



**TREATMENT OF LANDFILL LEACHATE AT
PADANG SIDING PERLIS USING MICROBIAL
FUEL CELLS AND FENTON METHODS**

by

**ISSA RAMADAN M. ALABIAD
(1341211140)**

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LIST OF ABBREVIATIONS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
TSS	Total suspended solid
MFC	Microbial fuel cell
MSW	Municipal solid waste
PEM	Proton exchange membrane
BC	Black carbon
MW _s	Nanowires
AOX	Antioxidant

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LIST OF SYMBOLS

A	Number of PLS or PCA components in the model
H ₂ O ₂	Hydrogen peroxide
FeSO ₄	Ferrous Sulphate
H ₂ O	Water
CO	Carbon monoxide
CO ₂	Carbon dioxide
NH ₃	Ammonia
NH ₄	Ammonium
H	Hydrogen
NO ₃	Nitrate
Zn	Zinc
C	Carbon
NH ₃ -N	Ammoniacal Nitrogen
O ₂	Oxygen gas
OH	Hydroxide
·OH	Hydroxyl radical
Na ⁺	Sodium
K ⁺	Potassium
Ca ²⁺	Calcium
Mg ²⁺	Magnesium
Pt	Platinum

Rawatan Bahan Larut Resap Tapak Pelupusan Sampah di Padang Siding, Perlis Menggunakan Kaedah Microbial Fuel Cells dan Fenton

ABSTRAK

Bahan larut resap tapak pelupusan sampah umumnya dikenali sebagai air sisa yang sukar dikendalikan dan mengandungi bahan-bahan terlarut dan terampai. Kajian ini menunjukkan penyingkiran komponen-komponen dalam larut resap seperti Permintaan Oksigen Kimia (COD), Permintaan Oksigen Biokimia (BOD), jumlah pepejal terampai, ammonia dan warna dengan mengintegrasikan kaedah bio-elektrokimia dan kaedah fenton. Integrasi ini bertujuan untuk kedua-dua kaedah saling melengkapi. Sel bahan bakar mikrobial (MFC) telah dibentuk untuk mengolah larut resap tapak pelupusan sampah sambil menghasilkan tenaga elektrik secara berterusan. Tiga jenis telah anod telah diujikaji dalam MFC reactor iaitu: karbon hitam, karbon teraktif dan elektrod zink. Pergerakan dalam MFC reactor semasa operasi merupakan faktor utama untuk diujikaji. Oleh itu, sistem ini beroperasi dalam mod yang berbeza : statik dan dinamik. Kedua-dua mod menunjukkan tahap ammonia yang berlainan dalam tiga anod yang digunakan. Kajian ini membandingkan mod statik dan dinamik dalam penyingkiran ammonia. Pergerakan reaktor yang berterusan boleh meningkatkan kadar penyingkiran komponen ammonia. Reaktor tersebut juga menyediakan satu keadaan yang mampu mencapai penyingkiran ammonia yang maksima. Pergerakan reaktor menyebabkan enapcemar menjadi kecil dan membolehkan ammonia dipisahkan dari larut resap dengan mudah. Penyingkiran ammonia juga berpunca daripada pemindahan ammonium melalui membran atau daripada kehilangan ammonia. Pertukaran kandungan ionik yang berterusan telah memanfaatkan prestasi MFC dengan meningkatkan penghasilan tenaga dan mengurangkan rintangan bahan elektrod. Kajian ini membentangkan hasil analisis olahan larut resap yang dikumpul dari tapak pelupusan sampah di tapak pelupusan sampah yang terletak di Padang Siding, Perlis. Penyingkiran ammonia telah dipertingkatkan dengan menggunakan pelbagai jenis elektrod. Dalam kedua-dua mod, karbon teraktif mempunyai prestasi yang lebih baik daripada karbon hitam dan zink. Jumlah peratusan penyingkiran bagi COD, BOD dan TSS adalah 490 mg/L (96.45% penyingkiran), 249 mg/L (77.98% penyingkiran) dan 106 mg/L (42.20% penyingkiran) 13 mg/L (97.66% penyingkiran). Sampel bahan larut resap tersebut kemudiannya dirawat dengan menggunakan kaedah Fenton bertujuan untuk merendahkan komponen yang tertentu. Bagi proses Fenton, kesan pengaruh parameter telah diverifikasi melalui kaedah statistik, dimana 17 eksperimen telah dijalankan dengan menggunakan Response Surface Methodology (RSM) daripada perisian Design of Experiment (DOE). Keputusan kajian ini telah dipatuhi dengan keputusan ramalan daripada RSM. Kondisi optimum bagi FeSO_4 dan H_2O_2 dan pH bagi penyingkiran ammonia, COD, BOD, TSS dan warna adalah pada pH (3.94), FeSO_4 (19.68 mg/L) dan H_2O_2 (40.39 mg/L). peratusan penyingkiran untuk ammonia, COD, BOD, dan TSS adalah ~16.92%, 78.72%, 88.35 %, 75.91% and 88.16%.

