CHAPTER ONE

INTRODUCTION

1.1 Background

One of the major consequences of human activities is the generation of waste, particularly solid waste. The wastes can be classified as domestic waste, garden waste, food waste, light industrial waste, street cleaning waste and animal farm waste. The components of the waste are heterogeneous, which are very complex in nature (Agamuthu, 1997). As a result, the management of municipal solid waste (MSW) is very complicated. Therefore, the waste must be managed and disposed properly in accordance with the best principals of MSW management practice in order to avoid nuisance to general public and environmental degradation.

When looking back to history, western countries realised the importance of managing MSW, then they started to manage their waste effectively by introducing Integrated Solid Waste Management approach and proper landfill. A lot of efforts were put to improve MSW management as the effects of modernisation and changes in life style have a direct implication on waste quality and quantity. Asian countries should be more cautious in their approach in waste management and they should not repeat the mistakes of the developed nations (Agamuthu, 1997). The mistakes they have made were dumping the waste in low lying area with permeable soil strata underneath so that the water intensity could dilute the infiltrated downward leachate. In actual fact is the toxic leachate would contaminate groundwater and surface water bodies.

Solid waste management is concerned with generation, on-site storage, collection, transfer, transportation, process and recovery, and the ultimate disposal to landfill sites (McBean, 1995). Integrated Solid Waste Management Approach, which is built-up based on the principle of MSW management of Material Treatment 3R's (Reduction, Reuse and Recycle), Biological Treatment (composting) and Thermal Treatment (incinerating) are the waste processing efforts. From these processing efforts the quantity of wastes send to landfill is greatly reduced, nevertheless, the waste residue and ash still need to be landfilled (Tchobanoglous *et al.,* 1993). Therefore, landfill has become an ultimate place for solid waste disposal, and that every effort must be taken care of to ensure that this facility will not cause any environmental damage and degradation. Landfill should be provided with final-cover system to minimise leachate generation.

The MSW management may be defined as a discipline associated with the control of waste generation and minimisation, storage, collection, transfer, transport, processing and finally disposing of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics and environmental considerations. In this scope solid waste management includes all administrative, financial, legal, planning and engineering functions. It involves an interdisciplinary approach (Agamuthu, 1997).

Generally, management of MSW is a demanding and challenging task. It has created an opportunity to business in landfill industry. The corporate organisation that runs business and operates landfill industry is responsible to ensure that the landfill does not cause any environmental damages for both short and long term durations (Daniel and Estornell, 1990). An engineered landfill is a controlled method of waste disposal. The site of the landfill must be geologically, hydrologically, and environmentally suitable so that unwanted and unforeseen impact can be avoided. On top of that, constructions of landfill facility need proper planning, site investigation, where it incurred capital investment and need to be maintained.

In early history, the disposal sites were just open dump, and latter upgraded to control tipping where waste was covered by soil and compacted daily. The latest technology is sanitary landfill which has adopted engineering principles in waste containment system in order to isolate waste from the environment. The waste containment system is to protect environmental degradation by restricting infiltration and controlling gas emission (Robinson *et al.,* 1992). Although waste were disposed into landfills, these landfills continuously posed short and long term hazards and risk to human being and environment due to leachate generation and migration as well as gas emission. This leachate migration caused groundwater pollution and gas emission caused air pollution. These unwanted impacts happened because there is no engineered waste containment system to restrict leachate from contaminating surface and groundwater resources (McBean, 1995).

Furthermore, the uncontrolled landfill leachate and methane gas produced could contaminate water resources and atmosphere. The production of leachate is mainly due to infiltration of precipitation and groundwater intrusion. According to Agamuthu (2004) the Malaysian MSW landfill produced leachate at the rate of 150-200 lit/tonne where the volumes of local MSW is 100-150 m^3/tonne. In addition, the production of methane gas from MSW is estimated about 1.3-7.5 lit/kg/year. Therefore to minimise undesired environmental impacts and risk to an insignificant level, the waste disposal facilities need to be properly lined with engineered final-cover and bottom liner systems (Christine *et al.,* 1994).

Landfill leachate and gas would contaminate water resources, land and atmosphere. Hence, toxic gas and liquid leachate would be hazardous to human health besides floral and fauna life (Mohamed *et al.,* 1995).

