MANAGING LANDFILL LEACHATE USING BIOLOGICAL APPROACH

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ABSTRACT

Poor management of landfill would accompany with the production of leachate wastewater that would lead to environmental and public hazards. Hence, a study related to the use of biological treatment for leachate management was carried out.The research objectives of this research study were pathogenic microorganism detection, raw leachate wastewater characterization and identification of effective leachate treatment. A leachate sample was collectedfrom both Simpang Renggam Landfill and Bakri Landfill via compositing sampling method.The leachate sample was collected from two sampling points at the leachate drain. Selective selection and serological test had been carried out and the microorganism detected in the leachate samples were *Escherichia coli*, *Staphylococcussp* and *Listeriasp*.Triplicate samples of each raw leachate wastewater were used for leachate characterization. The parameters used for leachate characterization were chemical oxygen demand measured via Reactor Digestion method and ammonia nitrogen concentration measured via Nesslerization method. Besides that,the heavy metals content in the leachate sample were measured via Atomic Absorption Spectroscopy. The ammonia nitrogen concentration and chemical oxygen demand in the raw leachate samples show that both leachate samples were characterized as mature leachate. *Brevibacillus panacihumi* strain ZB1 was used for biological treatment and lightweight aggregate was used for adsorption process. Triplicate of each leachate samples were treated via sole biological treatment, combined dilution with biological treatment and combined adsorption with biological treatment. Removals of ammonia nitrogen from both Simpang Renggam and Bakri leachate samples treated by three treatments were nearly37% to 47%, 63% to 77% and 83% while chemical oxygen demands removed were 37% to 42%, 63% to 75% and 41% to 74%, respectively. Although final concentration of pollutants after treatment processes exceeded the discharge standard, all treatment methods proved able to reduce the pollutants concentration.

ABSTRAK

Penggunaan sistem kambus tanah secara tidak sistematik mengakibatkan penjanaan air kurasan yang menimbulkan masalah persekitaran dan kesihatan.Oleh itu, satu kajian yang berkenaan pengolahan air kurasan dengan menggunakan kaedah biologi telah dijalankan.Objektif kajian ini adalah penentuan mikroorganisma patogenik, pencirian air kurasan dan pencadangan kaedah efektif untuk pengolahan air kurasan.Pensampelan air kurasan dari tapak pelupusan Simpang Renggam dan tapak pelupusan Bakri dijalankan melalui "compositing sampling".Sampel air kurasan dijalankan di dua titik pensampelan. "Selective selection" dan "serological test" telah dijalankan dan mikroorganisma yang terdapat didalam air kurasan ialah *Escherichia coli, Staphylococcus* sp., dan *Listeria* sp. Tiga sampel air kurasan telah digunakan untuk proses pencirian. Parameter digunakan untuk proses pencirian ialah keperluan kimia oksigen diujidengan "Reactor Digestion method" dan kepekatan nitrogen ammonia diuji dengan "Nesslerization method".Selainitu, kandungan logam berat dikaji dengan "Atomic Absorption Spectroscopy".Kepekatan nitrogen ammonia dan keperluan kimia oksigen yang terdapat didalam air kurasan menunjukkan bahawa kedua-dua sampel air kurasan adalah bersifat matang.*Brevibacillus panacihumi* strain ZB1telah digunakan untuk pendekatan biologi dan "lightweight aggregate" digunakan untuk kaedah penjerapan.Tiga sampel air kurasan telah diolah melalui pendekatan biologi, kaedah pencairan dengan pendekatan biologi dan kaedah penjerapan dengan pendekatan biologi.Penyingkiran nitrogen ammonia daripada air kurasan dicapai oleh ketiga-tiga pendekatan adalah dalam lingkungan 37% ke 47%, 63% ke 77% dan 83% manakala keperluan kimia oksigen yang disingkir adalah dalam lingkungan 37% ke 42%, 63% ke 75% dan 41% ke 74%. Walaupun kepekatan bahan pencemar selepas proses pengolahan masih melebihi tahap pelepasan, semua kaedah pengolahan yang digunakan dibuktikan dapat mengurangkan kepekatan bahan pencemar yang terdapat didalam air kurasan.