Treatment of Landfill Leachate at Padang Siding Perlis Using Microbial Fuel Cells and Fenton Methods

ABSTRACT

Landfill leachate is generally known as high-strength wastewater that is highly difficult to handle and contains extracted dissolved matter and suspended matter. This study presents the removal of the leachate components such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solid, ammonia and colour using an integrated bio-electrochemical and Fenton method. The integration was carried out so that the two methods could complement each other. Microbial fuel cells (MFCs) were designed to treat landfill leachate while continuously producing power (voltage output). Three anodes were tested in the MFC reactor: black carbon, activated carbon, and zinc electrodes. Movements in the MFC reactor during treatment were a key factor for testing. Thus, the system was operated in different modes: static and dynamic. Both modes showed a difference in the ammonia level of the three anodes used. This study compared the static and dynamic modes of the MFC in removing ammonia. The continuous reactor movement could increase the rate of ammonia component removal. The reactor also provided a viable condition for maximum removal. The reactor movement caused the sludge to disintegrate and enabled the ammonia to separate easily from the parent leachate. Ammonia removal also resulted from the transfer of ammonium through the salt bridge or from ammonia loss. The constant exchange of ionic content benefited the MFC performance by increasing power production and decreasing internal electrode material resistance. This paper presents the results of leachate treatment analysis from the solid waste landfill located in Padang Siding Landfill, Perlis. Ammonia removal was enhanced using different types of electrodes. In both modes, activated carbon provided better performance than black carbon and zinc. The percentages of leachate components removal for activated carbon zinc and black carbon with dynamic mode was generally higher over static mode. The final values of the ammonia, COD, BOD, TSS and colour were 13 mg/L (97.66% removal), 490 mg/L (86.10% removal), 249mg/L (77.98% removal) and 106mg/L (42.20% removal) respectively. The leachate samples were further treated with Fenton in order to reduce the level of the components. For Fenton process, the effect of influential parameter were verified by statistics approach, 17 experiments were run based on RSM generated DOE. The experimental results were fully complied with predicted results from the RSM. The optimal conditions in term of FeSO_4 and H_2O_2 concentrations and pH for ammonia, COD, BOD, TSS and Color removal are pH (3.94), FeSO_4 (19.68 mg/L) and H_2O_2 (40.39 mg/L). The removal efficiencies of ammonia, COD, BOD, TSS and Color are approximately ~16.92%, 78.72%, 88.35 %, 75.91% and 88.16% respectively.

CHAPTER 1 : INTRODUCTION

1.1 Background of the study

The contaminations of landfills have created serious threat to human health as well as a threat to the environment for example causing hazardous air emissions and ground water pollution. Generally, landfills generate leachate which is a major issue that threatens environmental quality in Malaysia (Ismail & Manaf, 2013). Leachate resulted from the escalation of solid waste, which comprises unwanted matter produced by human activities (Ariffin, et al., 2014). In Malaysia, the increase in population reflects the escalation of solid waste generation. Given its stable political conditions, Malaysia is known as one of the most economically successful developing countries in the world. According to Statistic Department Annual Report 2017 (Department of Statistics Malaysia, 2017), Malaysia population is increased by 1.3% in one year, consequently, the production of various products including food, automotive, crops, light and heavy industries are booming and expanding annually (Ariffin, et al., 2014).

