LEACHATE TRE D SUBSURFACE FLOW CONSTUCTED WETLAND

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ABSTRACT

Leachate is a complex and highly polluted wastewater which produced from solid waste in landfill. Leachate has high content of heavy metals, chlorides, organic nitrogen, phosphate, sulphate and high in organic matters and inorganic ion concentrations. Due to the concentration of leachate that highly polluted, the treatment process is very complicated, expensive and generally requires multiple processes. Therefore, the purpose of this study was to assess the impact of the combination of limestone and subsurface flow constructed wetland in treating a landfill leachate. Size of limestone that has been used in the limestone filter was 5mm to 12mm while type of plant used in the subsurface flow constructed wetland was common cattail *(Typha Latifolia)*. Sample of raw leachate was collected from Jerangau-Jabor Landfill, Kuantan. There are several parameters considered in this study which are BOD_5, COD, TSS, ammoniacal nitrogen and heavy metals (Fe, Pb, Cu, Mn, Zn, Cr). In addition, the treatment processes conducted in two modes which are hourly treatment mode and daily treatment mode. Based on the analysis, the combination of limestone and subsurface flow constructed wetland are effective in treating leachate. The percentage removal; BOD_5 56.4%, COD 97.7%, TSS 99.0%, ammoniacal nitrogen 99.2% while for Fe, Pb, Cu, Mn, Zn and Cr is 100%. Thus, these show that the treatment system is very efficient in removing contaminants in the landfill leachate.

ABSTRAK

Cecair larut resap adalah air sisa yang kompleks dan sangat tercemar yang terhasil daripada sisa pepejal di tapak pelupusan sampah. Cecair larut resap mempunyai kandungan logam berat, klorida, nitrogen organik, fosfat, sulfat dan kepekatan yang tinggi dalam bahan organik serta bahan bukan organik. Disebabkan oleh kepekatan cecair larut resap yang sangat tercemar maka proses rawatan adalah sangat rumit, mahal dan secara amnya memerlukan banyak proses. Oleh itu, tujuan kajian ini adalah untuk menilai kesan kombinasi batu kapur dan tanah lembap aliran subpermukaan buatan dalam merawat cecair larut resap. Saiz batu kapur yang digunakan dalam penapis batu kapur adalah 5mm sehingga 12mm manakala jenis tumbuhan yang digunakan dalam tanah lembap aliran subpermukaan buatan ialah pokok banat biasa *(Typha Latifolia)*. Sampel cecair larut resap mentah diambil dari Tapak Pelupusan Sampah Jerangau-Jabor, Kuantan. Terdapat beberapa parameter yang dipertimbangkan dalam kajian ini iaitu BOD_5, COD, TSS, nitrogen ammoniacal dan logam berat (Fe, Pb, Cu, Mn, Zn, Cr). Di samping itu, proses rawatan dijalankan dalam dua kaedah iaitu kaedah rawatan mengikut jam dan kaedah rawatan mengikut hari. Berdasarkan analisis, kombinasi batu kapur dan tanah lembap aliran subpermukaan buatan berkesan dalam merawat cecair larut resap. Peratusan penyingkiran; BOD5 56.4%, 97.7% COD, TSS 99.0%, nitrogen ammoniacal 99.2% manakala bagi Fe, Pb, Cu, Mn, Zn dan Cr adalah 100%. Oleh itu, ini menunjukkan bahawa sistem rawatan ini sangat berkesan dalam merawat bahan tercemar dalam cecair larut resap.

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LIST OF SYMBOLS AND ABBREVIATIONS

MSW	-	Municipal Solid Waste
BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
SSF	-	Subsurface Flow Wetland
NO_3	-	Nitrates
NO_2	-	Nitrites
Zn	-	Zinc
Cu	-	Copper
Pb	-	Lead
Mg	-	Magnesium
Fe	-	Iron
TSS	-	Total Suspended Solid
MPK	-	Majlis Perbandaran Kuantan
UMP	-	Universiti Malaysia Pahang
$CaCO_3$	-	Calcium Carbonate
XRF	-	X-ray Fluorescence
EDX	-	Energy Dispersive X-ray
AMD	-	Acidic Mine Drainage
OLD	-	Oxic Limestone Drainage
O_2	-	Oxygen
CO_2	-	Carbon Dioxide
FWS	-	Free Water Surface
VSB	-	Vegetated Submerged Bed
N	-	Nitrogen

NH_3	-	Ammoniacal Nitrogen
NO_2^-	-	Oxidised Oxygen
NH_3	-	Ammonia
AAS	-	Atomic Absorption Spectroscopy

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CHAPTER 1

INTRODUCTION

1.1 Preamble

It has been observed that the solid waste generation in Malaysia has increased concurrently with the development of the country. Waste generation is a global issue where waste is generated by daily human activities in all economic sectors and it is generally an unavoidable by-product. Solid waste generation in Malaysia has increased more than 91% over the past 10 years, due, in particular, to the rapid development of urban areas (Agamuthu and Fauziah, 2006). Currently Malaysia produced approximately 30,000 metric tons of waste everyday or 1.3 kg/person/day (Agamuthu, 2009). Each year, there are about 8 million tonnes of solid waste being generated which accounts to each person generates about 1 kg of solid waste per day (LUMES, 2000 - 2001).

