site in Malaysia. Nihla (2006) writes that nowadays there are 230 official dumping sites in Malaysia where the majority of it are crude landfills with only 10% providing leachate treatment ponds and gas ventilation systems and with most having no control mechanisms and supervision. In conjunction, the increasing of solid waste will increase the number of landfill for waste disposal.

However, the increasing number of landfill will increase the production of leachate. Solid waste contain organic matter that mostly is biodegradable and can be divide into anaerobic and aerobic microorganisms which are leading to the formation of gas and leachate. Leachate treatment nowadays becomes major issue because it has potential to degrade the environment. Leachate is generated when water passes through the waste at landfill. Leachate from landfill contains various compositions depending on the age of the landfill and type of waste that contain in that landfill. Leachate can contain both dissolved and suspended solid. Leachate also has specific meaning of a liquid that has dissolved or trapped in harmful substances which may enter to the environment.

1.2 Problem Statement

The term "leachate" refers to liquids that migrate from the waste carrying dissolved or suspended contaminants. The generation of leachate principally results from precipitation percolating through waste deposited in landfill and from moisture that exists in the waste when it is disposed. Leachate also generate from surface runoff, infiltration, and storage capacity. Leachate contains organic matters, pathogenic microorganisms and various potential harmful compounds. The composition in leachate varies greatly from site to site and can vary within a particular site. The composition of leachate is affected by age of landfill, types of waste, degree of composition that has taken place and physical modification of the waste.

If uncontrolled, landfill leachate can be source of pollutions such as ground water, surface water and odour. The unpleasant odour of leachate will disturb people's daily activities. The leachate can contaminate the surface water, ground water and surrounding soil especially during rainy season (Patnukao *et al.*, 2003). It will harm both environmental and people health who consumes water from those contaminated sources since the pollution of ground water and surface water will affect the water quality. Besides that, once groundwater is contaminated, it is very costly to be treating. Leachate also poses potential risks and hazards on the ecosystems such as disturbance on aquatic life.

Due to the increasing of leachate production, the requirements on leachate treatment also increase. Leachate treatment is essential to reduce mainly the organic and nitrogen content in the leachate. Leachate treatment should base on the specific situation respecting the relevant regulation and costs (Stegmann *et al.*, 2005). Renou *et al.*, 2005 has reported that the most common technologies used for leachate treatment can be classified into four main group which are leachate transfer (recycling, lagooning and combined treatment with domestic sewage), biodegradation (aerobic and anaerobic processes), chemical and physical methods (chemical oxidation, adsorption,chemical precipitation, coagulation/flocculation, sedimentation/flotation and air stripping) and membrane filtration(microfiltration, ultrafiltration, nanofiltration and reverse osmosis).

However, those treatments required highly skilled labour and high operation cost as well as high maintenance cost. A relevant leachate treatment method which is green technology and using natural resources should be implemented to reduce the treatment cost. Green technology leachate treatment offer low demand of resources, low energy consumption, low production of residues especially hazardous wastes, zero environmental impact and economical efficiency in operation. Therefore, in order to treat leachate as well as to keep the environment clean, Vertical Subsurface (VSS) Flow constructed wetland (CW) is to be proposed. The combination system offers an eco-technology which involves the natural resources for leachate treatment.

1.3 Objectives

i) To determine the raw leachate characteristics such BOD, COD, total suspended solid, pH, oil and grease (O&G) and heavy metals (Copper, Lead, Iron, Zinc, Manganese and Nickel).

ii) To identify the performance of limestone filter and VSS Flow wetland with the variation of flowrate in treating leachate.

1.4 Scope of Study

Actual raw leachate will be collected from Jerangau-Jabor Landfill, Kuantan, Pahang. The 20*l* of polyethylene container will be used for leachate collection. The leachate will be preserved at 4°C in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1992).

The limestone will be obtained from Kuari Tinjau Makmur Sdn. Bhd. located at Felda Bukit Sagu 4, Kuantan, Pahang. The limestone size used as a filter media was 2mm, 5mm, 10mm and 14mm which mixed using a ratio of 30:25:25:20, respectively. The limestone filter was made of acrylic material with dimensions of 1.5m length × 0.35m diameter.