In view of this, a research was conducted to compute quantity of leachate generated in a landfill after various models of landfill final-cover systems were simulated using a computer program called Visual HELP (VHELP). The effect of the cover system on water balance components was also studied. The design of final-cover systems of landfill is an important issue because it determines the performance of landfill. Mohamed Kamil (1999) reported that, almost 95 % of Malaysian landfills were not equipped with any engineering waste containment system, (e.g. compacted clay liner, geomembrane or geosynthetic clay liners). Thus, nothing restricts precipitation, from infiltrating into the landfill to form leachate and eventually contaminates water resources and surrounding land. If those landfills were covered with an effective landfill final-cover system, the water resources could have been protected from contamination of toxic leachate.

Having realised that, the effectiveness of landfill cover systems should be studied and investigated in depth so that waste disposal facility will not pose major pollution to groundwater system, land, and air. In this study, landfill final-cover performance was assessed based on water balance components (WBCs). Thus, the quantity of leachate generated reflects the performance of landfill besides other quantity of WBCs (Mohd Ridhuan, 1995). Final-cover consisted of many profiles of different layers were also tested to determine their respective performance.

Generally, every computer program needs input data to execute analysis. In this simulation, VHELP needs daily input such as precipitation, solar radiation and mean temperature. Soil parameters were obtained from documented file data in the program. This study involves modeling of landfill where profiles of final-cover systems were simulated. The types of barrier cover systems designed are explained in Chapter Three. The amount of leachate generated depends both on the waste moisture content and precipitation that infiltrated into the landfill, as well as, groundwater intrusion. The final-cover system which normally consist of topsoil, drainage layer and hydraulic barrier layer would minimise the infiltration of precipitation that produced leachate (Qian *et al.,* 2002).

1.2 Scope of Study

In this study the final-cover system is simulated. Landfill final-cover profiles were modeled and studied using VHELP program to determine their performances. Figure 1.1 illustrates a typical final-cover profile model for computation of WBCs which includes leachate generated in the landfill. Weather data, soil data, and design data for the final-cover were obtained from the data files of the program for the purpose of water balance analyses.

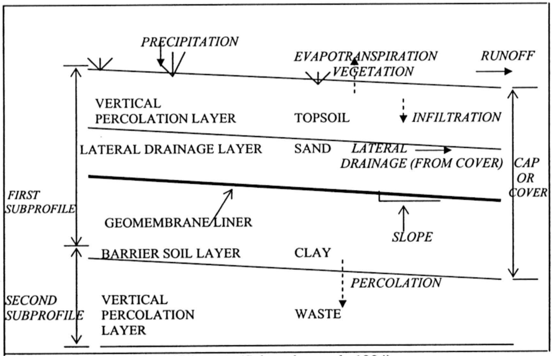

Figure 1.1 Profile of landfill cover (Schroeder *et al.,* 1994)

The MSW landfill is constructed with many components as shown in Figure 1.2. It includes final-cover system, bottom liner system, gas collection system, leachate collection and removal system, groundwater and gas monitoring system and storm water management system (Legrand, 1969).

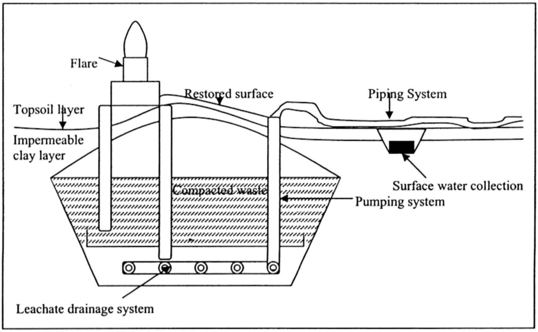

Figure 1.2 Typical sanitary landfill (David E. Daniel, 1993).

Parameters such as thickness, surface slope, surface area, slope length and the level of vegetation on the landfill sites were tested and entered into the input program. These parameters included saturated hydraulic conductivity values of topsoil materials, drainage material and barrier soil material obtained from documented data file of the program. Besides these data, climatic data were obtained from Department of Metereology, Petaling Jaya for duration of 2 years (2001-2002).

The daily climatic data which includes precipitation, temperature and heat radiation, wind speed, relative humidity and cloud cover are entered as input data required by the program. With the parameters input into the program, the landfill final-cover profiles can be studied using the method of water balance analysis. The landfill performance can be measured based on leachate generation and other WBCs. All quantity of WBCs is measure in term of depth with unit millimeter because it was assumed that the surface area of the landfill cover is constant throughout study.

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The word 'evaluation' means an assessment to the landfill final-cover which comprised of multi layers. 'Performance' in this context will reflect the effectiveness or efficiency of each layer that make up the landfill final-cover system. The effectiveness of the final-cover systems will be assessed from the quantity of WBC and leachate generated in the landfill. The cover system is considered good and of acceptable design when the amount of leachate produced is the minimum at a reasonable cost. The basic idea used in this water balance analysis is based on the principle of mass conservation (Qian, 2002).