A widely used method for treating municipal solid waste (MSW) is disposal landfill. Up to 95% of the MSW collected worldwide is disposed of in landfills (Fadel, 1997). In Malaysia, there are about 230 landfills recognized officially and about three times of illegal dumps (Chenayah, 2001). In a landfill, solid waste undergoes physico-chemical and biological changes. Degradation of the organic fraction of the wastes in combination with percolating rainwater produces a highly contaminated liquid called "leachate" (Kurniawan, 2006), which often is the most important point source of organic ground water contamination.

Leachate from municipal, chemical or sanitary landfills are among the most contaminated polluted waters known (Oppenlander, 2003). Over 200 individual organic compounds have been identified in leachate, including cyclic and bicyclic compounds and aromatic hydrocarbons, at concentrations from < 1 µg/l to several hundred µg/l (Paxeus, 2000). The type of leachate depends on factors such as age and type of landfill, pH, and biological oxygen demand (BOD)/chemical oxygen demand (COD) ratio. Leachate may be classified as young (or raw), and stabilized (mature). To remove or reduce refractory pollutants in landfill leachate, several types of treatment have been adopted.

Characterization and treatment of landfill leachate has only taken place within the last 40 years. The main applicable methods are physical, chemical and biological. Since it is difficult to obtain satisfactory effluent quality by using any one of those methods alone, a combination of physical, chemical and biological methods are employed for efficacious treatment of landfill leachate (Kargi and Pamukoglu, 2004). In the physical treatment technologies used for landfill leachate treatment, air-stripping, absorption and membrane filtration are the major ones. Coagulation-flocculation, chemical precipitation and oxidation are the common chemical leachate treatment methods. Meanwhile, biological treatment technologies consist of aerobic, anoxic and anaerobic processes, which are widely employed for biodegradable contaminants removal from landfill leachate.

1.2 Problem Statement

Leachate pollution is one of the big issues in environmental conservation. Leachate is produced when water percolates through the waste in landfill, carrying several types of contaminants, such as heavy metals, ammoniacal nitrogen, BOD, COD, colour and suspended solids. Leachate generation continues in a cyclic pattern in operating and closed landfill sites where precipitation or groundwater may enter the landfill cell, and will correspond directly to the net infiltration rates, modified by runoff and evapotranspiration patterns (Oweis and Khera, 1998).

Waste composition, site hydrology, landfill type, landfill operation and its age are the main factors affecting leachate quality (Muzaini, 1995). Generally high concentrations of heavy metals, BOD, suspended solids, COD and ammoniacal nitrogen are present in leachate (Jokela, 2002). Numerous cases of leachate-contaminated ground and surface water have been documented (Chong, 1999).

Contamination of water bodies and natural streams by leachate causes serious problems to humans, animals and plants. Colour can cause hazards to the environment due to the presence of a large number of contaminants such as acids, bases, inorganic contaminants and toxic organic residues (Isa, 2006). High concentration of heavy metals such as iron, zinc, lead, copper, cadmium and chromium can cause serious water pollution and threaten the environment (Aziz, 2004). Ammoniacal nitrogen decreases the dissolved oxygen required for aquatic organisms. So to prevent these problems it is a necessity to remove these contaminants from leachate (Celik, 2001).

Leachate treatment is very complicated, expensive and generally requires multiple processes (Ozturk and Bektas, 2004). Many factors need to be considered when designing a leachate treatment system. These include leachate flows, landfill age and leachate characteristics. The leachate requires treatment during the active years of the landfill and for many additional years after landfill is closed. Leachate treatment options include, recirculation, biological, chemical, physical and their combinations. A very wide variety of materials have been studied as adsorbents. Some of these materials include activated carbon, zeolite, organic polymers, palm ash, sand and activated carbon, commercial activated carbon, clay mineral, sepiolite, Indian rosewood, sulphur and limestone, chitosan, activated carbon prepared from agricultural waste and fungus Aspergillus's niger.

