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OPTIMIZATION OF AMMONIA-NITROGEN REMOVAL BY AN INTEGRATED SYSTEM OF LIME PRECIPITATION AND AMMONIA STRIPPING FOR SCHEDULED WASTE LANDFILL LEACHATE

NURUL HANIRA BINTI MAT LAZIM

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By

NURUL HANIRA BINTI MAT LAZIM

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April 2018

Chair: Associate Professor Hasfalina Che Man, PhD
Faculty: Engineering

Various advanced waste disposal methods are available, nevertheless, landfilling is still widely adopted in most countries, due to its low cost and simplicity. However, the generation of a highly complex and polluted liquid leachate from landfill is a major concern as it threatens human health and environment. The presence of different constituents in leachate had made it difficult to be treated, and different treatment approach is needed dependent on the target pollutants. Despite the increasing number of documented scientific literatures in various wastewater and leachate treatment, the understanding of the leachate characteristics and treatment methods from scheduled waste landfill (SWL) are limited. Besides, SWL treatment need different approach as direct biological treatment is not suitable, due to its high NH_3-N concentration that inhibits microorganism's activity. These limitations have led to a thorough investigation in finding improved SWL leachate pre-treatment process on the removal of NH_3-N by chemical and physical treatment prior to biological treatment. The main aim of the study is to find the right chemical and dosage for pH adjustment and apply ammonia stripping to reduce the concentration of NH_3-N in SWL leachate. A preliminary study was carried out to find the most suitable chemicals, either hydrated lime, $Ca(OH)_2$ or sodium hydroxide (NaOH); and the optimum dosage for effective NH_3-N removal from SWL leachate and to raise pH prior to ammonia stripping. Batch jar test experiments with different types and dosage of chemicals ranging from 0 to 12 g L^{-1} were performed in this study. A Historical Data Design (HDD) of Response Surface Methodology (RSM) was employed to evaluate the parameters affecting the NH_3-N, COD and colour removal efficiency. The

result showed that $Ca(OH)_2$ was found to be more effective in the removal of NH_3-N (52%), COD (18%) and colour (65%) compared to NaOH, with less dosage required (5.9 g L^{-1}). The lime pre-treatment only achieved half of removal efficiency, thus, further experiment using ammonia stripping technique to enhance NH_3-N removal was adopted. A laboratory scale ammonia stripping column was constructed to evaluate the removal of NH_3-N. Response surface methodology (RSM) was used to design the experiments incorporating four major factors at three levels; namely air/liquid ratio (20, 50 and 80), $Ca(OH)_2$ dosages (4, 5 and 6 g L^{-1}), packing height (20, 40 and 60 cm) and types of packing materials (Polyurethane foam, Polyurethane nylon and non-woven Polyester) where the interrelationship of the parameters on the removal of NH_3-N were studied. The comparative analysis was done using RSM and artificial neural network (ANN) in a predictive model of the experimental data obtained in accordance with the central composite design. The ammonia stripping successfully removed NH_3-N at 76% within 8 hours of treatment. Prolonged leachate treatment up to 12 hours successfully removed 88% of NH_3-N. In addition, removal efficiencies of COD, Turbidity, Phosphate, Total Iron, Colour and Manganese were 5%, 55%, 49%, 100%, 38% and 18% after 12 hours of treatment, respectively. The validation results showed there was a good agreement between the predicted values obtained from the RSM and ANN model and the experimental NH_3-N removal efficiency. The result also presented that RSM and ANN model gives comparable results, with R^2 value of 0.9659 and 0.9347, respectively. This specifies that both models can be applied to describe the ammonia stripping process and can be used to predict the NH_3-N removal from SWL leachate. The overall results in this study indicated that the integration of pre-treatment with $Ca(OH)_2$ precipitation and ammonia stripping process is a feasible approach for NH_3-N removal.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGOPTIMUMAN PENYINGKIRAN AMMONIA-NITROGEN DENGAN INTEGRASI SISTEM PEMENDAPAN KAPUR DAN PERLUCUTAN AMMONIA UNTUK AIR LARUT RESAP TAPAK PELUPUSAN SISA PEMBUANGAN TERJADUAL

