CHAPTER 1

INTRODUCTION

1.1 Introduction

The use of municipal solid waste (MSW) landfills is the most widely utilized method of solid waste disposal around the world. In Malaysia, landfill and/or open dumping of MSW is very common. The main pollution issues associated with landfill sites are the production of potentially explosive gases and liquid leachate. Among these, leachate emissions from landfill sites are of growing concern, primarily due to their toxic impact when released unchecked into the environment, and the potential for landfill sites to generate leachate for many hundreds of years following closure (Jones *et al*, 2006). Landfill leachate, mainly generated due to the penetration of precipitation through the waste, was characterized by its high concentrations of organic matter and included toxic and carcinogenic chemicals (Schrab, 1993). It is reported that small amount of landfill leachate can pollute large volume of groundwater, rendering them unusable for domestic and many other purpose. Therefore, more attention has been paid to research on toxicity of landfill leachate (Li *et al*., 2007).

Sanitary landfill for the disposal of municipal solid wastes continues to be widely accepted and used in the several countries. This method generally offers lower cost of operation and maintenance as compared to others. However, leachate migration from the landfill could be a potential source of surface and groundwater contaminations. Landfill leachate is a very dark coloured liquid formed primarily by the percolation of precipitation through open landfill or through the cap of the completed site. The decomposition of organic matter such as humic acid may cause the water to be yellow, brown or black (Zouboulis *et al*., 2004).

Leachate is produced when moisture enters the refuse in a landfill, extracts contaminants into the liquid phase, and produces moisture content sufficiently high to initiate liquid flow. Leachate composition depends on many factors such as the waste composition, site hydrology, the availability of moisture and oxygen, design and operation of the landfill and its age. There is a considerable number of studies reported in the literature for metals concentrations from full-scale landfills, test cells, and laboratory works (Christensen et al., 2001; Christensen et al., 1994; Kjeldsen & Christophersen, 2001; Revans et al., 1999; Reinhart & Grosh, 1998).

Leachate has always presented a problem to landfill operators. Therefore, stricter water quality standards require leachate to be processed in a leachate treatment before it is discharged to the environment. In this case, strict monitoring of leachate is required according to legislative regulation in terms of efficient elimination of refractory pollutants.

1.2 Problem Background

Sanitary landfills have been the most popular method of municipal solid waste disposal. Although attention has been drawn to increased recycling, waste reduction and incineration, the sanitary landfill will remain its dominant in the solid waste disposal methods for the next decade due to the rapid population growth (Qasim and Chiang, W. 1994). In conjugation with the increasing number of solid wastes and sanitary landfills, more leachates which have high contamination are generated. Landfill leachates will cause environmental problems if it is not properly handled. Increase in landfill leachate creates challenges for those demand efficient treatment methods to process this wastewater.

Chemical coagulation process could remove organics reasonably well, but it would produce a large amount of sludge which caused another problem. Activated carbon processes can remove organic content from landfill leachate effectively, but activated carbons and subsequent treatment of spent carbons are costly. Therefore, more efficient and economical technologies are needed to treat highly contaminated leachate. Consequently, there are many researchers try to explore more efficient processes to remove organic content from leachate such as; rreverse osmosis, membrane technologies, electrochemical oxidation, flotation, ozonation, Ozone-activated carbon, coagulation/flocculation, ozonation and photocatalytic processes to treat landfill leachate (Fan *et al*.,2007). The purpose of this research is trying to develop an alternative coagulation and flocculation process using the application of magnetic field for the removal of suspended solids, COD and BOD_5 in municipal landfill leachate.

The use of magnetic fields as a means of water treatment compared with chemical treatment has considerable financial and environmental implications. Chemicals are generally effective. However, they are costly and are subject to strict regulations, and in many cases they can damage the environment. A reliable, low-cost and more environmentally wastewater treatment begin alternative that eliminates or significantly reduces the need for chemicals would have obvious attractions. Among different physical and chemical methods of water and wastewater treatments, magnetic applications attract a special attention due to their environmental friendliness, ecological purity, safety and simplicity.