Usually, a combination of two physical-chemical treatment or physico-chemical and biological treatment is required for optimum treatment of stabilized leachate (Tatsi, 2003). Thus, this research will focus on leachate treatment using combination of limestone and wetland in one system. Type of wetland that will be use in this research is subsurface flow wetland (SSF).

1.3 Research Objective

There are three objectives for this research based on the problem statement. The objectives are as below:

a) To investigate the suitability of combination limestone and SSF wetland as leachate treatment method. The parameter to be removed are biological oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, total suspended solid (TSS) and heavy metals which are Zinc (Zn), Copper (Cu), Lead (Pb), Manganese (Mn), Iron (Fe) and Chromium (Cr).
b) To study the optimum contact time in the treatment process.
c) To determine the percentage removal of contaminant in leachate by using limestone and SSF wetland.

1.4 Scope of Research

This research mostly focuses on leachate. The leachate samples will be obtained from Jerangau-Jabor Landfill in Kuantan District. Furthermore, the limestone will be obtained from Bukit Sagu Quarry located at Bukit Sagu 4, Kuantan, Pahang. Plant selection for SSF wetland is cattail (*Typha latifolia)* that will be obtained from Gebeng Industrial area. Leachate characteristics are identifying in terms of physical and chemical characteristics. A series of experiments will be conduct to determine the chemical characteristics based on the parameter of BOD, COD, ammoniacal nitrogen, TSS and heavy metals (Zn, Cu, Pb, Mn, Fe, Cr). Thus, this research will focus on leachate treatment using combination of limestone and SSF wetland in one system.

1.5 Significant of Research

The research on leachate treatment by using limestone and SSF wetland are important in order to improve the efficiency and provide variation methods in leachate treatment. Leachate treatment by using limestone and SSF wetland will become other alternative treatment which could reduce the overall cost of conventional leachate treatment. At the end of this study, one method of low cost leachate treatment will be proposed. This treatment can be used and practice widely by municipal authorities in order to control and reduce pollution posed by leachate from sanitary landfill and especially from transfer station.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the variables involved in the research will be defined based on several literature reviews. The variables are; leachate: composition and leachate treatment; limestone: properties, mechanism of removal and usage in waste water treatment, and constructed wetland: types, mechanism of removal and type of plant used in subsurface flow wetland (SSF). Therefore, all the variables regarding leachate, limestone and constructed wetland will be described. In the matter of leachate, the composition of leachate will be defined in detail and the existing treatment that able to treat leachate will be explained. Besides that, this chapter will also elaborate about the properties of limestone, mechanism of removing contaminant in leachate by limestone and limestone usage in waste water treatment. Last but not least, types of constructed wetland, mechanism of removing pollutant in the leachate and types of plant used in SSF will be discussed.

2.2 Leachate

The growing production of domestic and industrial wastes in the world causes serious disposal problems. Solid waste landfill site are often defined as hazardous and heavily polluted wastewater with considerable variations in both composition and volumetric flow (Lopez, 2004). One of the major pollution problems caused by the landfill is landfill leachate, which is generated as a consequence of precipitation, surface run-off, and infiltration or intrusion of groundwater percolating through a landfill, biochemical process in waste's cells and inherent water content of wastes themselves (Amalendu, 1990). **Figure 2.1** shows the schematic diagram for leachate production.