Oleh

NURUL HANIRA BINTI MAT LAZIM

April 2018

Pengerusi: Prof. Madya Hasfalina Che Man, PhD
Fakulti: Kejuruteraan

Terdapat pelbagai kaedah pelupusan sisa yang maju, namun, kambus tanah masih diterima pakai secara meluas di kebanyakan negara, kerana kos yang rendah dan mudah. Namun, penghasilan cecair larut resap yang sangat kompleks dan tercemar dari tapak pelupusan adalah kebimbangan utama kerana ia mengancam kesihatan manusia dan alam sekitar. Kehadiran kandungan yang berbeza di dalam air larut resap telah membuatkan ia sukar untuk dirawat, dan pendekatan rawatan berbeza diperlukan bergantung kepada sasaran bahan tercemar. Walaupun terdapat peningkatan jumlah literatur saintifik didokumenkan mengenai pelbagai rawatan air sisa dan air larut resap, kefahaman mengenai ciri-ciri dan kaedah rawatan air larut resap dari tapak pelupusan sisa terjadual (SWL) adalah terhad. Selain itu, rawatan SWL memerlukan pendekatan yang berbeza kerana rawatan biologi secara terus tidak sesuai, disebabkan kepekatan NH_3-N yang tinggi menghalang aktiviti mikroorganisma. Batasan-batasan ini telah membawa kepada siasatan menyeluruh dalam mencari rawatan air larut resap SWL yang lebih baik yang memberi tumpuan kepada penyingkiran NH_3-N melalui rawatan kimia dan fizikal sebelum rawatan biologi. Matlamat utama kajian ini adalah untuk mencari bahan kimia dan dos yang tepat sebagai pelarasan pH dan menggunakan perlucutan ammonia untuk mengurangkan kepekatan NH_3-N dalam air larut resap SWL. Kajian awal telah dijalankan untuk mencari bahan kimia yang paling sesuai, sama ada kapur terhidrat, $Ca(OH)_2$ atau natrium hidroksida (NaOH); dan dos yang paling optimum untuk penyingkiran NH_3-N yang efektif dari air larut resap SWL dan untuk meningkatkan pH sebelum

perlucutan ammonia. Kajian sesekelompok eksperimen ujian jar dengan pelbagai jenis dan dos bahan kimia yang berbeza daripada 0 hingga 12 gL^{-1} telah dilakukan dalam kajian ini. Rekabentuk Data Sejarah (HDD) melalui Kaedah Tindak-balas Permukaan (RSM) telah digunakan untuk menilai parameter yang mempengaruhi kecekapan penyingkiran NH_3-N, COD dan warna. Hasil kajian menunjukkan bahawa $Ca(OH)_2$ telah didapati lebih berkesan dalam penyingkiran NH_3-N (52%), COD (17.5%) dan warna (65%) berbanding NaOH, dengan kurang dos diperlukan (5.9 gL^{-1}). Pra-rawatan secara kapur hanya mencapai separuh daripada kecekapan penyingkiran, oleh itu, rawatan fizikal lanjut menggunakan teknik perlucutan ammonia untuk meningkatkan penyingkiran NH_3-N telah diterima pakai. Sebuah kolum ammonia berskala makmal telah dibina untuk menilai penyingkiran NH_3-N. RSM telah digunakan untuk menyediakan rekabentuk eksperimen yang melibatkan empat faktor pada tiga peringkat; iaitu nisbah udara-cecair (20, 50 and 80), dos $Ca(OH)_2$ (4, 5 and 6 gL^{-1}), ketinggian medium penapis (20, 40 and 60 cm) dan jenis-jenis bahan pembungkusan (foam Polyurethane, nylon Polyurethane and Polyester bukan tenunan) dimana hubungkait di antara parameter terhadap penyingkiran NH_3-N telah dikaji. Analisis perbandingan telah dilakukan menggunakan RSM dan rangkaian neural tiruan (ANN) dalam model ramalan data eksperimen yang didapati mengikut reka bentuk komposit pusat. Perlucutan ammonia berjaya menyingkirkan 76% NH_3-N dalam masa 8 jam rawatan. Pelanjutan rawatan air larut resap sehingga 12 jam berjaya menyingkirkan 88% NH_3-N. Di samping itu, kecekapan penyingkiran untuk COD, kekeruhan, fosfat, Jumlah Besi, warna dan Mangan adalah 5%, 55%, 49%, 100%, 38% dan 18%, masing-masing, selepas 12 jam rawatan. Keputusan pengesahan menunjukkan terdapat persamaan yang baik di antara nilai-nilai ramalan yang diperolehi daripada model RSM dan ANN, dan nilai eksperimen kecekapan penyingkiran NH_3-N. Hasil juga mendapati bahawa model RSM dan ANN memberikan hasil yang setanding, dengan nilai R^2 0.9659 dan 0.9347, masing-masing. Ini menentukan bahawa kedua-dua model boleh diaplikasi untuk menerangkan proses perlucutan ammonia dan boleh digunakan untuk meramalkan penyingkiran NH_3-N daripada air larut resap sisa terjadual. Keseluruhan keputusan dalam kajian ini menunjukkan bahawa gabungan pra-rawatan menggunakan pemendapan $Ca(OH)_2$ dan proses perlucutan ammonia adalah satu pendekatan yang boleh dilaksanakan untuk penyingkiran NH_3-N.