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LIST OF SYMBOLS AND ABBREVIATION

NH_3	-	Ammonia nitrogen
BA	-	Bakri
BOD	-	Biochemical oxygen demand
B.	-	*Brevibacillus*
COD	-	Chemical oxygen demand
CAN	-	Colistin Nalidixic Acid
^oC	-	Degree Celsius
EMB	-	Eosin Methylene Blue
E. coli	-	*Escherichia coli*
X	-	Fold
L.	-	*Listeria*
µL	-	Microliter
mg/ L	-	Milligram per litre
mL	-	Millilitre
Nm	-	Nanometer
O_2	-	Oxygen
%	-	Percent
Rpm	-	Revolutions per minute
SR	-	Simpang Renggam
SMAC	-	Sorbitol-MacConkey

sp.	-	Species
U. S. EPA	-	United States Environmental Protection Agency
v/v	-	Volume per volume
w/v	-	Weight per volume
W. P.	-	Wilayah Persekutuan

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Urbanization and industrialization had greatly contributed to a huge amount of different types of municipal solid wastes generation (Ismail & Manaf, 2013; Yabroudi, Morta, & Alem, 2013). Landfilling had been selected for solid waste management. In the past, the majority of landfills were open dumping due to lack of public awareness and environmental education (Clean Malaysia, 2015).However, the use of poor-managed landfill will always be accompanied by the production of leachate wastewater. Leachate refers to a strong odour and turbid liquid collected from the landfill site. Leachate is generated due to waste decomposition and rainwater percolation. Many different types of wastes had been disposed at the landfill and hence, leachate will containorganic matters, hazardous contaminants and pathogenic microorganisms.All contaminants present in the raw leachate wastewater will lead to unexpected environmental hazards and public health and safety hazards.

According to the Global Environment Centre, improper leachate treatment haspollutedthe rivers in Malaysia.For instances, a landfill in Cameron Highland had oozed toxic wastes into nearby valleys and rivers. Three of 126 rivers running through Cameron Highland were seriously polluted and became unsuitable for any purpose even after the treatment process (Clean Malaysia, 2015).Due to unexpected adverse impacts caused by leachate wastewater, raw leachate wastewater needs to be collected and treated properly before discharging into the environment. Several methods can be used to treat leachate wastewater, which is divided into

biological and physiochemical methods. Since physiochemical methods are costly and may lead to unpredictable adverse impacts, biological treatment involves the use of microorganisms for degradation of pollutants is widely recommended for a long term leachate management (Fu & Wang, 2011).

As studied by Lim *et al.* (2016), there was five bacterial strains had been isolated from the Simpang Renggam landfill leachate sample. As compared to isolated bacterial strains that only removed nearly 3% to 15% of ammonia nitrogen from leachate sample, introduction of *Brevibacillus panacihumi* strain ZB1 able to remove more than 20% of ammonia nitrogen from same leachate sample under identical treatment condition (Lim *et al.,* 2016). Hence, *Brevibacillus*was used as biological agent for leachate management in this study. The biological treatmentefficiency is expected can be improved when used together with physiochemical methods(Reinhart & Grosh, 1998; Abbas *et al.,* 2009).In this study, biological treatment has been carried out together with the adsorption process and the adsorbent used is lightweightaggregates.As reported by Lim *et al.* (2016), lightweightaggregates had increased the ammonia nitrogen removal rate when lightweight aggregate was used as final polishing step for leachate management.

1.2 Problem statement

Malaysia economic grew rapidly with a huge amount of wastes production including food wastes. There are many methods can be used to manage solid wastes such as landfilling and incineration. In Malaysia, landfilling is the main choice for solid waste management due to economic advantage and simple operation (Flores-Tena *et al.,* 2007; Fitzke *et al.,* 2013). However, the landfill should only be used when coupled with proper landfill design such as impermeable lining system, well-managed leachate collection system and effective leachate treatment facilities (Masirin *et al.,* 2008; Liu, 2013). Regardless of the category of landfills, the production of leachate wastewater is the main problem faced when using landfill sites for solid waste management (Naveen *et al.*, 2014). This scenario would become more serious once the leachate wastewater is discharged or flow into the environment.

Leachate wastewater is generated due to the waste decomposition process that occurs at the landfill site and the leachate volume will be increased when the rainwater seeps through the landfill sites (Raghab, Meguid, & Hegazi, 2013). The leachate composition and toxicity is varying due to the disposal of different wastes at landfill sites (Fitzke *et al.*, 2013). Direct release or leaching of untreated leachate into the environment will lead to environmental hazards (Enuneku, Ezemonye, & Adibeli, 2013). Instead of carrying hazardous contaminants, leachate wastewater also carries pathogens such as *Salmonella* sp., *Shigella* sp. and *Escherichia coli* contributing to waterborne diseases (Koster *et al.*, 2001; Kalwasinska & Burkowska, 2013) such as diarrhoea and health hazards (WHO, 2016) when released into the environment.