Wetland size is 1m length x 0.5 m wide x 0.6 m depth. The wetland will be filled with 4 layers of medium which are 14-20mm aggregate (10%), 10-14mm aggregate (10%), 5-10mm aggregate (30%) and sand (50%). T*ypha latifolia* will be chosen as CW plant as it is widely available in Malaysia. The plant will be obtained from upper edges of estuaries or any damp land at Gebeng area.

1.5 Significant of Study

This system will provide new treatment of leachate wastewater using green technology and natural resources. This system offer low cost and less maintenance since it will use limestone from quarry and common reed which is easily get from damp. This system can improved oxygen transfer to the soil layer. Limestone found to be effective in removing heavy metals. CW offer many benefits to environment such as decreased energy consumption. It is also crucial for the future to promote effective leachate treatment process with easy way and low cost of investment.

1.6 Expected Outcome

i) The characteristics of raw leachate such as BOD, COD, total suspended solid pH, oil and grease and heavy metals (Copper, Lead, Iron, Zinc, Manganese and Nickel) should be determined.

ii) Limestone filter and VSS Flow wetland with the variation of flow rate should show the efficiency in treating leachate.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a summary of the important information of the source but the information is reorganized or reshuffling. It might give a new interpretation of old material or combine new with old interpretations. It discusses published information in a particular subject area and sometimes information in a particular subject area within a certain time period. Generally, the purpose of a review is to analyze a segment of critical points of knowledge through summary, classification and comparison of prior research study, review of literature and theoretical articles. More understanding about landfill leachate, limestone filter, constructed wetland and vertical subsurface flow will achieve through literature review.

2.2 Jabor Landfil

Jabor-Jerangau Landfill was first opened in 1993 for municipal solid waste for the Kuantan town, Pahang. The landfill has two separate cells located at northwest (Cell 1) and south (Cell 2) of the landfill. Cell 1 is a smaller landfill and its size is one third that of Cell 2. The landfill was not designed as a sanitary landfill when it was first used by Kuantan

Municipal Council in 1993. So, there was no proper landfill management carried out at site. There was also no leachate collection system installed and no proper venting or collection of landfill gases at the landfill site.

After the disposal, the municipal solid waste was covered with thin layer of soil for basic sanitary purpose only. Fire outbreaks were reported sometimes as there was no proper venting of landfill gases. There is a leachate treatment plant installed at the landfill for treatment of leachate prior to their discharge to the nearby drain. However, because of the increase of solid waste sent to the landfill and there is a lack of additional space to handle the load, the landfill is unable to have install full leachate collection system at part of the landfill. So, the landfill should upgrade to the sanitary landfill and have ventilation or collection system for gases.

2.3 Landfill Leachate

Landfill also known as a dumping site for the disposal of waste materials and known as the oldest form of waste treatment. The purpose of landfill is to stabilize the waste and to make hygienic through the use of natural pathways. Nowadays, modern landfills are designed with highly engineered facilities mainly to eliminate or minimize the adverse impact of the waste on the surrounding environment (Wiszniowski *et al.*, 2006). However, the generation of contaminated leachate remains an unavoidable consequence of the existing waste disposal practice and the future landfills. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site (Mor *et al.*, 2006).

Landfill leachate produced from this areas, is generated by decomposition of landfill organic waste and precipitations, which percolates through the waste material (Justin *et al.*, 2008). Landfill leachate are toxic and classified as problematic wastewater since it is represent a dangerous source of pollution for the environment due to it fertilizing and toxic effect (Kamarudzaman *et al.*, 2011). Landfill leachate is varying depending on type of waste, landfill operation and the age of the landfill. Landfill leachate mainly consists of heavy metals, organic matters with different biodegradation and inorganic matters such as ammonia and sulphate (Kamarudzaman et al., 2011). Proper collection, treatment and disposal of landfill leachate are important to offer a better environment and healthful condition. Table 2.1 below show the classification of landfill leachate based on age of the landfill.

