1.0 INTRODUCTION

1.1 SOLID WASTE MANAGEMENT

Solid waste management involves the overall management of activities related to waste generation, storage, collection, transfer and transportation, processing and disposal or reuse and recycling. Solid wastes comprise countless different materials ranging from dust, food wastes, packaging materials in the form of paper, metals, plastic or glass, discarded clothing and furnishing, garden waste, construction waste, etc.

The generation of solid wastes resulting from human activities varies with the types of dwellings and socio-economic groups. The type produced depends upon various factors, such as the standard of living, occupation and habits of the contributing population, which in turn are affected by climatic and dietary habits. The characteristics, both physical and chemical, also vary within the same geographic location in different seasons. Knowledge about the characteristics of refuse is essential in order to decide the type of disposal method to be adopted and the desired frequency of the collection system.

Although man has produced solid wastes ever since the beginning of civilization, in recent years the problem has been aggravated by the rapid industrialization of many developing countries. As the industries become more and more sophisticated, so are the solid wastes produced which require at times specialized techniques to treat and dispose of.
Landfilling is one of the primary technologies used to dispose off solid waste. It is defined as a method of refuse disposal where the waste is systematically covered by layers of earth, and this significantly limit the volume of the waste. Buried waste degrades as a result of natural oxidation and microbial action. Landfilling stands alone as the only waste disposal method that can deal with all materials in the solid waste stream. It is also considered the simplest and in many areas, the cheapest of the disposal methods (Agamuthu, 2001).

Sanitary landfill or controlled tipping is defined as a method of disposing refuse on land without creating nuisance or hazard to public health or safety by utilizing the principles of engineering to confine the refuse to the smallest practical area and to reduce it to the smallest practical volume and cover it with a layer of earth at the conclusion of each day’s operation or at such more frequent intervals as may be necessary (Mantel, 1975). Sanitary landfill consists of depositing the wastes in 1-2 m thick layers in low-lying lands or excavations, compacting it to the smallest practical volume and covering it with earth to a thickness of 15-25 cm daily. Lining materials at the bottom of the landfill prevents toxic substances and heavy metals in the leachate from leaking into the groundwater.

In Malaysia there are about 230 landfills recognized officially and an estimated three times more illegal dumps (Agamuthu, 2001). Almost all the landfills do not come under the sanitary landfill classification because either there are no facilities to collect and/or treat the leachate or there is no infrastructure to exploit the landfill gas (Agamuthu, 2001). Globally there are 453 facilities for landfill gas usage
and the estimated amount of gas from domestic solid waste is 730 billion m$^3$
(Gendebien et al., 1991)

Sanitary landfill is the most widely distributed system for the disposal of municipal wastes and others, such as sewage sludge and ash. From an environment point of view, one of the main problems of landfill operation is the treatment and long-term control of leachate. Leachate amount depends on several factors linked to climatic, meteorological and hydrogeological characteristics of the site, and to design and management of the landfill. By excluding any contact with surface and ground-waters, leachate is formed by rain infiltration through the waste mass, while contribution of biochemical reaction is negligible. Leachate composition is very different as far as organic and inorganic pollutant concentrations are concerned. Pollutants in a leachate can be grouped into carbonaceous and nitrogenous substrates, biorefractory organic compounds and heavy metals. The polluting load of each of the above components is not constant but depends on the development of biochemical processes in the landfill.

Leachate treatment can be challenging because of low biodegradable organic strength, irregular production rates and substrate composition. Because of the nature of leachate, physical or chemical treatment processes are the most likely option (Debra, 1998). It is generally accepted that biological treatment provides the most economical solution. Of the various biological methods available, waste stabilization ponds defined as pond systems designed for biological waste treatment, are the simplest and cheapest for implementation.
Generally, where onsite treatment and discharge are selected, several unit processes are required to address the range of contaminants present. For example, leachate treatment processes at the Air Hitam Sanitary Landfill in Selangor, utilizes aerobic processes (aeration pond) before discharge into the river. An alternative aerobic system is the algal ponding system consisting of ponds where algal activities contribute wholly or in combination with other microorganisms, to the treatment and purification of wastewater. Examples of algal ponding systems are the Oxidation Pond, High Rate Algal Pond (HRAP) and Advanced Integrated Pond System (AIPS) (Phang, 1995).