Several leachate leaching cases have been reported in the newspaper for the past decade. As reported by The Star Online (2006, March 30), failure of leachate treatment facility construction at Bukit Tagar sanitary landfill had led to flow of leachate wastewater into Sungai Selangor and contributed to foul-smelling tap water in some Klang Valley areas. Besides that, overloading of leachate wastewater from retention pond of Pulau Burung sanitary landfill had adversely affected the forest reserve and sea fish farms (The Star Online, 2016, May 12 and The Star Online, 2017, October 16). As reported by Sin Chew Daily (2017, April 17), poor management of Ladang CEP landfill had been identified as the primary cause for ammonia pollution at River Benut and lead to inconvenience more than 9500 families at the nearby residential areas including Simpang Renggam.

According to the previous report, leachate wastewater had greatly affected the environment and public health and safety (Jaishankar *et al.*, 2014; Sharma & Gupta, 2014). Hence, leachate wastewater needs to be collected and treated properly to meet the acceptable discharge standard before released into the environment. The leachate wastewater treatment methods can be divided into physiochemical and biological methods. Although physiochemical methods are efficient to treat the leachate within a short duration, biological treatment is also highly recommended for wastewater management due to lower treatment cost with less adverse impacts towards the environment and public health and safety. To increase the treatment efficiency, biological treatment can be coupled with physical or chemical method since there is no single method can treat the leachate efficiently (Reinhart & Grosh, 1998; Abbas *et al.*, 2009).

1.3 Research questions

As referring to the issues discussed, there are several research questions had been introduced which were:

i. What are the pathogenic microorganisms that present in the leachate sample?
ii. How to characterize raw leachate wastewater?
iii. What are thetreatment methods can be used to treat the raw leachate wastewater effectively?

1.4 Objectives of study

The objectives of the study are:

i. To determine the presence of pathogenic microorganisms in the raw leachate sample.
ii. To characterize the raw leachate wastewater based on the parameters such as COD, ammonia nitrogen and heavy metals contents.
iii. To propose the treatment method that can treat the leachate wastewater effectively.

1.5 Scope of study

Since landfill is widely chosen for solid waste disposal, it is important to find an efficient method to treat leachate wastewater. The aims of this study were detected the waterborne pathogens present in the raw leachate sample, characterize the raw leachate sample and treat the leachate sample before discharging into the environment. The leachate samples were collected from Simpang Renggam Landfill and Bukit Bakri Landfill. Isolated *Brevibacillus panacihumi* strain ZB1 was used to treat the leachate wastewater biologically. Besides that, other methods such as dilution and adsorption process were used together with biological treatment to treat

the leachate wastewater effectively. The parameters that used for leachate treatment efficiency measurement were chemical oxygen demand (COD), ammonia nitrogen level and heavy metals levels. The leachate characterization was carried out before and after the treatment process to study the overall treatment efficiency of each treatment process. At the end of this research study, the better treatment method would be identified.

1.6 Significance of study

Since water is one of the most important resources required for survival of living thing, hence water bodies cannot afford to any forms of water pollution. Landfilling has been widely used for solid waste management.Use of landfilling make us cannot be avoided from the negative impacts contributed by leachate wastewater. By continuous identifying the suitable treatment methods, the raw leachate wastewater is expected can be treated properly and minimize the unexpected adverse impacts towards the environment and public health and safety.In this research, leachate wastewater was not only treated solely via biological treatment by using *Brevibacillus panacihumi* strain ZB1 but also treated together with the lightweight aggregates. Use of lightweight aggregates prior to biological treatment able remove a high level of pollutants from the leachate wastewater and createsa better growth environment for *B. panacihumi.* Suitable growth condition has encouraged microbial growth and better treatment efficiency can be achieved at lower treatment cost.

1.7 Structure of thesis

The structure of this thesis had been divided into five chapters which were Introduction, Literature Review,Methodology,Results and Discussion andthe last chapter was Summary and Suggestion. Figure 1.1 had summarized the core contents that made up each chapter.

Chapter 1: Introduction

This chapter compiled of the introduction, research background, problem statement, research question, research objectives, scope of study and significance of study.

