

**NATURAL FLOCCULANT FROM *Durio zibethinus*  
SEED STARCH FOR MUNICIPAL SOLID WASTE  
LANDFILL LEACHATE TREATMENT**

**MOHD FAIZ MUAZ BIN AHMAD ZAMRI**

**UNIVERSITI SAINS MALAYSIA**

**2016**

**NATURAL FLOCCULANT FROM *Durio zibethinus* SEED STARCH FOR  
MUNICIPAL SOLID WASTE LANDFILL LEACHATE TREATMENT**

**by**

**MOHD FAIZ MUAZ BIN AHMAD ZAMRI**

**Thesis submitted in fulfilment of the requirements**

**for the degree of**

**Doctor of Philosophy**

**September 2016**

## ACKNOWLEDGEMENTS

First of all, Alhamdulillah, thanks to Allah Who gives strength and patience to me along the accomplishment of this thesis. I would like to express my gratitude to my supervisor, Associate Prof.Dr. Mohd Suffian Yusoff for sharing his experience in guiding and assisting me throughout the years of my study. I would also like to thank my co supervisors, Prof. Dr. Hamidi Abdul Aziz and Prof. Dr. Ahmad Zuhairi Abdullah for their advice and encouragement. I also wish to express my deepest gratitude to the Ministry of Higher Education and USM RCMO for supporting me with their scholarship under MyBrain 15 and RUI grant project 1001/PAWAM/814166. To all the staff in the School of Civil Engineering, Universiti Sains Malaysia, my special gratitude goes to them for being so kind and generous to me during my study.

Finally, I like extend my deepest gratitude to my mother, Umimaktom Bt Ramli; my wife, Raihana Binti Bahru; my son, Ahmad Miftahuddin; my siblings Along, Angah, Abg Chik, Kak Ita, Kak Shida, Tiara; and my research colleagues, Anuar, Awang, Zaidi, Kak Lin, Tehah, Kak Chik, Aina, Kak Liza, Azim, Kya, Ihsan, Dinie and Mufiza, for their continuous encouragement and *du'a*, without which I would not have been able to submit this thesis on time. In loving memory of my father Ahmad Zamri Bin Yang Ahmad who passed away on 18 October 2010, may the grace of Allah enables us to meet again in *Jannah. Ameen.*

## TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT .....	ii
TABLE OF CONTENTS.....	iii
LIST OF FIGURES .....	viii
LIST OF PLATES .....	xii
LIST OF TABLES.....	xiii
LIST OF ABBREVIATIONS.....	xvi
ABSTRAK.....	xviii
ABSTRACT.....	xx
CHAPTER ONE .....	1
INTRODUCTION .....	1
1.1 Overview.....	1
1.2 Problem statement.....	2
1.3 Research objectives.....	6
1.4 Research Scope and Limitation .....	6
1.5 Organisation of the Thesis .....	8
CHAPTER TWO .....	10
LITERATURE REVIEW .....	10
2.1 Landfill Leachate Generation .....	10
2.1.1 Leachate Formation Phases.....	12

2.1.2	Leachate Composition and Characteristics .....	15
2.2	Landfill Leachate Treatment.....	20
2.3	Coagulation.....	27
2.3.1	Basic Principles of Coagulation .....	27
2.3.2	Dispersed Particles .....	28
2.3.3	Coagulation Mechanism.....	30
2.3.4	Coagulants .....	34
2.4	Flocculation .....	38
2.4.1	Basic Principles of flocculation.....	38
2.4.2	Flocculation Mechanism .....	39
2.4.3	Flocculants .....	41
2.4.4	Starch Based Flocculants .....	46
2.5	Leachate treatment based on natural flocculants .....	61
2.6	Design of Experiment .....	66
2.7	Summary of Literature Review.....	68
CHAPTER THREE .....		70
MATERIALS AND METHODS.....		70
3.1	Research Framework .....	70
3.2	Material and chemicals .....	71
3.3	Landfill Leachate Sampling.....	71
3.4	<i>Durio zibethinus</i> Seed Starch Extraction .....	73
3.4.1	Dry Milling Extraction .....	73