Technical papers pertinent to magnetic treatment claimed that magnetic fields has the ability to alter the physicochemical properties of water and suppressed nucleation of $CaCO_3$ (Beruto and Giordani, 1995). In addition Parson, *et al*., (1997) has constructed a test rig of circulation flow to investigate the effect of an orthogonally applied magnetic field (up to 7000 Gauss) on solution of $CaCO_3$ and accompanying changes in scale deposits formed by the solution. The result showed that the magnetic treatment had a significant effect on the precipitation of $CaCO_3$ from the solution under a controlled physico-chemical condition such as temperature, pH and degree of saturation. On the other hand, magnetic field was shown to influence significantly the zeta potential and particle size distribution of particle formed in solution. It was found that the magnetic treatments also enhanced the crystallization process (Donaldson and Grimes, 1988) and intensify the coagulation and precipitation of colloid particles (Tsouris and Scott, 1995). Currently, the application of magnetic treatment has been used in industrial water treatment (Hibben, 1993); removal of phosphate from wastewater (Bogatin *et al*,. 1999), removal of existing scale (Baker and Judd, 1996); Florenstano, *et al*., 1996), corrosion control (Grutsch and McClintock, 1984) and reducing the formation of wax and paraffin in the oil rigs (Partidas, 1995).

Sakai *et al*. (1991, 1992a, b) added magnetic ferrooxide powder to activated sludge to improve the efficiency of sedimentation. Ozaki *et al*. (1991) also applied a magnetic particle and magnetic fields for phenol biodegradation. Sakai (1994) has studied the submerged filter system consisting of magnetically anisotropic tubular support for the sewage treatment with a biofilm system. The activated sludge was supplemented with the ferromagnetic powder for the preparation of the biofilm. The biofilm was formed within 15 minutes on magnetic support media by magnetic attraction. The magnetic support media were able to treat sewage containing 0.2 g/L COD and remove 72%-94% COD with a retention time of 8 hours. Liu *et al*. (2000) applied a magnetic field for enhancement of nitrification using chitosan-magnetite, and they found that there was higher removal of ammonia under aerobic conditions. Hattori *et al*. (2001) applied an external magnetic field on the flocs size and found that the flocs size of the sludge was enlarged. Johan *et al* (2004) applied magnetic fields on suspended particles in sewage and concluded that magnetic technology had the potential to be used to further increase the efficiency of sewage by increasing the removal of suspended particles. However these technologies have some disadvantages, such as the use of magnetic particles and the necessity of recovering them considering the environmental viewpoint and practical cost problem. Moreover, they may be too complicated for practical application. Yavuz and Celebi (2000) have reported the sedimentation enhancement of activated sludge with an external magnetic field without addition of magnetite into the sludge, using cultivated activated sludge that was acclaimed with a synthetic sewage, and accompanied by the enlargement of the flocs size. The flocs size and sedimentation were improved by the addition of $FeCl_3$ to the activated sludge. However the mechanism of sedimentation enhancement effects is still unclear. The general lack of acceptability of magnetic fields as an effective and creditable alternative to water treatment has largely resulted from poor experimental data, particularly insufficient details of an experimental design to enable work to be repeated and the results to be reproduced.

1.3 Problem Statement

The management of leachate from municipal waste landfills is a major aspect of a landfill design and operation. Leachate is formed from water that infiltrates through a landfill. As leachate migrates through the refuse, it accumulates soluble contaminants present in the solid waste and soluble products from anaerobic decomposition reactions. Increasing awareness of the human and environmental risks that result from discharging this leachate into the environment has increased demands for efficient treatment facilities (Christensen *et al*., 2001). Many studies have shown that untreated landfill leachate can be acutely toxic to several aquatic organisms (Clément *et al*., 1997, Kjeldsen *et al*., 2002 and Marttininen *et al*., 2002).

The composition of landfill leachate is site specific and depends on various factors. Typical contaminants in leachate include organic compounds (that contribute to BOD_5 or COD), suspended solids, soluble metals and volatile nonionic compounds such as ammonia. Due to the complex nature of leachate characteristics and increasingly stringent treatment standards, it is difficult to treat leachate in a single traditional treatment process.