The High Rate Algal Pond (HRAP) first introduced by Oswald, evolved from meandering channels mixed by propellers to a wide range of configuration to optimize and improve the dual function of biomass generation and waste treatment (Phang, 1995). To attain this, the pond is usually very shallow, not exceeding 50 cm in depth, to maximize algal growth. The typical design is a single-loop raceway mixed by paddle wheels. The effluent after primary treatment enters the HRAP where algal biomass production is optimized. Here the remaining soluble compounds are recovered in the form of algal cells. Selection of algal species for culture will determine the quality of biomass produced. The use of microalgae for nutrient recovery with biomass production from effluent has been shown to be a good alternative water treatment system. Algae act as an ideal waste remover in nature. It acts not only on agro-industrial but animal waste as well, by converting the nutrients in the waste to food material. Algae can also play an important role in the gradual degradation and metabolism of pesticides and herbicides, transforming them into less harmful forms. Algal biomass yield in a HRAP system
may reach 36 g.m⁻².day⁻¹. A combination of coagulation and dissolved air flotation may be used for harvesting the algal biomass. The biomass may be processed for use as animal feed, extraction of useful biochemicals like pigments (carotenoid, phycocyanins or even fatty acids), fertilizer, etc.

The first HRAP system in Malaysia was tested by the Rubber Research Institute of Malaysia for secondary treatment of rubber effluent. A hydraulic retention time of six days was found sufficient to treat the rubber effluent. In Singapore, the HRAP was successfully tested for piggery waste treatment (Phang, 1990). The HRAP system was investigated for treatment of rubber effluent from latex concentrate factory and generation of Chlorella biomass at the Institute Postgraduate Studies, University of Malaya. Using a HRAP of 4 m surface area and pond depth of 0.2 m between 6-8 days of algal biomass peaked and chemical oxygen demand (COD), ammoniacal-nitrogen, orthophosphate removal reached 98.6 %, 96.6 % and 94.6 % respectively. 360 mgL⁻¹ dry weight of algal biomass was obtained which had average protein, lipid and carbohydrate contents of 55 %, 12.5 % and 22 % respectively. Total carotenoids reached 2.42 mgL⁻¹ dry weight (Phang et al., 2001).

The advantages of an algal ponding system have yet to be appreciated by the industry involved, especially with regards to the potential of valuable product recovery. Ponding systems have evolved into integrated and highly efficient systems and have good potential for application in wastewater treatment.
This present project forms part of the national project on “Development of an Integrated Landfill Leachate Treatment System Using Microbial Processes”, that is funded through the Environmental/Industrial Biotechnology Cooperative Centre (BBC) of the National Biotechnology Directorate of Malaysia.

This project investigates the use of a high rate algal pond system to complete the final polishing of the treated leachate from an existing landfill system. The high rate algal pond (HRAP) is based on an optimized algal-bacterial system whereby complex organic compounds are first converted to simple compounds by aerobic bacteria. The microalgae grow on these bacterial products, while providing photosynthetic oxygen to the bacteria. In the HRAP, both organic (COD) and inorganic (NH₄-N, PO₄), constituents of the wastewater are converted into a useful product, the microalgal biomass, which may serve as a source of animal feed, biofertilizer or useful biochemicals like pigments. Microalgal species which can be used in the HRAP system will have to be tolerant to any toxic compound found in the leachate, besides having other biochemical properties which make them sources of commercial products.

1.2 STUDY SITE

The leachate that was used in this study was obtained from the Air Hitam Sanitary Landfill owned by the Worldwide Landfills Sdn Bhd which is a Malaysian waste management company. The landfill is located at Sri Kembangan, Selangor (Figure 1).
Figure 1: Worldwide Landfills Sdn Bhd maps.

Figure 2: Landfill site
Today, 'open dumping' is still one of the most common ways of eliminating many types of solid waste. Recognising the importance and the need to protect the environment, as well as to address the solid waste disposal problems in Selangor, the concept of sanitary landfill was introduced. To accomplish this, the Selangor State Government commissioned Worldwide Landfills Sdn Bhd to establish, operate, maintain and manage the Air Hitam Sanitary Landfill.

This involves the disposal of domestic waste, commercial waste, light industrial waste, market waste, street/public cleansing waste, construction waste and condemned food waste from seven councils within the Klang Valley. This sanitary Landfill does not accept toxic, hazardous or clinical wastes and its operating hours started from 7 am until 7 pm everyday receiving average daily volumes of wastes of about 1400 tonnes \( d^1 \).

The Air Hitam Sanitary Landfill is an engineered waste disposal facility with specific pollution control technologies designed to minimize potential environmental impacts. New scientific techniques to treat waste in an environmental-friendly way are implemented, ensuring protection of the natural surroundings. The risk of pollution is also minimized through a strict and permanent monitoring system.

Waste disposed at the Air Hitam Sanitary Landfill is contained and isolated in a dedicated area, where it is subsequently compacted and covered (Figures 2 & 3). Specific landfill technologies are utilized at the Air Hitam Sanitary Landfill to ensure safe and proper disposal of waste and to minimize potential environmental impact.
Figure 3: Solid waste at the landfill site

Figure 4: Aeration pond, for primary treatment for landfill leachate
These include the use of an impermeable liner system, leachate collection system, leachate treatment, landfill gas control and an environmental monitoring system.

