PROCESS PERFORMANCE OF ELECTROCOAGULATION IN TREATING SANITARY LANDFILL LEACHATE AS PRETREATMENT UNIT

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by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
APHA	American Public Health Association
$AgNO_3$	Silver nitrate
As	Arsenic
Ag	Silver
Al	Aluminium
Ba	Barium
BOD_5	Biological oxygen demand
C	Carbon
Cs	Caesium
Ca	Calcium
Cu	Copper
Cr	Chromium
Cd	Cadmium
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CC	Chemical coagulation
CCD	Central composite design
cPAM	Cationic polyacryamide
$C_8H_5KO_4$	Potassium hydrogen phthalate
$K_2Cr_2O_7$	Potassium dichromate
DOE	Design of experiments
EQA	Environmental Quality Act
EC	Electrocoagulation

Fe	Ferum
H_2O	Water
H_2SO_4	Sulphuric Acid
$HgSO_4$	Mercury(II) sulfate
ICP-MS	Inductively coupled plasma mass spectroscopoy
Mn	Manganese
Mg	Magnesium
NaOH	Sodium hydroxide
NTU	Nephelometric Turbidity Unit
NaCl	Sodium chloride
Na	Sodium
Ni	Nickel
NH_3-N	Ammoniacal nitrogen
pH	Hydrogen Ions
PbO_2	Lead dioxide
PBLS	Pulau Burung Landfill Site
PAHs	Polycyclic aromatic hydrocarbon
RSM	Response surface methodology
Si	Silicon
SnO_2	Tin dioxide
Sr	Strontium
$TiCl_4$	Titanium tetrachloride
USDA	United States Department of Agriculture
TEM	Transmission electron microscope
TOC	Total organic carbon

TSS	Total suspended solids
TDS	Total dissolved solids
Zn	Zinc

PRESTASI PROSES ELEKTRO-PENGGUMPALAN DALAM MERAWAT LARUT RESAP DARI TAPAK PELUPUSAN SEBAGAI UNIT RAWATAN AWAL

ABSTRAK

Rawatan larut resap kambus tanah memerlukan beberapa tahap rawatan dan proses elektro-penggumpalan (EC) berpotensi untuk melengkapi unit rawatan yang utama seperti membran dan rawatan biologi. Justeru itu, EC dicadangkan dalam kajian ini untuk mengatasi sesetengah masalah yang berkaitan dengan rawatan konvensional. Rawatan larut resap kambus diambil dari Tapak Pelupusan Sampah Pulau Burung. Dalam kajian ini pemboleh ubah dari EC prosess dioptimumkan seperti ketumpatan electrik, masa EC, dan jenis elektrode. Di samping itu, penyingkiran Cu dan As juga dikaji disebabkan logam berat tersebut belum dikaji oleh pengkaji lain. Keberkesanan proses EC ditentukan oleh peratusan penyingkiran keperluan oksigen kimia (COD), jumlah pepejal terapai dan kekeruhan. Penambahan polyacrylamide (cPAM) kationik sebagai pembantu penggumpalan juga dikaji untuk meningkatkan prestasi proses. Hasil daripada eksperiment itu di optimumkan lagi menggunakan kaedah statistik sambutan balas permukaan (RSM). Berdasarkan pada hasil eksperimen, penggunaan (cPAM) meningkatkan keberkesanan penyingkiran efisiensi sebanyak (6%, 28% dan 20%) COD, jumlah pepejal terapai dan kekeruhan masing- masing berbanding dengan EC sahaja (39 %, 43% dan 68 %). Seterusnya, taburan saiz zarah juga menunjukkan bahawa cPAM mempunyai saiz zarah yang lebih besar (56.85µm) berbanding dengan EC sahaja (25.39µm). Penyingkiran jumlah karbon organic (TOC) juga dikaji dan hasil kajian menunjukkan bahawa penambahan cPAM mengurangkan TOC sebanyak 44 mg/l berbanding dengan penggunaan EC sahaja (26 mg/l). Hasil kajian juga

menunjukkan bahawa, prestasi EC proses meningkat dengan penambahan cPAM. Jadi, cPAM menambahbaikkan proses penggabungan, peneutralan cas dan penggumpalan agen penggumpal dengan bahan pencemar. Sebagai kesimpulannya, EC sesuai untuk digunakan sebagai unit rawatan awal bagi larut resap.

