ALTERNATIVE L[illegible]EMENT KILN DUST

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ABSTRACT

The generation of solid waste that increasing concurrently with increasing of population due to activity of human and animals. Due to open dumping problem in Malaysia, it is feared that untreated leachate that generated will harm the ecosystem. The major part in leachate treatment is chemical treatment that comprised such coagulation-flocculation, chemical precipitation and oxidation. The high composition of calcium oxide, CaO in CKD is found to be most important parameter in determination of this product to be an effective coagulant. Hence, the current coagulation-flocculation process in leachate treatment effectiveness could be increase. The main focus of this study is to determine the suitability of cement kiln dust as coagulant in coagulation-flocculation process in leachate treatment. The results are prior to percentage removal of BOD, COD, TSS and manganese. Coagulation-flocculation was performed in a standard jar-test apparatus comprising of six paddle rotors (24.5 x 63.5 mm) and equipped with 6 beakers, using 1000 mL of leachate sample. The agitation speed (rapid and slow mixing) and settling time were selected as 300 rpm for 1 min before adding CKD doses at 1, 2, 3, 4, 6, and 8g followed by flash mixing for 10 minutes and 10 rpm for 1 min and finally settling for 60 min. Thus, the optimum coagulant doses and effect of contact time in this process are revealing. The optimum dosage of CKD is found to be 2 g/L which the percentage of BOD, COD, TSS and manganese (Mn) removal is up to 6.88%, 92.04%, 83.63% and 98.13% respectively. All parameter tested for wastewater leachate such as BOD, COD, TSS and heavy metal which is Manganese (Mn) is showing high percentage removal by coagulation-flocculation process (es) by using CKD as coagulant.

ABSTRAK

Penghasilan sisa pepejal yang meningkat serentak dengan peningkatan penduduk berikutan oleh aktiviti manusia dan haiwan.Oleh kerana masalah pembuangan sampah secara terbuka di Malaysia, ia dikhuatiri bahawa larut-lesapan (leachate) yang tidak terawat yang dihasilkan akan memudaratkan ekosistem. Sebahagian besar dalam rawatan larut-lesap adalah rawatan kimia yakni antaranya penggumpalan-pemberbukuan, pemendakan kimia dan pengoksidaan.Komposisi kalsium oksida CaO yang tinggi, dalam CKD menjadi parameter terpenting dalam menentukan produk ini bagi sebagai suatu penggumpal yang berkesan. Oleh itu, keberkesanan proses pembekuan-pemberbukuan dalam rawatan (leachate) dapat dipertingkatkan. Fokus utama kajian ini adalah untuk menentukan kesesuaian debu tanur simen (CKD) sebagai agen penggumpal dalam proses pembekuan-pemberbukuan dalam rawatan (leachate). Keputusan berdasarkan peratusan penyingkiran BOD, COD, TSS dan mangan. Penggumpalan-pemberbukuan telah dilakukan dalam balang peralatan standard-ujian yang terdiri daripada enam rotor paddle (24.5 x 63,5 mm) dan dilengkapi dengan 6 bikar, menggunakan 1000 mL sampel air leachate. Kelajuan pergolakan (cepat dan perlahan pencampuran) dan masa pengenapan telah dipilih sebagai 300 rpm selama 1 minit sebelum menambah dos CKD pada 1, 2, 3, 4, 6, dan 8g diikuti oleh campuran pantas selama 10 minit dan 10 rpm selama 1 minit dan akhirnya dibiarkan mendap selama 60 minit. Oleh itu, dos koagulan optimum dan kesan masa sentuhan dalam proses ini dibuktikan. Dos optimum CKD iaitu 2 g / L menunjukkan peratusan penyingkiran BOD, COD, TSS dan mangan (Mn) sehingga 6.88%, 92,04% 83,63% dan 98,13% masing-masing. Semua parameter yang diuji untuk air sisa leachate seperti BOD, COD, TSS dan logam berat yang Mangan (Mn) menunjukkan peratus penyingkiran tinggi oleh proses pembekuan-pemberbukuan dengan menggunakan CKD sebagai agen penggumpal.