Leachate has a complex structure and high pollutant load, and its treatment is quite hard to supply the discharge standards. Leachate becomes ahead of wastewaters as being the most difficult to treat as it is a wastewater with a complex and widely variable content generated within a landfill. Therefore, many pretreatment and combined treatment methods have been proven to treat leachate. By today, many treatment methods for its treatment have been proven. Some treatment stories such as membrane processes (Chianese *et a*l., 1999), Ahn *et al*., 2002 and Tabet *et al*., 2002, advanced oxidation techniques Wu *et al*.,2004 and Zhang *et al*., 2006, coagulation–flocculation methods (Amokrane *et al*., 1997), lagoon and wetland applications (Mæhlum, 1995) have been examined in the literature. Because its characteristics change with advancing years of the landfill, these test methods have troubles such as decreasing treatment efficiencies and increasing cost (Wu *et.al*., 2004). Therefore, the implementation of a joint treatment comprising of a few treatment steps has been used to solve the problem (Ilhan *et al*., 2008).

In recent years, magnetic treatment having features like relatively more economic and higher treatment efficiency has been a promising method. Magnetic treatment is one of the simple and efficient methods (Kurinobu *et al*., 2007). In this technique, this is characterized by its simple equipment and easy operation. The coagulant is generated by the influence of magnetic field to the colloidal particles at an appropriate pH, to the insoluble metal hydroxide which is able to remove a large variety of pollutants (Adhoum *et al*., 2004). These metal hydroxide species neutralize the electrostatic charges on suspended solids to facilitate agglomeration or coagulation and resultant separation from the aqueous phase (Mollah *et al*., 2001 and Feng *et al*., 2001).

A growing research interest is reported on the new methods to intensification elimination of wastewater pollution, which not required extension of existing plants of building very expensive bioreactors, are still searching. In recent years increasing attention has been directed to the possibility of improvement of wastewater treatment by static magnetic field (Tomska and Wolny, 2008). Magnetic separation is a method for the separation of particles on the basis of their magnetic properties and has been used in the mineral processing and the recycle industries for many years for concentration and purification requirements. Efficient use of magnetic separation methods in mineral processing has encouraged its use in wastewater treatment. In the 1970s, the introduction of high-gradient magnetic separators (HGMS) developed not only for the recovery of useful materials but also rapid treatment of wastewater, has made the magnetic separation method applicable to the handling of weekly submicron particles (Karapinar, 2003).

As a matter of fact, it has been well known that magnetic separation has been used for the removal of magnetic solid particles in wastewater. Recent progress in this field is the removal of nonmagnetic water pollutants such as virus, algae and dissolved pollutants by magnetic separation that relies on the usage of magnetic seeding technique to enhance the magnetic properties of pollutants to be removed (Anderson *et al*., 1983, Anand *et al*., 1985, Treshima *et al*., 1986, Van Valsen *et al*., 1991, De Reuver, 1994, Gillet and Diot, 1999 and Franzreb and Höll, 2000). In spite of the fact that the subject was first studied by De Latour, 1973 and till now a number of reports have been published on the subject (Moffat *et al*., 1994, Prenger *et al*., 1994 and Karapinar, 2003), magnetic separation method is a not well-known process in wastewater treatment facilities.

In this regard, magnetic separation method may overcome separation difficulties associated with Fe oxides adsorbent by considerably accelerating solid/liquid separation process, and hence increasing the throughput. However, to do this, iron ions can be precipitated a ferrite sludge with magnetic properties (Tamaura *et al*., 1991 and Barrado *et al*., 1998), or precipitated slurries are seeded with very fine magnetite powder (Treshima *et al*., 1986 and Anderson *et al*., 1991). When the ferrihydrite is made magnetic, fluid can be treated directly in HGMS without a need for sludge sedimentation.

The primary concern of this research is to study the feasibility of magnetic technology in assisting sedimentation of suspended solids and to better understand the mechanism and effect of magnetic application in wastewater. Previously most studies regarding to magnetically treated wastewater were only concentrating on the usage of magnetite (magnetic particle and slurry). However, there are still very fews studies on the specific effect of magnetic field (non-invasive) on wastewater properties. This encouraged the writer to hold this study to investigate the feasibility of magnetic application in enhancing the sedimentation of wastewater's suspended particles as well as to find out its effect on the wastewater properties.

Recently, magnetic has been worked to treat the wastewater to reduce organic matter by some researchers: magnetic field enhance of biological wastewater treatment for COD removal (Tomska and Wolny, 2008), magnetic ion exchange effectively removes significant amounts of organic matter in the wastewater up to 80% removal within a short contact time of 20 min (Zhang *et al*., 2008; Zhang *et al*., 2007), magnetic field effect on activity of activated sludge that enhance microorganisms growth rates and substrate removal at pH 7.5, which was about 44% (Yavuz and Çelebi, 2000), There is no doubt that high COD in the landfill leachate are of the most important problems in leachate management. In particular, the magnetic treatment for treating landfill leachate can reduce high COD levels in landfill leachate.