The principle of water balance analysis is explained briefly below and is shown in Figure 1.3. Precipitation that fell on the cover of the landfill can either become surface runoff or infiltrated into the topsoil and, thus leachate generated in a landfill during active and post closure conditions.

The simplest form of mass conservation principle equation can be represented as:

$$q_{in} = q_{out}$$

Where; q_{in} = precipitation and groundwater intrusion

q_{out} = evapotranspiration, surface runoff, and sub-surface lateral drainage.

In addition, the principle of hydrologic budget for small catchments (less than 2.5km^2) is adopted in this water balance method. The amount of surface-runoff, infiltration, lateral drainage, evaporation and transpiration or evapotranspiration and leachate generated were obtained and estimation was made from precipitation that fell on the surface of the landfill final-cover.

The landfills have to be covered, regardless of the potential for water intrusion. The purpose is also to prevent the production of leachate that can contaminate groundwater. The effect of keeping water out of the landfill is to maintain dry conditions and hinder the process of biodegradation, making most landfills merely storage facilities.

An equation that relates the hydrological component is;

$$L_p = P - S_{rm} - E_{va} - Q_L$$

where L_p = leachate produced

P = Precipitation

S_{rm} = surface runoff

E_{va} = Evapotranspiration, and

Q_L = Lateral drainage

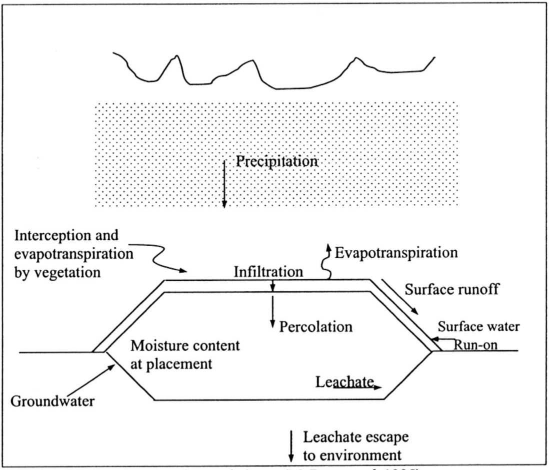

Figure 1.3 Components of water balance (McBean *et al.*, 1995)

The Hydrologic Evaluation of Landfill Performance (HELP) model is an alternative to the above water balance analysis model (Schroeder *et.al.,* 1984). The VHELP model is based on the same hydrological principles as the water balance method but utilises a more detailed sequence of calculations. The model also has the ability to examine water fluxes throughout the complete vertical profile of a landfill, such as that depicted in Figure 1.1. The program was developed to conduct water balance analyses of landfills, cover systems, and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety landfill designs. The program performs water balance analysis for a minimum period of one year. The model can simulate water routing or storage in up to twenty layers of soil, waste, geosynthetics or other materials for a period of 1 to 100 years. As many as five liners systems, either barrier soil, geomembrane or composite liners, can be used. The model has limits on the order that layers can be arranged in the landfill profile. Each layer must be described as being one of four operational types: vertical percolation, lateral drainage, barrier soil liner or geomembrane liner.

All simulations start on January 1 and end on December 31. The condition of the landfill, soil properties, thicknesses, geomembrane hole density, maximum level of vegetation are assumed to be constant throughout the simulation period.

From the data, statistical analyses were carried out namely; One Way ANOVA and Linear Correlation. The statistical analysis used software called SPSS v.11. The aim of the statistical analyses were to determine the significance level of the cover models tested and correlations between variables.

1.3 Research Objectives

The aim of this study is to investigate the landfill final-cover systems performance. It measured the effectiveness and efficiency of the covers. The performance of the final-cover will be evaluated based on WBCs. The WBCs comprised of surface runoff, evapotranspiration, lateral drainage, and leachate generated.

The analyses were carried out using computer programme called VHELP. The amount of leachate generated has become the main criteria in determining the efficiency of landfill cover systems besides the other quantity of WBCs collected in each layer of the cover components. The quantity of WBCs and leachate generated were measured in term of depth with unit millimeter (mm).

It was assumed that the surface area of the landfill to be constant throughout this study. The quantity of WBCs which includes leachate generated determined the effectiveness of the final-cover systems at an economical cost.

The objectives of the research are summarised as follows:

1. To investigate the effectiveness and efficiency of five models of final-cover systems.
2. To determine the quantity of water balance components in each layer of the cover, including the quantity of leachate generated, and
3. To evaluate the economics of the proposed landfill cover systems.