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LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminum Oxide,
BOD	-	Biological Oxygen Demand
CaO	-	Calcium Oxide
CaO	-	Calcium Oxides
CKD	-	Cement Kiln Dust
Cl	-	Chlorine
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
DOE	-	Department of Environmental
DOM	-	Dissolve Organic Matter
EPA	-	Environment Protection Agency
Fe_2O_3	-	Iron (III) oxide
H_2O	-	Water
K_2O	-	Potassium Oxide
L.O.I	-	Loss of Ignition
MgO	-	Magnesium oxide
MnO	-	Manganese oxide
MSW	-	Municipal Solid Waste
Na_2O	-	Sodium Oxide
OMW	-	Olive Mill Wastewater
P_2O_5	-	Phosphorus pentoxide
PC	-	Portland cement
SiO_2	-	Silica Dioxide
SO_3	-	Sulphur Trioxide
TiO_2	-	Titanium Dioxide
TSS	-	Total Suspended Solid

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CHAPTER 1

INTRODUCTION

This chapter explains the background of research, research problem, research objectives, research scope and significance of this research.

1.1 Preamble

The generation of solid waste that increasing concurrently with increasing of population due to activity of human and animals. Thus, the cheaper method in solid waste management is more preferable. Many countries including Malaysia are using most common method in order to manage municipal solid waste (MSW) which is landfilling. However, unkempt and improper management of landfill would lead to many adverse effects not only to human health, but also damage the ecosystems. There are about 177 disposal sites in Peninsular Malaysia and most cases, open dumping is being practiced and takes place at about 50% of the total landfills (Penang, 2001). This number could be arise if improper management of current landfills.

One of the most important aspects related to siting, planning, design, operation and long-term management of Municipal Solid Waste (MSW) landfill is the management of leachate (H.A Aziz *et al.* 2007). Due to open dumping problem in Malaysia, it is feared that untreated leachate will harm the ecosystem. Leachate is characterized as very contaminated wastewater very easy to pollute groundwater through percolation. Thus, the collection and managing leachate including treatment of leachate become the compulsory part in maintaining sanitary landfill.

Treatment of leachate is very complicated, expensive and generally requires various process applications due to high concentrations of COD and nitrogen as well as colour (Ozturk, 2003). The major part in leachate treatment is chemical treatment that comprised such coagulation-flocculation, chemical precipitation and oxidation. Coagulation is common physical–chemical processes used to remove non-biodegradable organic material, i.e., dissolved organic matter, (DOM) and anthropogenic organic chemicals, from leachate because the process is economical and simple to implement (Comstock, *et al.* 2010).

In cement manufacturing that mostly using limestone as consumable resources, the production of cement kiln dust, CKD is become the major part. High composition of calcium oxide, CaO in CKD has been reveal in several studies. Orescanina *et al.* (2011) has reveal that application of calcium oxide for treatment of landfill leachate taken from old sanitary landfill had resulted in the reduction of color, turbidity, suspended solids and ammonia successfully. Therefore, the effectiveness of CKD as coagulant in this study are reveal.

1.2 Problem Statement

The high amount of contaminant in leachate is contributed from different type of waste that has been generated. This scenario has rise concern due to lack of proper landfill management. Generally, leachate is generating from percolation of water through bulk of waste and picked up the contamination. In Malaysia, wet and dry weather throughout the year has become major contribution to leachate generation especially in open dumping area where there are no daily cover and lack of management to reduce leachate generation. This concern is due to the potential of contamination of groundwater and surface water.

Leachate is characterized with highly contaminated wastewater due to high amount of biological oxidation demand (BOD), chemical oxidation demand (COD), total suspended solid (TSS), and heavy metals. Serious problem for humans, animals and plants will result, if untreated leachate is discharged directly into water bodies and natural streams (Aziz, H.A and Ahmed, F.A, 2009). Therefore, proper collection and treatment are mandatory. The adverse impacts of landfill leachate on adjacent surface and groundwater have prompted a great number of studies since 1980 (Fatta *et al.* 1999).

There are several parameters in leachate that can cause serious problem to human, animal and plant is discharge directly to water bodies. High concentration of heavy metals such as iron, zinc, lead, copper, cadmium and chromium can cause serious water pollution and threaten the environment. The biotoxic effects, when unduly exposed to heavy metals could be potentially life threatening hence cannot be neglected (Duruibe, J. O. *et al.* 2007). Besides, ammoniacal nitrogen decreases the dissolved oxygen required for aquatic organisms. So to prevent these problems it is compulsory to remove these contaminants from leachate before discharge to wetland.