Table 2.1: Classification of leachate parameters based on age of leachate

leachate type	Young	Intermediate	Stabilised
Landfill age yr	<5	5-10	>10
pH	<6.5	7	>7.5
COD g/l	>20	3-15	<2
BOD/COD	>0.3	0.1 - 0.3	<0.1
TOC/COD	0.3	-	0.4
Organic matter	70 - 90 % VFA	20 - 30 % VFA	HMW
Nitrogen	100 - 2000 mg/l TKN		
Metals g/l	2	<2	<2

2.3.1 Leachate Generation

Leachate is highly contaminated wastewater. It contains high concentration of organic matter measured as biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia and heavy metals. The main contributor to the generation of landfill leachate is rainfall on the top of the landfill. Some leachate is produced from groundwater entering the waste and some from waste decomposition where additional leachate volume produced. Other than that, it is also generate when additional surface water run onto waste from its surroundings. Generally, direct function of the amount of external water entering the landfill will contribute to the leachate formation (Visvanathan *et al.*, 2004). Figure 2.1 below show the movement of water in the landfill which leading to leachate generation.

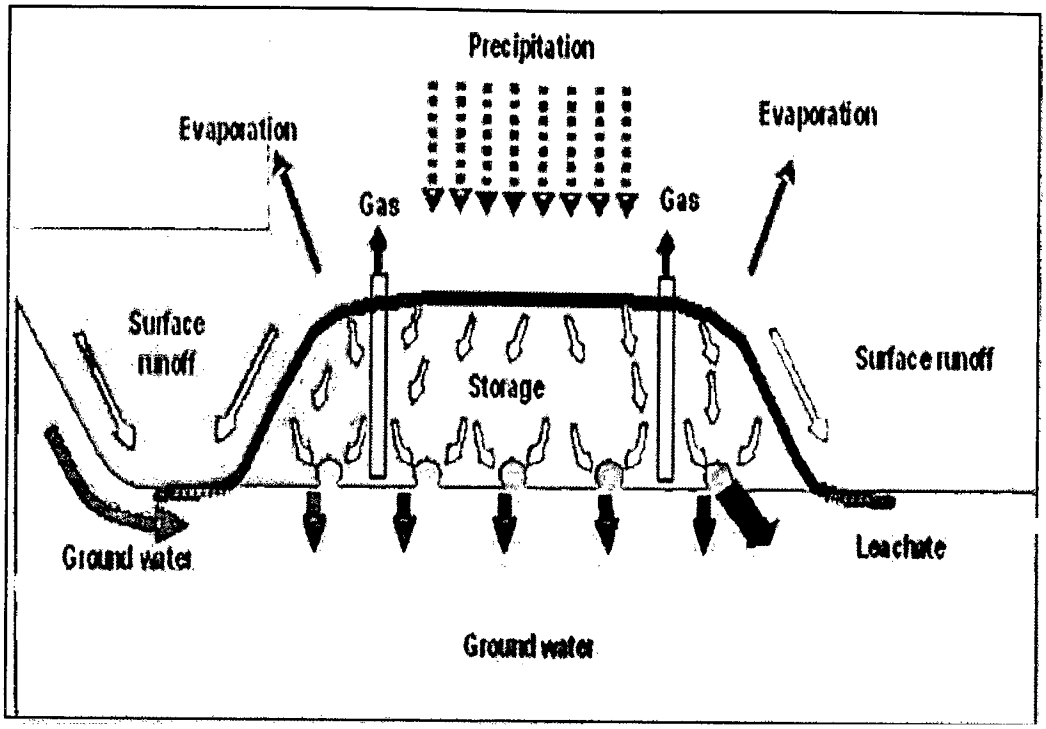

Figure 2.1: Movement of water in the landfill

The precipitation percolates through the waste and traps in dissolved and suspended components from the biodegrading waste, through physical and chemical process. The sources of percolating water are precipitation, irrigation and runoff. Leachate seeping into groundwater is produced by several potential sources such as gravity drainage of pore water and pond water, inflow of groundwater and infiltration. Thus, leachate generation and transport depend on many disposal sites specific and sediment factor (Schroeder *et al.*, 2003). The components, which contribute to leachate formation, follow a certain pattern (Visvanathan et al., 2004). The patterns are based on the physical processes taking place within the landfill that can be summarized as follows:

i) Precipitation on the landfill initiates runoff while some amount infiltrates into the surface.

ii) Some of the infiltration evaporates from the surface and/or transpires through vegetative cover while some part is retained as the soil moisture.

iii) The remainder of the infiltration percolates within eventually forming leachate at the base of the landfill.

iv) Percolation may be increase by infiltration of groundwater.