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APPROVAL

I certify that a Thesis Examination Committee has met on 19 April 2018 to conduct the final examination of Nurul Hanira binti Mat Lazim on her thesis entitled "Optimization of Ammonia-Nitrogen Removal by an Integrated System of Lime Precipitation and Ammonia Stripping for Scheduled Waste Landfill Leachate" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Aimrun Wayayok, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Salmiaton Ali, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Latifah Abd Manaf, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Internal Examiner)

Shafiqur Rahman, PhD
Associate Professor
Department of Agricultural and Biosystems Engineering
North Dakota State University
United States of America
(External Examiner)

RUSLI HAJI ABDULLAH, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 30 August 2018

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Hasfalina Che Man, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Luqman Chuah Abdullah, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ahmad Makmom Abdullah, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

Mohd Rashid Mohd Yusof, PhD
Professor
Malaysia-Japan International Institute of Technology
Universiti Teknologi Malaysia
(Member)

____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: ____________________
Name of Chairman of Supervisory Committee: Hasfalina Che Man

Signature: ____________________
Name of Member of Supervisory Committee: Luqman Chuah Abdullah

Signature: ____________________
Name of Chairman of Supervisory Committee: Ahmad Makmom Abdullah

Signature: ____________________
Name of Member of Supervisory Committee: Mohd Rashid Mohd Yusof

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
BOD	Biological Oxygen Demand
$Ca(OH)_2$	Hydrated lime
CCD	Central composite design
COD	Chemical Oxygen Demand
CV	Coefficient of Variation
MSW	Municipal Solid Waste
NaOH	Sodium Hydroxide
NH_3	Ammonia gas
NH_3-N	Ammonia-nitrogen/ Ammoniacal-nitrogen
ORP	Oxidation Reduction Potential
RSM	Response Surface Methodology
SWL	Scheduled Waste Landfill

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia is experiencing a rapid economic growth, urbanization and industrialization. The rapid development in the country accelerates human consumption rates, which leads to the high generation of industrial and solid waste on a daily basis. This significantly contributes to the major environmental, economic and health problems (Malik and Mehta, 2014; Oz and Yarimtepe, 2014).

Several waste disposal methods have been widely practiced such as sanitary landfill, open dumping, incineration, composting, milling, hog feeding, grinding, reduction and anaerobic digestion. But to date, due to its low cost and simplicity, landfilling is the most prevalent waste disposal methods practiced in Malaysia (Aziz et al., 2010; Ismail and Manaf, 2013). A few types of landfill are available in this country such as open dumping landfill, sanitary landfill and scheduled waste landfill. Despite being the most accepted method of waste disposal, the production of a highly complex and polluted liquid leachate from landfill activities is one of the greatest concerns, as it posed environmental and human health hazards (Kulikowska and Klimiuk, 2008).

Leachate is a concentrated liquid generated from percolation of precipitation through waste deposited in a landfill. Generally, leachate comprises heavy metals, biodegradable organic matter, recalcitrant organic matter (such as humic substances), inorganic salts as well as high concentration of ammoniacal-nitrogen (Kjeldsen et al., 2002; Kargi and Pamukoglu, 2003; Lopez et al., 2004; Kurniawan et al., 2006; Renou et al., 2008; Aziz et al., 2009). Leachate pollutes soil and contaminates groundwater (Renou et al., 2008). It comprises high concentrations of pollutant compared to raw sewage or industrial wastes (Qasim and Chiang, 1994).