According to Abu Foul (2007), leachate treatment is very complicated, expensive and generally requires multiple processes (Ozturk and Bektas, 2004). There are several factors to be considered when designing a leachate treatment system. However, according to Chian and DeWalle (1976) the appropriate treatment methods are mainly based on specific characteristics leachate under examination (Samadi *et al.* 2010). These include leachate flows, landfill age and leachate characteristics. Thus, each leachate treatment in different landfill has consumed the cost in term of design. Alternative methods of leachate management have been also suggested, including the recirculation of produced leachate through the disposed wastes (Samadi *et al.* 2010).

Leachate treatment usually consists of both physic-chemical treatment and biological treatment for optimum efficiencies. Biological methods are very effective for the treatment of landfill leachate with a high value of BOD (biological oxygen demand) but are ineffective if recalcitrant organic compounds are present, so that they must be supported by a physico-chemical process (Cossu *et al.* 1998). Common practices in physico-chemical process are chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, sedimentation/flotation and air stripping.

Coagulation-flocculation is one of the physico-chemical processes which define by Samadi *et al.* (2010) as an essential process in water and industrial wastewater treatment. However, limited information exists on the efficiency of this physico-chemical process when applied for the removal of pollutants from leachates, partially stabilized by recirculation, or from recently produced leachates (Heng *et al.* 2009). CKD are found to be a new resources in performing as coagulant in leachate treatment will become a new outcome as an advance coagulation-flocculation processes.

1.3 Research Objectives

There are several objectives that must be achieved at the end of this research, which are:

i. To investigate the suitability of CKD as coagulant in coagulation-flocculation process for removal of BOD, COD, TSS and manganese from leachate.

ii. To determine the optimum coagulant doses of CKD.

iii. To study the effect of contact time in coagulation process.

1.4 Scope of Research

The main focus of this study is to determine the suitability of cement kiln dust as coagulant in coagulant-flocculation process in leachate treatment. The results are prior to percentage removal of BOD, COD, TSS and manganese. The leachate samples will be obtained from Jerangau-Jabor Landfill in Kuantan District with cooperation from Majlis Perbandaran Kuantan (MPK) and Alam Flora Sdn. Bhd whereas CKD are obtained from Pahang Cement Sdn Bhd near Felda Bukit Sagu 4, Kuantan.

Coagulation-flocculation was performed in a standard jar-test apparatus comprising of six paddle rotors (24.5 x 63.5 mm) and equipped with 6 beakers, using

1000 mL of leachate sample. Thus, the optimum coagulant doses and effect of contact time in coagulant process are revealing.

1.5 Significant of Research

The high composition of calcium oxide, CaO in CKD is found to most important parameter in determination of this product to be an effective coagulant. Hence, the current coagulation-flocculation process in leachate treatment effectiveness could be increase. This is important in order to determine and reduce the consumable cost and resources in the next stage of conventional leachate treatment. Therefore, this new alternative resource could become the vital part in leachate treatment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will define the variables investigated in this study based on several literature reviews. The variables are; leachate, composition and leachate treatment; and cement kiln dust (CKD) that consist of source(s) of CKD, composition of CKD, and previous study on CKD that used in this research. Therefore, all variable regarding leachate and CKD 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. Furthermore, this chapter will also elaborate about properties of CKD, mechanism of CKD in removing contaminant in leachate, and treatment process (es) that involve using CKD. Thus, the effectiveness of CKD in leachate treatment is revealing.

2.2 Leachate

The generation of solid waste that increasing concurrently with increasing of population due to activity of human and animals. Thus, the cheaper method in solid waste management is more preferable. Many countries including Malaysia are using most common method in order to manage municipal solid waste (MSW) which is landfilling. However, unkempt and improper management of landfill would lead to many adverse effects not only to human health, but also damage the ecosystems. There are about 177 disposal sites in Peninsular Malaysia and most cases, open dumping is being practiced and takes place at about 50% of the total landfills (Penang, 2001). This number could be arise if improper management of current landfills.

One of the most important aspects related to siting, planning, design, operation and long-term management of Municipal Solid Waste (MSW) landfill is the management of leachate (H.A Aziz *et al.* 2007). Due to open dumping problem in Malaysia, it is feared that untreated leachate will harm the ecosystem. Leachate is characterized as very contaminated wastewater very easy to pollute groundwater through percolation. Thus, the collection and managing leachate including treatment of leachate become the compulsory part in maintaining sanitary landfill.