The increments of processes and productions have caused serious concerns regarding solid waste management (Masron, et al., 2012; Wu, et al., 2010). In addition, by the year 2020, the number of city in peninsular Malaysia will increase by 400% as compared to the number of city in 1957 (Adhikari, et al., 2014). This will definitely cause the productions of waste acceleration and normally the waste will end up in a landfill. As a result, the Malaysian government has to impose stricter rules, regulations and policies to underpin the management of waste in the country.

Moreover, the rapid urbanization and industrialization in Malaysia have changed the characteristics of solid waste (Hasan & Nair, 2014). Thus, effective solid waste management practices must be updated to suit the current waste quantity is necessary. Landfilling has been the primary method of waste disposal in Malaysia for many decades. The Solid Waste Management and Public Management Cleansing Corporation is one of Malaysian policy for solid waste management that was implemented in 2011 (The Commissioner of Law Revision, 2007) to manage all the waste produce in the country. Although the policy is being implemented currently however we have yet to see stringent measures undertaken. Due to that, Malaysia is currently facing serious landfill problems which include lack of capacity, overflowing landfill sites, serious odour without ventilation, and lack of leachate treatment facilities. Figure 1.1 reveals the real problem in Padang Siding, Perlis Landfill area which is the overflowing of rubbish that creates serious odour problems to the surrounding. The landfill is owned by the private institution that is design to abide by the rules and regulation imposed by the Government.



Figure 1.1: Overflowing Padang Siding Landfill, Perlis

According to Fauziah & Agamuthu (2012), the privatization of landfills will contribute to improved management strategies. For example, Alam Flora was appointed to manage Kundang Landfill at Selangor, and Idaman Bersih was appointed to manage Pulau Burung Landfill at Penang. Several landfill facilities have been upgraded through privatization such as based on the landfill capacity, the facilities need to be upgraded to levels 3 and 4. Level 3 facility normally equipped with a leachate circulation system, while a comprehensive leachate treatment facility is dedicated for level 4 landfill (Ariffin, et al., 2014). However, this has not been implemented in Padang Siding, Perlis Landfill.

Dealing with landfill waste is an important issue for the environmental protection policy of any developing country. Landfill leachate is a major problem for municipal solid waste (MSW) landfills because it causes significant threats to surface water and groundwater. Leachate is defined as a liquid that passes through a landfill and

contains extracted dissolved matter and suspended matter. Although numerous current features have somehow improved the processing of MSW landfills, several problems still remain, such as processing of leachate. Generally, leachate is characterized by high values of chemical oxygen demand (COD), pH, ammonia nitrogen, colour and heavy metals. Leachate also generally possesses a strong colour and bad odour. However, the characteristics of leachate also vary with its composition, volume, and condition of biodegradable matter in the leachate.

Different sources of leachate produce leachate with different quantities and compositions. Various factors influence the production and composition of leachate. One of the major factors is the climate of the landfill (H. Li, et al., 2010). For example, climates with a high amount of precipitation allow a large volume of water to enter the landfill, thus producing a high amount of leachate (Wu, et al., 2010). Therefore, proper leachate treatment and control are necessary to improve aquatic inhabitant management for human welfare.

To date, there are many technologies implemented and under research to tackle the problem associated with leachate at landfill area such as physical, chemical and biological processes are still not utilised. This research work will investigate the seriousness of landfill leachate pollution at Padang Siding Landfill, Perlis, Malaysia (6°26'51.45''N, 100°18'15.93''E) and eventually suggested necessary treatment methods including bio-electrochemical and Fenton method. The Padang Siding area is about 20 hectares, and it receives an abundant amount of MSW, with a loading of approximately 300 tonnes/day covering Perlis region.

A Fenton reagent is a mixture of hydrogen peroxide and ferrous ion. The mixing of these two reagents generates hydroxyl radicals. There are several primary factors that affect the Fenton process which include; pH value, organic concentration, ferrous concentration and hydrogen peroxide concentration. Microbial Fuel Cell (MFC) was constructed to suit particular chemical and biological requirements in leachate treatment. Several studies have designed and constructed MFC devices particularly for leachate treatment. Usually, MFCs comprise two sections: anodic chamber and cathodic chamber. Bacteria in the anode chamber convert substrates into electrons and protons (Rahimnejad, et al., 2015). The anode and cathode are connected by a wire, and the two chambers are connected by a salt bridge, which allows the produced protons to pass from the anodic chamber, to complete the circuit MFC.