1.4 Objectives of The Study

The aim of this study was to evaluate the application of magnetic treatment in treating landfill leachate. The performance of a circulation magnetic device on reduction of suspended particles and organic concentrations in landfill leachate treatment was studied. The objectives of this research project are as follows:

(i) To determine the effect of the magnetic application on suspended solids sedimentation in leachate by circulation flowing system due to magnetic field strength of 0.55 Tesla.

(ii) To evaluate the performance of the magnetic field strength of 0.55 Tesla on removal efficiency based on turbidity, SS, BOD_5, COD of leachate under different operating conditions such as flow rate, circulation period, pH and retention time.

(iii) To formulate an empirical relationship between the controlling parameters of flow rate, circulation period, retention time, pH and the removal efficiency of SS, BOD_5 and COD of leachate for the application of 0.55 Tesla magnetic field strength which were found to be statistically significant.

1.5 Scope of The Study

The scope of work for this study can be stipulated as follows:

(i) Raw and pretreated leachate samples were collected from Pasir Gudang landfill, Johor Bahru. Upon collection, the leachate was stored at 4°C to minimize any further change that might occur in its physicochemical and biological properties until the experiment analyses were carried out within a day. The characteristics of the raw and pre-treated leachate samples in this study were analysed;

(ii) The magnetic application with magnetic field strength of 0.55 Tesla and the circulation flowing system was adopted in conducting such experimental work in treating landfill leachate;

(iii) The monitoring of influent, effluent and evaluation performance of the magnetic treatment device on the removal of suspended solids and organics concentration had been conducted at indoor laboratory in room temperature;

(iv) The operating parameters were selected for this experimental work, they were flow rate in the range of (1 mL/s to 5 mL/s), circulation period between (1 to 6 hours), retention time (0 to 120 minutes) and pH (2 to 13 of leachate sample). Each variable was replicated several times to get a clear point of view regarding those parameters;

(v) The methods used for analytical parameters were specified by the "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association (APHA), 2000).

1.6 Significance of The Research

Magnetic application has been shown in the past to be a promising treatment process that can enhance water quality. Magnetic substances (magnetic particles) and magnetic fields have been applied in wastewater treatment to improve sedimentation efficiency (Ozaki *et al*. 1991; Sakai *et al*. 1991, 1992a,b, 1994; Jung *et* *al*., 1993; Liu *et al*. 2000; Hittori et al.2001; Johan *et al*. 2004). The significance of this study is to extend the development of magnetic treatment of landfill leachate based on magnetic devices initiated by previous researchers. This research contributes to the field of environmental engineering by proposing the design, operation and optimization of landfill leachate treatment using a magnetic device. The incorporation of the models is developed here into mathematical models utilized to predict the efficiency of magnetic treatment in landfill leachate.

1.7 Thesis Structure

This thesis consists of six chapters; Introduction, Literature Review, Research Methodology, Analysis of the Results, Respond Surface Methodology, Findings, Summary, Conclusion and followed by Appendix. The brief description for each of them is presented as follows

Chapter one, as an introduction provides a general introduction and brief overview of the research objectives, the research questions, and the research methodology to be employed, and the research problem, the research background and motivation of this research, and the research significance. The scope and objectives of this work are discussed in this chapter.

Chapter two provides an extensive overview of the landfill leachate, and describes the main background theory of this research: innovation milestones in magnetic treatment, magnetic devices, factors affecting magnetic water treatment, magnetic effects on colloidal particles and magnetic technologies used in wastewater treatment.

Chapter three describes the methodology used in the laboratory simulations; specific experimental equipments of the magnetic water treatment unit, the treatment run procedures and sample analysis methods.

Chapters four and five present the analysis of the results and the discussion of the results and describes the analysis of experimental results and the experimental design using statistical software. A detailed discussion of the process development of models of landfill leachate treatment using magnetic device are presented.

Chapter six presents the summary findings correlate the experimental results to the research objectives. It presents the summary conclusions, limitations and contributions of the study, and the future research needs.