Environmental compliance requirements have become increasingly difficult to attain in both wastewater discharge and chemical handling (Wang, 2005).The high amount of contaminant in leachate is contributed from different type of waste that has been generated. This scenario has rise concern due to lack of proper landfill management. Generally, leachate is generating from percolation of water through bulk of waste and picked up the contamination. In Malaysia, wet and dry weather throughout the year has become major contribution to leachate generation especially in open dumping area where there are no daily cover and lack of management to reduce leachate generation. This concern is due to the potential of contamination of groundwater and surface water.

2.2.1 Leachate Composition

Leachate is characterized with highly contaminated wastewater due to high amount of biological oxidation demand (BOD), chemical oxidation demand (COD), total suspended solid (TSS), and heavy metals. Serious problem for humans, animals and plants will result, if untreated leachate is discharged directly into water bodies and natural streams (Aziz, H.A and Ahmed, F.A, 2009). Therefore, proper collection and treatment are mandatory. The adverse impacts of landfill leachate on adjacent surface and groundwater have prompted a great number of studies since 1980 (Fatta *et al.* 1999).

There are several parameters in leachate that can cause serious problem to human, animal and plant is discharge directly to water bodies. High concentration of heavy metals such as iron, zinc, lead, copper, cadmium and chromium can cause serious water pollution and threaten the environment. The biotoxic effects, when unduly exposed to heavy metals could be potentially life threatening hence cannot be neglected (Duruibe, J. O. *et al.* 2007). Besides, ammoniacal nitrogen decreases the dissolved oxygen required for aquatic organisms. So to prevent these problems it is compulsory to remove these contaminants from leachate before discharge to wetland.

However, leachate composition depends on many factors as the waste composition, site hydrology, the availability of moisture and oxygen, design and operation of the landfill and its age (Abdul Aziz, 2004). The Leachate contain four groups of pollutants: Dissolved organic matter, inorganic micro components, heavy metals, and xenobiotic organic compound (Sizirici and Tansel, 2009). Generation of leachate and odours are the main disadvantage of sanitary land filling (Foul & Hamidi, 2009).

In groundwater, the risk arises from the migration of leachate contamination into water supplies where the presence of ammoniacal nitrogen is and even its breakdown product nitrate will render the whole aquifer unsuitable for drinking (Howard, 2002). Therefore, managing the Leachate through proper treatment methods which designed to prevent pollution into surrounding ground and surface waters become the challenging part in order to maintain a landfill.

2.2.2 Leachate Treatment

According to Abu Foul (2007), leachate treatment is very complicated, expensive and generally requires multiple processes (Ozturk and Bektas, 2004). There are several factors to be considered when designing a leachate treatment system. However, according to Chian and DeWalle (1976), the appropriate treatment methods are mainly based on specific characteristics leachate under examination (Samadi *et al.* 2010). These include leachate flows, landfill age and leachate characteristics. Thus, each leachate treatment in different landfill has consumed the cost in term of design. Alternative methods of leachate management have been also suggested, including the recirculation of produced leachate through the disposed wastes (Samadi *et al.* 2010).

Treatment of leachate is very complicated, expensive and generally requires various process applications due to high concentrations of COD and nitrogen as well as colour (Ozturk, 2003). The major part in leachate treatment is chemical treatment that comprised such coagulation-flocculation, chemical precipitation and oxidation. Coagulation is common physical–chemical processes used to remove non-biodegradable organic material, i.e., dissolved organic matter, (DOM) and anthropogenic organic chemicals, from leachate because the process is economical and simple to implement (Comstock *et al.* 2010).

Several processes, drawn from wastewater and drinking water technology, have been applied for the treatment of landfill leachates, such as anaerobic and/or aerobic biological degradation, chemical oxidation, coagulation-precipitation, activated carbon adsorption, photo-oxidation and membrane processes (Maleki et al. 2009). **Table 2.1** indicates operations used for the treatment of leachate.