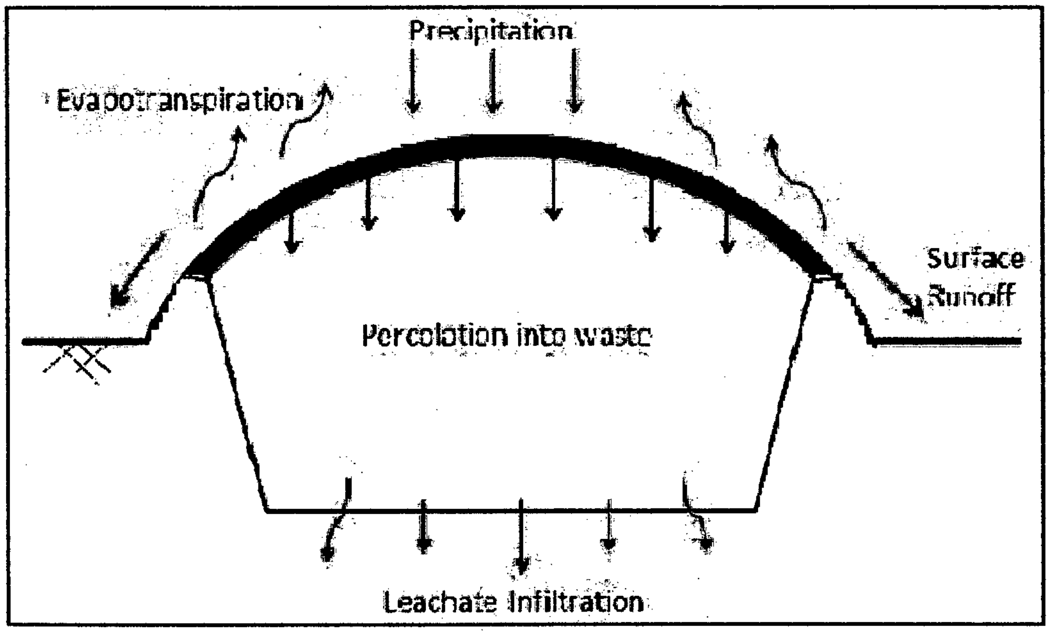

Figure 2.1: Schematic diagram for landfill leachate generation

After a landfill site is closed, a landfill will continue to produce contaminated leachate and this process could last 30 to 50 years. The discharge of landfill leachate can lead to serious environmental problems, since the leachate contains a large amount of organic matter (both biodegradable and non-degradable carbon), ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts (Tatsi, 2003). Although some of the pollutants can be degraded by microorganisms, the limitation of common biological process has made it difficult to meet the correlative discharge standard (Ugyur, 2004). Since all sanitary landfills generate leachate and leachate may migrate from the wastes and contaminate the surface water and groundwater, collection and treatment of leachate is necessary part of the overall facility (Wilson, 1981).

2.2.1 Leachate Composition

Leachate has high content of iron, chlorides, organic nitrogen, phosphate, sulphate and high in organic matters and inorganic ion concentrations (Ugyur, 2004). Factors that affect the leachate quality vary in many elements such as the landfill age, degree of precipitation, seasonal weather variation, waste types and composition (depending on lifestyle of the surrounding populations) (Renou, 2007). Composition and solubility of the waste constituents become two primary factors that affect the leachate quality. Changing in waste composition due to biodegradation and weathering will then change the quality of leachate with time. The characteristics of the leachate are influenced by the waste material deposited in the site. For example, inert wastes will produce a leachate with concentrations of components, whereas a hazardous waste leachate tends to have a wide range of components with highly variable concentrations. The decomposition rate of the waste also depends on aspects such as pH, temperature, aerobic or anaerobic conditions and the associated types of microorganism. Associated with leachate is a malodorous smell, due mainly to the presence of organic acids (Williams, 1994). Thus, the typical data on leachate composition are illustrates in **Table 2.1**.

Table 2.1: Data on composition of landfills leachate (Tchobanoglous S. C., 1979)

Constituent*	**Range**	**Typical**
BOD_5 (5 day Biochemical Oxygen Demand)	2000-30,000	10,000
TOC (Total Organic Carbon)	1500-20,000	6000
COD (Chemical Oxygen Demand)	3000-45,000	18,000
Total Suspended Solids	200-1000	500
Organic Nitrogen	10-600	200
Ammonia Nitrogen	10-800	200
Nitrate	5-40	25
Total Phosphorus	1-70	30
Ortho Phosphorus	1-50	20
Alkalinity as $CaCO_3$	1000-10,000	3000
pH	5.3-8.05	6
Total hardness as $CaCO_3$	300-10,000	3000
Calcium	200-3000	1000
Magnesium	50-1500	250
Potassium	200-2000	300
Sodium	200-2000	500
Chloride	100-3000	500
Sulfate	100-1500	300
Total Iron	50-600	60

*All units in miligrams per liter except pH

2.2.2 Leachate Treatment

Leachate treatment is very complicated, expensive and generally requires multiple processes (Ozturk, 2003). Many factors need to be considered when designing a leachate treatment system. These include leachate flows, landfill age and leachate characteristics. The leachate requires treatment during the active years of the landfill and for many additional years after landfill is closed. Technologies used for leachate treatment can be classified into four major groups: (a) leachate transfer: recycling, lagooning and combined treatment with domestic sewage, (b) biodegradation: aerobic and anaerobic processes, (c) chemical and physical methods: chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, sedimentation/flotation and air stripping and (d) membrane filtration: microfiltration, ultrafiltration, nanofiltration and reverse osmosis (Renou, 2007). **Table 2.2** indicates operations used for the treatment of leachate.

Table 2.2: Representative biological, chemical and physical processes used for the treatment of leachate (Tchobanoglous S. L., 1981)

Treatment Process	Application	Comments
A. Biological Processes		
Activated sludge	Removal of organics	Defoaming additives may be necessary; separate clarifier needed
Sequencing batch reactors	Removal of organics	Similar to activated sludge, but no separate clarifier needed; only applicable to relatively low flow rates
Aerated stabilization basins	Removal of organics	Requires large land area