The most problematic pollutant in leachate is ammonia and its concentration may vary from 800 to 5210 mg L^{-1} (Kjeldsen et al., 2002; Lopez et al., 2004; Karadag et al., 2008; Ferraz et al. 2013). NH_3-N is generated from slow leaching process and the release of soluble nitrogen from solid waste in landfills, which may last for several decades (Hoilijoki et. al., 2000; Jokela et. al., 2002; Tyrrel et. al., 2002). The removal of NH_3-N is crucial as it is one of major toxicant that causes toxicity to most organisms (Clément and Merlin, 1995; Tam and Wong, 1996; Jokela et al., 2002). The release of leachate containing NH_3-N into natural watercourses accelerates the growth of aquatic plants and algae, which leads to eutrophication in lakes and creating unbalanced ecosystem (Clément and Merlin, 1995; Jokela et al., 2002; Cai et al., 2013). Additionally, the effectiveness of biological treatment processes would decrease as high concentration of ammonia of 1000 mg L^{-1} may inhibit the activity of microorganisms (Shiskoswski and Mavinic, 1998; Wiszniowski et al., 2007). Both nitrite oxidizing bacteria and ammonia oxidizing bacteria would be affected if exposed to high free ammonia concentration. It was reported that nitrite-oxidizing bacteria are sensitive to ammonia in the range of 0.1 to 1.0 mg L^{-1}, whereas ammonia-oxidizing bacteria can tolerate ammonia in the range of 10–150 mg L^{-1} (Ibrahimpašić et al., 2010). Thus, a pre-treatment is required prior to biological treatment process, to remove the NH_3-N.

The composition and organic matter content in landfill leachate influence the selection of its treatment, either by physical, chemical or biological process (Cheung et al., 1997). A number of methods were studied for finding the most efficient treatment for ammonia removal from wastewater and leachate of various types of landfills such as coagulation-flocculation, adsorption, chemical oxidation, chemical precipitation, air stripping, electrocoagulation and magnetic field separation (MoayeriKashani et al., 2012). Nevertheless, study on the treatment of scheduled waste landfill (SWL) leachate is very limited or almost non-existence in the literature. Scheduled waste landfill (SWL) leachate is a leachate originated from toxic and hazardous waste landfill facility. These toxic and hazardous wastes are from industrial activities consisting of fly ash, incinerated ash, bottom ash, sludges, metallic residues and others which are pacified then landfilled in a secured landfill.

Recently, leachate treatment using chemicals has created considerable attention, particularly for leachate that is not easily treated by conventional biological method. A direct biological treatment is not always suitable for leachate that is toxic to biological growth. Biological treatment is effective for young leachate, but not for stabilized leachate, especially for leachate that contains high concentration of ammonia and COD (Zazouli et al., 2012; Gotvajn and Pavko, 2015). Therefore, the combination of both biological and physical-chemical techniques is commonly applied, in this case where the latter is introduced prior to the former. Among the currently employed chemical and physical leachate treatment, the addition of chemicals via precipitation and ammonia stripping received significant attention for yielding high ammonia removal (Kurniawan et al., 2006; Blauvelt, 2009; Alam and Hossain, 2009; El-Gohary et al., 2013; Ferraz et al., 2013; Sani et al., 2014; Hanira et al., 2015; Hossini et al., 2015). At high pH (>10) majority of ammonia is in the gas form and mechanical mixing is sufficient for assisting ammonia evaporate from leachate (Poveda et al., 2016).

1.2 Problem statement

To date, there is limited information available regarding SWL leachate. Numerous scientific informations are available for municipal solid waste (MSW) landfill leachate, ranging from its characteristics to the treatment methods, whilst information on scheduled waste landfill (SWL) leachate is very scarce (Kurniawan et al., 2006; Sani et al., 2014; Hanira et al., 2015). Studies using real leachate are more challenging, which draws less interest among people to explore this area. The fundamental aspect that needs to be considered in designing a sustainable scheduled waste treatment is the availability of information on the characteristics of the leachate being generated. Thus, the characterization of SWL leachate is paramount in the early stage of the study.

Another concern is the high concentration of NH_3-N in SWL leachate, ranging from 1790 - 2570 mgL^{-1}, which makes downstream biological treatment difficult. NH_3-N concentration of more than 1000 mg L^{-1} is toxic to microorganisms and inhibits the biodegradation process by nitrite and ammonia oxidizing bacteria (Liu et al., 2012; Sani et al., 2014; Zhang, 2015). This limitation had led us to emphasis more on the physical-chemical treatment for SWL leachate.