2.3.2 Leachate Properties

The variations of leachate quality are based on three aspects of landfill which are waste type, landfill environment and filling technique (Visvanathan *et al.*, 2004). The grade of decomposition with seasonal variance in the waste disposal affected the leachate composition. As example, the disposal of battery contributes to the high concentration of cadmium, Cd. Every landfill has different environment and physical process taking place like waste degradation phase, humidity, precipitation, temperature and others contribute to the overall variance in leachate quality and composition. Other contributor to the variation of leachate quality and composition is filling technique. The filling techniques are waste compaction, landfill cover and height of landfill layers. Leachate characteristics may be expected to evolve over time, increase from low values to peak values and then subsequently decreasing as the potential contaminants are either flushed out from the system, biodegraded or precipitated (Rowe *et al.*, 1995).

Generally, the leachate characteristics will change with time. In particular, the composition of landfill also varies greatly depending on the age of the landfill (Renou *et al.*, 2008). Young landfill containing large amount of biodegradable organic matter (Renou *et al.*, 2008). The early phase of landfill lifetime is acid phase which causes a decrease of pH in the leachate but high concentration or organic and inorganic ions (Cl^- , SO_4^-, Ca^{2+}). The next phase is methanogenic phase which characterized by a pH range from 6 to 8 and have relatively low BOD values and low ratios of BOD/COD (Stegmann *et al.*, 2005). Generally, the composition of leachate is categorized into two characteristics which are physical and chemical characteristics. Renou *et al.* (2008) also reported that some of the most relevant factors that affecting the quality of leachates are age of landfill, precipitation, seasonal weather variation, waste type and composition (depending on the standard of living of the surrounding population, structure of the tip).

The characteristics of landfill leachate usually represents by the basic parameters including BOD,COD, the ratio BOD/COD, pH, suspended solid (SS), ammonium nitrogen (NH_3-N), total Kjeldahl Nitrogen (TKN) and heavy metals(Renou et al., 2005). The physical appearance of leachate is when the leachates show the colour such as black colour, has temperature, turbidity and suspended solid. The smell of leachate normally is acidic and offensive because of reaction with hydrogen, nitrogen and sulfur. Chemical composition of leachate will vary greatly depending on the age of landfill and the events proceeding the time of sampling. Chemical composition of leachate includes dissolved oxygen, BOD, COD, pH, alkalinity and heavy metals. Table 2.2 below shows some of the physical and chemical parameters in leachate from some landfill in Norway, USA.

Table 2.2: Example of leachate analysis from some landfill in Norway

Parameter	Fill	Norway					
		Grønmo	Brånåsdalen	Yggeseth	Isi I	Isi II	Taranrød
COD	mg O_2/l	470	1080	9425	825	110	3455
BOD total	mg O_2/l	320	870	5250	590	50	2300
TOC	mg C/l	100	250	1700	180	30	800
Total N	mg N/l	182	254	250	155	16.6	156
NH_4-N	mg N/l	120	225	227	141	10.2	84
NO_3-N	mg N/l	0.04	0.01	0.04	0.02	0.79	0.68
Organic N [1)]	mg N/l	62	29	23	14	6	71
Total P	mg P/l	0.6	1.7	7.7	3.3	0.1	1.6
Suspended solids	mg/l	140	397	466	270	68	1079
Volatile suspen. solids	mg/l	85	98	182	229	11	602
Total solids	mg /	2960	2730	4160	3880	610	3160
Total volatile solids	mg/l	760	1005	2180	890	145	1670
pH		6.8	6.9	5.9	7.0	6.4	6.2
Alkalinity	meq/l	30	41	39	31	6.2	21.6
Spec. conductance	mS/cm	3310	3210	3380	3050	655	2370
Ca	mg Ca/l	188	198	400	173	99	218
Mg	mg Mg/l	66	96	54	58	13	40
Na	mg Na/l	462	229	206	312	34.8	197
K	mg K/l	200	172	187	219	21.3	214
Chloride	mg Cl/l	680	280	370	590	68	340