Table 2.1: Representative biological, chemical and physical processes used for the treatment of leachate (Tchobanoglous S. L., 1981)

Treatment Process	Application	Comments/Disadvantages
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
Fixed film processes (trickling filters, rotating biological contactors	Removal of organics	Commonly used on industrial effluents similar to leachate, but untested on actual landfill leachate
B. Chemical Processes		
Neutralization	pH control	Of limit applicability to most leachate
Precipitation	Removal of metals and some anions	Produces sludge, possibly requiring disposal as a hazardous waste
Wet air oxidation	Removal of organics	Costly; works well on refractory organics

Treatment Process	Application	Comments/Disadvantages
Oxidation	Removal of organic; detoxification of some inorganic species	Works best on dilute waste streams; use of chlorine can result in formation of chlorinated hydrocarbons
C. Physical Processes		
Sedimentation/flotation	Removal of suspended matter	Of limited applicability alone; may be used in conjunction with other treatment processes
Filtration	Removal of suspended matter	Useful only as a polishing step
Air stripping	Removal of suspended matter	May require air pollution control equipment
Steam stripping	Removal of volatile organics	High energy cost; condensate steam requires further treatment
Adsorption	Removal of organics	Proven technology; variable costs depending on leachate
Ion exchange	Removal of dissolved inorganic	Useful only as a polishing step
Ultra filtration	Removal of bacteria and high molecular weight organics	Subject to fouling; Limited applicability to leachate

2.2.2.1 Physico-chemical Treatment

Generally, leachate are classify into two types which is young leachate and old leachate. Treatments of young leachate usually are effective using biological process where the composition of volatile fatty acid is higher. However, as a landfill becomes older, there is a shift from a relatively shorter initial aerobic period to a longer anaerobic decomposition period, which has two distinct sub-phases: an acidic phase, followed by a methanogenic phase and the specific composition of the leachate determines its relative treatability (Heng et al. 2009). Besides, Yahh M. et al. (2007) reveal that although, young leachate can betreated easily by biological treatment, COD removal efficiency are usually low due to high ammonium ion content and the presence of toxic compounds such as metal ions (Sletten et al., 1995; Amokrane et al., 1997;Irene and Lo, 1997; Chiang et al., 2001).

The biorefrectory contaminant, contained mainly in older leachate, are not amenable to conventional biological processes, wheras the high ammonia content might also inhibitory to activated sludge microorganisms (Pieczykolan et al. 2009). reduce the capability of the activated sludge microorganism to inhibit. In open dumping area, it is difficult to determine the age of that leachate unless the proper management such as sanitary landfills method are inducted. The intermixture of young and old leachate has increased the difficulties of leachate treatment. There are several content such as phosphorus in leachate that affect the effectiveness of biological treatment process.

Leachate treatment usually consists of both physic-chemical treatment and biological treatment for optimum efficiencies. Biological methods are very effective for the treatment of landfill leachate with a high value of BOD (biological oxygen demand) but are ineffective if recalcitrant organic compounds are present, so that they must be supported by a physico-chemical process (Cossu *et al.* 1998). Common practices in physico-chemical process are chemical oxidation, adsorption, chemical precipitation, coagulation/flocculation, sedimentation/flotation and air stripping.

2.2.2.2 Coagulation-flocculation Process (es)

Coagulation is a common physical–chemical process used to remove non-biodegradable organic material, i.e., DOM and anthropogenic organic chemicals, from leachate because the process is economical and simple to implement (Comstock et al. 2010). However, limited information exists on the efficiency of this physico-chemical process when applied for the removal of pollutants from leachates, partially stabilized by recirculation, or from recently produced leachates (Heng *et al.*2009).

Common coagulant that use in coagulation-flocculation process(es) are reported in several studies are; Aluminum Sulfate (alum), ferrous sulfate, ferric chloride, polyaluminum silicate chloride and many more. With regard to olive mill wastewater (OMW) treatment, coagulation with iron salts was applied to remove suspended solids and the effluent was then subject to either Fenton oxidation (Ginos et al. 2006) or electrochemical oxidation over a titanium-tantalum anode (Giannis et al., 2007) and, in both cases, chemical oxygen demand (COD) was reduced by over 60% (Mavros et al. 2008).

Coagulation-flocculation is one of the physico-chemical processes which define by Samadi *et al.* (2010) as an essential process in water and industrial wastewater treatment.CKD are found to be a new resources in performing as coagulant in leachate treatment will become a new outcome as an advance coagulation-flocculation processes. It is concluded that the advantages of the proposed physico-chemical method for the treatment of leachates are mainly