PROCESS PERFORMANCE OF ELECTROCOAGULATION IN TREATING SANITARY LANDFILL LEACHATE AS A PRETREATMENT UNIT

ABSTRACT

Since leachate treatment requires multiple stages of treatment, electrocoagulation (EC) is proposed as a pretreatment unit to compliment the main unit operations treatment such as membrane or biological treatment. EC was proposed in this study to overcome some of the problems with conventional treatments. The landfill leachate sample was collected from Pulau Burung Sanitary Landfill. In this study, variables of the EC process such as current density, EC time and types of electrode were optimized. Besides that, Cu and As removals also been studied since these heavy metals was hardly investigated by others researchers. The process efficiency of the EC was determined by percentage removal of chemical oxygen demand (COD), total suspended solids (TSS) and turbidity. The addition of cationic polyacrylamide (cPAM) as a coagulant aid was also studied in order to increase the efficiency of the treatment process. The results were further optimized using Response Surface Method (RSM).According to the results also, the use of cPAM increased the removal efficiency by (6%, 28% and 20%) COD, TSS and turbidity respectively compared to those of EC alone (39 %, 43% and 68%). Next, the particle sizes distribution also showned that cPAM had larger sizes (56.85µm) compared to EC alone (25.39µm). Total organic carbon (TOC) was also studied and the results showed that cPAM addition reduced the TOC by (44 mg/l) compared to EC alone (26 mg/l). Based on the results, EC was improved by the addition of cPAM. This was because cPAM improved the bridging, charge neutralization and agglomeration of coagulant

agents with the pollutants. As a conclusion, EC was suitable as a pretreatment unit for leachate treatment.

CHAPTER ONE

INTRODUCTION

1.1 Sanitary landfill of leachate

As the time goes, the number of human population in the world will increase exponentially and correspondingly, the amount of municipal solid waste generated will also increase. For example in Malaysia, the population has been increasing at about 600,000 per annum or at a rate of 2.4% per annum, so that the municipal solid waste generation will also increase correspondingly (Manaf et al., 2009). This phenomenon is becoming a critical issue in the solid waste management. It was reported that the rate of solid waste generation for Peninsular Malaysia in 2010 was 23,000 tons per day and it rose up to 25,000 tons per day in 2012. In 2020, the generation of solid waste is expected to increase up to about 30,000 tons per day (Akinbile et al., 2012).

By definition, municipal solid waste is defined as generally a domestic waste such as kitchen, food, paper, and plastic waste. Mostly it contains biodegradable compounds such as kitchen waste (Nema, 2017). According to Hamidi et al. (2010), the components of a typical municipal solid waste landfill at Pulau Burung Landfill Site (PBLS) in Penang, Malaysia can be categorized into several major components such as food (40%), plastic (22%), paper (10.5%), metals (2.5%), glass (3.25%), textile (3.5%) and others (18.25 %). Leachate is generated by percolation of rainwater through the solid waste layer on the landfills through reaction of water with wastes (Orescanin et al., 2012). Therefore, it is expected that the leachate quality will fluctuate from time to time due variety of wastes.

In order to overcome the increment in solid waste numbers, various methods for solid waste disposal such as sanitary landfill, open dumping, incineration, composting, grinding and discharge to sewer, compaction, milling, reduction and anaerobic digestion are considered (Aziz et al., 2010). However, the most convenient method for municipal solid waste management is still sanitary landfill. The benefits of sanitary landfill compared to other alternative methods are such as low cost, simple disposal procedure and reclamation of derelict land. Apart from that, it can also minimize environmental impacts compared to other methods such as open-air burning and open-pit dumping (El-Salam and Abu-Zuid, 2014). Sanitary landfill will also allow solid wastes to decompose until they eventually result in stabilized materials and inerts (Renou et al., 2008).

1.2 Leachate

Commonly, the leachate that is produced will have high content of refractory materials (Lai et al., 2017). The components complex biochemical components and the physicochemical interactions between the components of the solid waste cause leachate to contain a wide variety of pollutants as its constituents (Clarke et al., 2015). The pollutants level in leachate can be measured based on several parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), ammoniacal nitrogen, suspended solid, heavy metal and others (Aziz et al., 2010). In terms of composition, the dominant organic substances in the leachate are humic substances. Humic substances can be further classified into three substances that are humic acid, fulvic acid and simple organic compounds i.e aromatic acids and phenolic compunds (Turki et al., 2013). The main characteristics of these substances are heterogeneity and complexity. Besides, they also play an important role in biogeochemistry and ecological in the environment (Labanowski et al., 2010; He and Fan 2016).

In terms of discharge of leachate there is a need to comply with the discharge standard Environmental Quality Act (EQA) 2009 that are enforced by the Department of Environment Malaysia in order to prevent detrimental effects of leachate to the environment. Leachate can cause contamination to of soil and groundwater which can pose vital effects on living things. In terms recirculation of leachate at detention pond it can be categorized into three types i.e. anaerobic, aerobic and semi-aerobic (He et al., 2012). For PBLS landfill, the detention pond starts with an anaerobic pond and then upgraded into a semi-aerobic pond. Figure 1.1 shows the schematic diagram of leachate formation in anaerobic and semi-aerobic landfills (Hamidi et al., 2010).