Currently, most treatment plant facilities are facing some difficulties in recent treatment technology. At present, treatmentfacilities practices zero discharged to the environment. The treated leachate is not discharge to the environment, but they are re-utilized to quench the flue gas temperature from 400 °C to 200 °C before entering fabric filter air pollution control system. However, in the future there will be more scheduled wastes generated, which consequently increases the production of SWL leachate. As more SWL leachate needs to be treated, the facility might not be able to cater for the high demands. Thus, the effluents after the treatment need to be released into the environment, instead of captivating them in a retention pond. Therefore, most facilities are trying to change their treatment strategies by doing a lot of research to improve the leachate effluent quality in order to meet the Department of Environment (DOE) Malaysia permissible limit standards.

The addition of chemicals until certain pH, without knowing the precise amount of chemicals used prior to stripping treatment is practiced by treatment plant facilities. They practiced the addition of ferric chloride ($FeCl_3$) as coagulant during physical and chemical treatment, where there is no specific amount of chemicals added. Chemicals are added into the treatment pond until the leachate achieved pH 11, which is known to be the most optimum pH for ammonia stripping. Then, stripping process takes place, by using blower at the bottom of the treatment pond to enhance NH_3-N removal from the leachate. However, using $FeCl_3$ has several drawbacks as it produced more sludges, the effluent colour turns more yellowish or brownish after the treatments and it is more expensive compared to other available chemicals such as sodium hydroxide (NaOH) and hydrated lime ($Ca(OH)_2$). Hence, study on the most optimum dosage of chemical used is crucial for sustainable of SWL leachate management.

In addition, $FeCl_3$ also cannot reduce NH_3-N to the desired level and only able to remove NH_3-N down to 400 mg L^{-1} after 5 days of treatment. The effluent after the treatment still cannot comply with DOE permissible limits standards, which is 20 mg L^{-1} as stated in Environmental Quality (Industrial Effluent or Mixed Effluent) Regulations 2009, Fifth Schedule (Standard B) (Ismail, 2015). Previous study by Poveda et al. (2016) observed that ammonia removal rates from all the tests using $FeCl_3$ were insignificant in the range from 1-4%. Hence, the treatmentfacilities are trying to switch to other chemicals that can increase the pH, remove NH_3-N and other pollutants effectively prior ammonia stripping. Besides, the efficiency of ammonia stripping column with controlled operating parameters for NH_3-N removal from SWL leachate has yet not been assessed.

Sani et al. (2014) study was the benchmark for SWL leachate research in Malaysia. They investigated the optimum dosage required to achieve the highest NH_3-N removal efficiency at 0 gL^{-1}, 2 gL^{-1}, 4 gL^{-1}, 6 gL^{-1} and 10 gL^{-1} of $Ca(OH)_2$ dosage. They achieved only 54% of NH_3-N removal, with 4 gL^{-1} of $Ca(OH)_2$ dosage via lime precipitation using jar test. However, NH_3-N removal is still considered low. Since a treatment plant facility is in the midst of experimenting with the possible chemicals to replace $FeCl_3$, which were $Ca(OH)_2$ and NaOH, a comparison of these two chemicals were done by

Hanira et al. (2015) in terms of NH_3-N removal efficiency at dosage of 0 gL^{-1}, 2 gL^{-1}, 4 gL^{-1}, 6 gL^{-1}, 8 gL^{-1} and 10 gL^{-1}. But, the NH_3-N removal was relatively the same for both $Ca(OH)_2$ and NaOH, which were up to 45% (6 gL^{-1}) and 48% (8 gL^{-1}). Hence, further research was carried out at a wider range of dosage (0 gL^{-1}, 1 gL^{-1}, 2 gL^{-1}, 3 gL^{-1}, 4 gL^{-1}, 5 gL^{-1}, 6 gL^{-1}, 7 gL^{-1}, 8 gL^{-1}, 9 gL^{-1}, 10 gL^{-1}, 11 gL^{-1} and 12 gL^{-1}) to find the optimum dosage and chemicals that can remove NH_3-N, COD and colour more effectively, which was conducted in this study. Nevertheless, both studies by Sani et al. (2014) and Hanira et al. (2015) only used jar test, and it is still difficult to remove NH_3-N from SWL leachate and achieved high removal efficiency. Therefore, this study will incorporate other treatment such as ammonia stripping to enhance NH_3-N removal.