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Chapter 2: Literature review

This chapter discussed landfill and leachate, waterborne pathogens, water quality indicators, and leachate characterization. Other than that, leachate treatment, review on microorganisms used for leachate treatment and importance of biological treatment had also been discussed. Information needed for this research study had been collected through literature study by studying academic journal, other thesis, articles, and some official reports.

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Chapter 3: Methodology

This chapter had discussed the sampling site, Simpang Renggam Landfill andBakri Landfill. Besides that, the leachate sample collection method and procedure had also been mentioned.Other than that, the pathogenic microorganisms' detection via selective selection and serological test had also been stated in this chapter. The treatment methods used for leachate management: sole biological treatment, combined dilution with biological treatment and combined adsorption with biological treatment had also been discussed in this chapter.Finally, the parameter analysis (Reactor digestion method, Nesslerization method and Atomic Absorption Spectroscopy) had also been mentioned at the end of this chapter.

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Chapter 4: Results and discussion

This chapter discussed the results obtained based on the objectives:

i. Waterborne pathogens identification
ii. Raw leachate wastewater characterization
iii. Effective leachate treatment

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Chapter 5: Summary and suggestion

This chapter had summarized the results and discussion mentioned in the previous chapter. Besides that, this chapter had also provided some suggestion for future study.

Figure 1.1: Structure of thesis

1.8 Conclusion

Landfilling had been selected for solid waste management (Fitzke *et al.*, 2013). Use of poor-managed landfill will always be accompanied by the production of leachate wastewater. Discharge of leachate wastewaterinto the environment will lead to unexpected environmental hazards and public health and safety hazards(Enuneku *et al.*, 2013; Naveen *et al.*, 2014). Hence, raw leachate wastewater needs to be collected and treated properly before discharging into the environment. In this research, *Brevibacillus panacihumi* strain ZB1 was used for the biological treatment to degradethe pollutantsfrom the leachate wastewater.Use of lightweight aggregates together with the biological treatment is expected able to promote theoverall treatment efficiency (Abbas *et al.*, 2009).

CHAPTER 2

LITERATURE REVIEW

2.1 Landfill

The huge amounts of different types of solid wastes have been generated in Malaysia and landfilling has been widely selected for solid waste disposal. As reported by Japan International Cooperation Agency (2004), idealsolid wastes management involved inspection of incoming wastes, effective management of landfill and effective leachate monitoring. During the introduction of solid wastes into the landfill, the type and quantity of each solid waste should be identified. Before disposal into landfill, solid wastes need to be kept in a safe mannerin the waste retaining facility and hazardous wastes should be separated from the non-hazardous wastes. Effective landfill management is highly essential to prevent any nuisance to public hazards (Japan International Cooperation Agency, 2004).

As reported by the National Waste Management Department (2015), there area total of 165 landfill sites currently operating in Malaysia until 31 March 2015. However, only few landfill sites have been categorized as sanitary landfills (as shown in Table 2.1). Sanitary landfill is an engineered landfill with proper landfill design (Long *et al.*, 2007), including the use of impermeable lining system and leachate collection system (Masirin *et al.*, 2008; Ismail & Manaf, 2013; Liu, 2013). Non-sanitary landfill should not be selected for solid waste management due to lack of integrated waste management system including landfill bottom liners, leachate collection and treatment system (Fauziah & Agamuthu, 2012).

Table 2.1: Category of solid waste landfills by the state until 31 March 2015 (Source: National Solid Waste Management Department, 2015)

State	Category		Total
	Sanitary	Non- sanitary	
Johor	2	12	14
Kedah	-	8	8
Kelantan	-	13	13
Melaka	-	2	2
Negeri Sembilan	-	7	7
Pahang	-	16	16
Perak	-	17	17
Perlis	-	1	1
Pulau Pinang	-	2	2
Sabah	-	19	19
Sarawak	3	46	49
Selangor	3	5	8
W. P. Kuala Lumpur	-	0	0
Total	8	156	164

Leachate willlead to environmental pollutions, health hazards and ecosystem degradation (Nwabueze, 2011; Fauziah & Agamuthu, 2012). Different types of solid wastes disposed at the landfill site will greatly affect the leachate compositions. Various waste compositions will finally affect the leachate quality (Kylefors, 2002) and indirectly affect the surrounding environment. Nearly 45% of wastes dumped at landfill site are food or organic wastes. Presence of a high amount of organic wastes will speed up the waste decomposition process (Leite *et al.*, 2016). However, nearly 45% of solid wastes being dumped at the landfill site are difficult to be degradedvia natural attenuation process such as plastics and metal (Leite *et al.*, 2016).

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