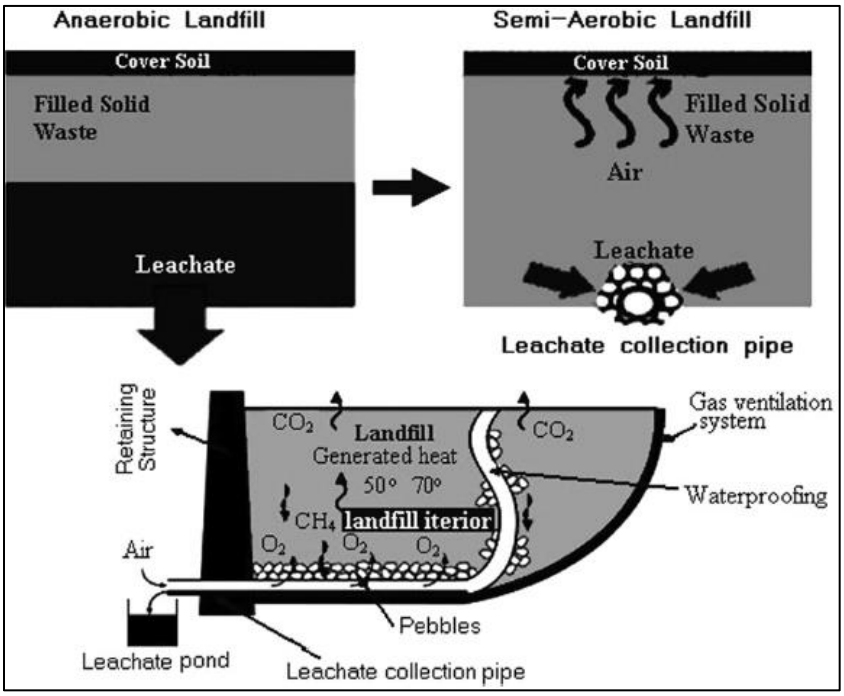

Figure1.1 Schematic diagram of anaerobic and semi-aerobic landfill (Hamidi et al., 2010).

1.3 Impact of leachate

The toxicity of leachate to the environment is undeniable. There are many studies showing that leachate components are highly unfavourable towards living things and the environment upon contacting with soil, ground water and surface water. Generally the main constituents of leachate can be divided into four groups i.e. organic matters, inorganic salts, heavy metals and xenobiotic organic compounds (Baderna et al., 2011).

High conductivity of leachate is an indication of the presence of high amounts of dissolved inorganic species such as ammonia, cyanide, carbon dioxide, nitrite, sulphite or the sum of the concentration of ions in the leachate. Besides, the high values of total suspended solid (TSS) and total dissolved solids (TDS) also have adversed effects on aquatic organism. For instance, high value of TDS may cause gill irritation to fish and suffocate the respiratory system of other aquatic organisms (Budi et al., 2015).

The presence of toxic components may also be assimilated by aquatic species to be passed through the food chain and might cause bioaccumulation over long-term exposure (Mavakala et al., 2016). Based on the European Environmental Agency, there are 13 substances that are considered the most hazardous substances that must be ceased out because these substances may cause bioaccumulation. Some of these 13 substances are hexachlorobenzene, polycyclic aromatic hydrocarbon (PAHs), cadmium and its compounds that are commonly found in leachate. Leachate may also cause genetic toxicity through its seepage into the ground or surface water (Matejczyk et al., 2011).

1.4 Electrocoagulation Process

Over the past decades, electrocoagulation (EC) has been established as one of the reliable wastewater treatment methods when dealing with urban and industrial wastewater. This is due to its high efficiency in removing inorganic matters and pathogens. The main difference between EC and chemical coagulation (CC) is the way active coagulant species is being introduced into the wastewater. In EC, the generation of coagulant achieved by in-situ process using electrical current supplied to specific electrode materials. On the other hand, coagulant in CC is generated through diffusion of specific chemical species such as polyelectrolyte polymers or metal salts (Oumar et al., 2016; Harif et al., 2012).

When dealing with EC, there are many variables that need to be optimized as it is one of electrochemical processes. The variables that need to be considered are such as current density, operation time, electrolytes conductivity and others (Orescanin et al., 2012). In general, EC process is an electrochemical production of destabilising agents (Fe, Al or others) that bring about neutralisation of surface charge for removing pollutants. At the time, the neutralization happens so that particles in the water will agglomerate to form larger mass until it will settle or undergoing flotation due to the generation of gas bubbles. Thus, the three main steps involved in EC are the electrode oxidation, gas bubble generation and sedimentation or flotation of flocs (Emamjomeh and Sivakumar 2009).

1.5 Problem statement

Currently, sanitary landfill is the common method for solid waste disposal all over the world. However, other negative impacts may arise from landfill such as leachate and gas formation and they need to be controlled. The impacts include fire and explosion, vegetation damage, unpleasant odour, landfill settlement, groundwater pollution, air pollution and global warming (El-Salam and Abu-Zuid, 2014).