The proposed study is an attempt to fulfill the current gap towards better understanding of SWL leachate's characteristics and finding an improved treatment strategy and the most practical means of reducing NH_3-N in SWL leachate to a practical or workable concentration based on actual scenario. The results of this study can be adapted by treatment facilities, in which the integration of chemical and physical treatment was applied in this study to achieve higher NH_3-N removal.

1.3 Research Objectives

The main objective of this study is to remove NH_3-N by the combination of lime precipitation and ammonia stripping treatment. To achieve this goal, four sub-objectives are defined as:

1. To characterize the scheduled waste landfill (SWL) leachate derived from industrial wastes.

2. To determine the most suitable type of chemical and dosage of either hydrated lime ($Ca(OH)_2$) or sodium hydroxide (NaOH) to attain optimum NH_3-N removal from SWL leachate through batch study.

3. To investigate the effect of different operating parameters such as air/liquid ratio, chemical dosage, types of packing materials and packing heights on NH_3-N removal from SWL leachate using ammonia stripping column.

4. To optimize the removal of NH_3-N by the ammonia stripping technique.

1.4 Scope of the study

In this study, scheduled waste landfill (SWL) leachate from a scheduled waste treatment plant facility in Malaysia was collected and sent to laboratory for characterization analysis. The leachate sample was subjected to pretreatment by lime precipitation and ammonia stripping to reduce the concentration of NH_3-N in the leachate. The suitability and optimum chemical dosage in the removal of NH_3-N, COD and colour, which is either hydrated lime ($Ca(OH)_2$) or sodium hydroxide (NaOH) used for the pH adjustment of SWL leachate was assessed. Then, the performance of the ammonia stripping column with controlled operating parameters was evaluated using different operating parameters such as air/liquid ratio, chemical dosage, packing heights and types of packing materials. The optimum conditions for NH_3-N removal efficiency at specific air/liquid ratio, chemical dosage, packing heights and types of packing materials were determined. Many different factors can affect NH_3-N removal efficiency, but these factors were chosen due to their importance, time limitation as NH_3-N concentration in SWL leachate is degrading over time which cause the inconsistency of initial NH_3-N concentration, and also limitation in number of running experiments due to limited samples and facilities.

1.5 Significance of the study

There is inadequate and limited information regarding SWL leachate in Malaysia. Therefore, this study is significant in providing information on the characteristics of SWL leachate and finding a suitable treatment for SWL leachate that can be helpful in reducing the high concentration of NH_3-N. The study will present a fundamental knowledge for the treatment of NH_3-N removal from SWL leachate in Malaysia in avoidance of potential health and environment impact problems from it. By identifying the characteristics of leachate and understanding its composition, the suitable treatment of NH_3-N in leachate can be determined in order to meet the permissible limit standards of NH_3-N which is 20 mgL^{-1} as set by Department of Environment (DOE) Malaysia.

Besides, the study will contribute on providing the effective and optimum dosages of chemical for pretreatment process of SWL leachate. It is crucial to remove NH_3-N due to its toxicity to aquatic organisms even at very low concentrations, which makes their removal from wastewater or leachate as an important issue in industries. If released to water bodies, leachate containing NH_3-N will accelerate the growth of algae and aquatic plants, cause eutrophication in lakes and deteriorate the balance of ecosystem as it is toxic to most organisms. Thus, controlling and minimizing the NH_3-N removal from its source or from treatment plant facilities is crucial towards better environment.

In addition, the study will improve the knowledge of scientists, environmentalists and plant operators about the factors that contribute to the NH_3-N removal and the treatment solutions for removing NH_3-N from SWL leachate before releasing to the environment. This study suggests lime precipitation and ammonia stripping as a pre-treatment, which are simple in operation and more cost-effective compared to other methods. It can be used as a baseline data for future studies regarding to effective treatment methods for NH_3-N removal in other high-strength wastewater and leachate in Malaysia through different strategies. The findings of this research can be used in fullscale industrial application and might also facilitate and assist in the decision-making process towards the development of treatment strategies for the NH_3-N removal.