The liner system is designed to prevent the leachate, from seeping into the ground and from contaminating underground water. In constructing Air Hitam Sanitary Landfill, the liner system was constructed together with a drainage blanket which also provides additional protection to the liner system in that it prevents hard objects being pushed down through the wastes which might puncture the liner. The liner itself is constructed from 2 mm thick, high density polyethylene (HDPE) sheets. The liner is site welded to the ground profile using extrusion welders. Protection is by way of a geotextile (synthetic liner) cover sheet laid directly between the subgrade and the underside of the HDPE, a top cover sheet again in geotextile membrane is also provide (Agamuthu & Nather, 1997).

The liner system is designed to capture any leachate (contaminated water) seeping from within the cell (a compartment constructed at the landfill, where the waste is dumped in it) and thereby contaminating the groundwater. To achieve this, each cell is normally sized at around 100 x 100 m with its own leachate collection pipes (160 diameter HDPE with welded joints). The leachate is drawn into the pipe by a series of pre-drilled holes. The pipe is surrounded by gravel and is wrapped in geotextile membrane to filter out anything that might otherwise block the pipe. The flow of the leachate is controlled at central pumping chambers by a system of valves, before being pumped to the onsite leachate treatment plant.
The leachate is then pumped to a treatment plant, where it undergoes on-site treatment. Chemical and physical treatments are used for primary treatment followed by aerobic treatment. In the aerobic process, the leachate is passed through three aerated lagoons in series (Figure 4), before discharge into the river. The first lagoon acts as an equalization pond and is equipped with four floating aerators. Lagoons 2 and 3 also have aeration. Activated sludge from the lagoons is collected in the settling ponds (Figure 5) and is recirculated through the lagoons. Capacity is sized on 200 m³ per day and the total hydraulic retention time is 35 days. The mixed liquor suspended solid concentrations maintained in the lagoons vary from 750 mgL⁻¹ to 3000 mgL⁻¹. Dissolved oxygen concentration is always maintained around 2 mgL⁻¹. pH values in the lagoons are in the range of 7.6-8.8. The plant is always operating at its optimum efficiency. Offsite analysis shows that the plant is consistently achieving 98% BOD removal and 90% COD removal.

To control landfill gas, an active system has been installed, using blowers to extract methane gas from vertical wells (Figure 6) and burning off the gas collected at a flare station (Figure 7). In strict adherence to safety and quality control standards, a monitoring system ensures that all equipment and technologies used are performing at their optimum (Worldwide Landfills Sdn. Bhd, 2001).
Figure 5: Settling pond for landfill leachate used after aeration processes

Figure 6: Gaswell for proper landfill gas venting
Figure 7: A flare station for burning off the methane gas
1.3 OBJECTIVES OF STUDY:

This project was conducted in view of stricter regulations governing the discharge of wastewaters as well as the possibility of more landfills being established in Malaysia. This project is part of a joint study to develop an integrated approach to bioremediation of landfill leachate. The objective of this specific project is to investigate the use of microalgae to treat the landfill leachate after primary treatment.

This is done through:

i. Characterisation of the treated leachate (after primary treatment)

ii. Selection of suitable microalgae for growth in the treated leachate.

iii. Design and operation of a high rate algal pond (HRAP) for treatment of the treated leachate.

iv. Determination of the growth and biomass production of microalgae in the HRAP system.

v. Assessment of the treatment efficiency of the HRAP.

The flow chart presented in Figure 8 outlines the various stages of investigation carried out in the study.
Treated leachate was obtained from the collection points at the Air Hitam Sanitary Landfill.

**CHARACTERISATION OF LEACHATE**
Determination of selected pollution parameters including pH, NH₃-H, PO₄, COD & TSS

**SCREENING OF SELECTED ALGAE**
- Microalgae isolates from the UMACC were used for growth studies in the treated leachate
- The inhibition concentration (IC₅₀) was calculated based on day 4 and day 8 results.
  - Effect of heavy metal on the growth of microalgae

**SELECTED SPECIES**
*Chlorella vulgaris* UMACC 011, *Scenedesmus quadricauda* UMACC 039, *Euglena* sp. UMACC 058, *Ankistrodesmus conventus* UMACC 101 and *Chlorococcum oviforme* UMACC 110

**TREATMENT POND, T₀**
Inoculum: mixture of microalgae from the UM lake

**HRAP STUDIES**
Total volume: 40L
Surface area: 0.71 m²
Culture depth: 0.15 m
Flow rate: 15 cm/s

**TREATMENT POND, T₁**
Inoculum: mixture of equal volume of the five selected species of microalgae

**MONITOR**
- Treatment efficiency
- Growth of microalgae
- Biomass production

Figure 8: Outline the various stages of investigation carried out in the study.