In previous studies, all experiments described single un-stacked units of MFCs (Zhang, et al., 2014; Wu, et al., 2010; J. Zhang, et al., 2008). Other researchers used multiple stacked MFCs electrically connected by a wire in series or in parallel to enhance the current output (H. Li, et al., 2010). MFCs were designed to treat landfill leachate while continuously producing power (voltage output) (Ganesh & Jambeck, 2013). In a research conducted by J. Zhang et al. (2008), different anodes were tested in an MFC reactor: black carbon, activated carbon, and zinc electrodes.

This research work is designated to deal with the real leachate that currently accumulated in Padang Siding Landfill, Perlis, Malaysia, left without any proper treatment to date. As it is known, landfill leachate is a very dark colored 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. Combinations of physical, chemical, and biological treatments are usually used to improve the treatment efficiency of landfill leachates. There are several techniques used for colour removal. These include chemical precipitation, adsorption through granular activated carbon, nanofiltration, ozonation, radiation, UV photolysis, chemical coagulation, biological treatment with various additives, anaerobic process, fluidized bio film process, and advanced oxidation (Ariffin, et al., 2014). However, there is no specific guideline for the treatment of colour in landfill leachate, especially in Malaysia. The most common approach used is coagulation followed by flocculation process is an effective way for removing high concentration of organic pollutants as well as the colour in leachate but this method could not provide reliable procedure. In this field of research, the performance of colour removal will be evaluated.

1.2 Problem Statement

This section presents the current issues related to this study, the leachate generated in land have caused serious concerns due to the following issues:

The major first issue with Padang Siding landfill leachates is the leakage of a large number of toxins into fresh water waterways, which ultimately end up in homes as drinking water or water for everyday use. Since Padang Siding landfills is located in and around large bodies of fresh water due to the constant rain fall Malaysia, the pollution toxin often goes undetected. The compounds submerge to the ground, to the ground water, and inevitably to the dinner tables. The pollution is also severely harmful to animal and plant life. Thus, Malaysia is one of the first Asian countries that realize

the need for sustainable environmental development and solid waste treatment in urban areas. This country has been developing since the 1980s because of rapid urbanization and the increasing diversity of its lifestyles. Therefore, it paramount to develop process that will allow complete treatment component in Padang Siding Landfill.

The second major is related to the cost of the waste management in Malaysia, due to large waste production in various field including Padang Siding, increasing waste management costs and securing final disposal landfills has become one of the most serious social issues in Malaysia, it has been reported that nearly 40 to 50 tonnes generated daily in Padang Siding (Budhiarta, et al., 2012). In response to this emerging issue, the Malaysian government in the 8th Malaysia Plan (2001–2005) included waste minimization, promotion of reuse, developing a recycling-oriented society, and implementation of a pilot project for recycling as its main policy goals. The 9th Malaysia Plan (2006–2010) further emphasized the continuation of reducing, reuse, recovery, and recycling of waste as well as a greater use of environmentally friendly products. In line with the basic policy framework articulated in the above plans, the Ministry of Housing and Local Government has been conducting national programs for the promotion of recycling and public awareness regarding such activities which has become the main concern as a mountain of waste has been created in most of the region's landfill.

The other issue is related to the technology, where until today there no any attempt to treat Padang Siding Landfill, however, several components of leachate have been found in Padang Siding landfill include inorganic substances, and ammonia nitrogen, high pH, high COD, and high amounts of ammonia nitrogen and heavy metals (H. Li, et al., 2010). Hence, leachate must be treated effectively with effective and cheaper process.

1.3 Research Objectives

The main objective of this study is to characterize and identify the leachate components from Padang Siding Landfill, Perlis and determine the effectiveness of bio-electrochemical and Fenton leachate treatment by studying the effects of various treatment parameters on the removal of ammonia, COD, BOD, and suspended solids. The important elements of the objective are as outlined below:

1. To characterize and identify physicochemical properties of leachate in the solid waste of Padang Siding Landfill, Perlis.
2. To examine and determine the effectiveness of using the Microbial Fuel Cells and Fenton treatment method in removing ammonia, COD, BOD, and suspended solids from leachate in Padang Siding Landfill, Perlis.