1.6 Organisation of the Thesis

The thesis comprises of five chapters. Chapter 1 discusses the background of the research, which is an introduction to the existing facts around the subject of scheduled waste leachate, ammonia-nitrogen (NH_3-N) and challenges in the treatment of NH_3-N. It also discussed the problem statement, suggests some promising solutions and possible treatment methods for NH_3-N removal, followed by an outline of the objectives, scope, significance and organisation of the thesis.

Chapter 2 presents review of other related literatures in connection with the main theme developed in this study. It includes general information on scheduled waste management in Malaysia, characteristics of landfill leachate, methods of NH_3-N removal and the application of response surface methodology (RSM) and artificial neural network (ANN).

Chapter 3 presents the methodology of the whole study involving the collection and analysis of the data obtained. These include collection and preservation of leachate sample, preliminary study on the determination of types of chemicals and dosage via jar test experiment, measurement of the parameters, optimization of NH_3-N removal efficiency at different operating parameters (air/liquid ratio, chemical dosage, packing height and types of packing materials) by the application of RSM and ANN model.

Chapter 4 presents the results of the experiments on the characteristics of raw scheduled waste leachate, the most suitable chemical dosage study results, modelling and optimization of NH_3-N removal efficiency using RSM. It also discusses the effects of different operating parameters of the ammonia stripping technique on the efficiency of NH_3-N removal and the optimum conditions for the highest NH_3-N removal. Results based on RSM and ANN model were also compared. It also presents the kinetic of ammonia stripping process under optimized conditions.

Chapter 5 is the overall conclusion of the study, which summarizes all results from the findings of the study and its contribution. It also presents the recommendations for possible future works on the subject matter.

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BIODATA OF STUDENT

Nurul Hanira Binti Mat Lazim was born in Terengganu, Malaysia on 28th November 1989. She graduated with a Bachelor of Science (Biological Sciences) from Universiti Malaysia Terengganu. Upon her graduation in 2010, she pursued her postgraduate study in Master of Environment (specialization in Environmental Sciences) at Faculty of Environment, Universiti Putra Malaysia. During her master's degree, she was awarded with MyBrain15-MyMaster Scholarship by Ministry of Higher Education Malaysia for 2 years. She successfully graduated in 2012.

She started her doctoral research in Agricultural Waste Engineering with the Faculty of Engineering, Universiti Putra Malaysia, in September 2012. She was awarded with MyBrain15- MyPhD Scholarship by Ministry of Higher Education Malaysia for three and half years during her PhD study. Throughout her post graduate journey, she enrolled and successfully passed series of courses such as Basic Statistical Analysis with SPSS for Engineers workshop, Response Surface Methodology Workshop, Thesis Writing workshop, and One Day Workshop on Literature Review using ATLAS.ti. She also has wide experiences as a teaching assistant, laboratory demonstrator, environmental analyst, and technical team member for conferences from September 2012 to September 2016.

She had presented two papers in International Conference on Mathematics, Engineering and Industrial Applications (ICOMEIA) 2014 with the title of "Comparison of Lime Powder and Caustic Soda as a Pre-treatment for Ammonia-Nitrogen Removal from a Scheduled Waste Leachate" and The 2nd IWA Malaysia Young Water Professionals Conference 2015 with the title of "Removal of Ammonia-Nitrogen (NH_3-N) from Scheduled Waste Leachate by Air Stripping". She also has several publications including 3 journal papers, 2 proceedings and one chapter in a book during her doctoral study period.

LIST OF PUBLICATIONS

Hanira, N.M.L., Hasfalina C.M., Rashid, M., Luqman C. A. and Abdullah, A. M. (2017). Removal of Ammonia-Nitrogen (NH_3-N) from Scheduled Waste Leachate by Air Stripping. *Desalination and Water Treatment*, 68: 330-337. (Q3, IF: 1.631)

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Hanira, N.M.L., Hasfalina C.M., Rashid, M., Luqman C.A. and Abdullah, A.M. Optimization of Ammonia Volatilization by Air Stripping Process from Scheduled Waste Leachate using Response Surface Methodology (submitted to Waste Management Journal).

Hanira, N.M.L., Hasfalina C.M., Rashid, M., Luqman C. A. and Abdullah, A. M. (2017). Effect of Dilution and Operating Parameters on Ammonia Removal from Scheduled Waste Landfill Leachate in a Lab-scale Ammonia Stripping Column. *IOP Conference Series: Materials Science and Engineering,* 206, 012076. Doi:10.1088/1757-899X/206/1/012076. (Indexed by: SCOPUS)

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