3.4.2	Wet Milling Extraction.....	74
3.5	Crosslinking Starch Modification.....	76
3.6	Preparation of Coagulant and Flocculants Stock Solution .....	76
3.6.1	Polyaluminium Chloride (PAC) stock solution .....	76
3.6.2	DSS Stock Solution.....	77
3.6.3	Anionic Polymer (AP) Stock solution.....	77
3.7	Jar Test Procedure.....	78
3.8	Preliminary Study of Experiment .....	79
3.8.1	Effects of pH and Dosage of Starch Coagulant.....	79
3.8.2	Effects of pH and Dosage of PAC Coagulant .....	79
3.8.3	Effect of Flocculants Dosage at Best PAC Condition.....	80
3.8.4	Effect of CWM-DSS Flocculants to PAC Dosage.....	81
3.9	Starch Characterization.....	82
3.9.1	Zeta Potential Charge Analysis .....	82
3.9.2	Total Kjeldahl Nitrogen (TKN).....	82
3.9.3	Surface Morphology and Elemental Analyses .....	82
3.9.4	Functional Groups .....	83
3.10	Contaminants Removal Characterization .....	83
3.10.1	Colour.....	83
3.10.2	Chemical Oxygen Demand (COD) .....	83
3.10.3	Suspended Solid (SS).....	84
3.10.4	Ammonia.....	84

3.10.5	Turbidity .....	84
3.10.6	Biochemical Oxygen Demand (BOD) .....	84
3.10.7	Heavy Metal Analysis .....	85
3.11	Floc and Sludge Characterization .....	85
3.11.1	Particle Size Analysis .....	85
3.11.2	Floc Morphology .....	86
3.11.3	Floc Formation .....	86
3.11.4	Sludge Settling Velocity .....	87
3.11.5	Sludge Volume Index (SVI) .....	87
3.11.6	Sludge Dewatering .....	88
3.12	Experimental Optimization .....	88
3.13	Mixing and Settling Tank Design .....	91
CHAPTER FOUR .....		92
RESULTS AND DISCUSSION .....		92
4.1	Leachate Characterization .....	92
4.2	Starch Characterization .....	94
4.3	Preliminary Experiments .....	104
4.4	Flocs Formation and Strength .....	132
4.5	Sludge Characteristics .....	145
4.5.1	Sludge Dewatering .....	145
4.5.2	Sludge Volume Index (SVI) and Settling Velocity .....	146
4.5.3	Sludge Surface Morphology .....	149

4.6	The Optimization of PAC CWM-DSS Dosage .....	151
4.6.1	Analysis of Variance .....	151
4.6.2	3D Plots and Factor Interaction for Contaminants Removal .....	159
4.6.3	Process Optimization.....	161
4.7	Design and Calculations of Mixing and Settling Tank.....	164
4.8	Summary of Findings.....	169
CHAPTER FIVE .....		171
CONCLUSIONS AND RECOMMENDATIONS .....		171
5.1	Conclusions.....	171
5.2	Recommendations.....	173
REFERENCES .....		174



## LIST OF FIGURES

		Page
Figure 2.1	Schematics of water balance access for landfill leachate formation	11
Figure 2.2	Illustrations of leachate and gas generation	13
Figure 2.3	Schematic diagrams of landfill leachate treatments	22
Figure 2.4	Condition of (a) stabilized and aggregated (b) particles	27
Figure 2.5	The boundary for typical size ranges of particulate material	28
Figure 2.6	Double layer of Gouy-Chapman and Stern model	31
Figure 2.7	Co-precipitation contaminant of the coagulated colloid	33
Figure 2.8	Classification of coagulants in waste water treatment	34
Figure 2.9	Agglomeration of destabilized particles with the flocculants	39
Figure 2.10	Schematics of sweep flocculation mechanism	40
Figure 2.11	The classification of polymeric flocculants in wastewater treatment	41
Figure 2.12	Schematic structures of (a) amylose and (b) amylopectin	47
Figure 3.1	Research flow diagram of the overall research work	70
Figure 3.2	Matang landfill site outline	72
Figure 3.3	Starch extraction process using dry milling method	73
Figure 3.4	Starch extraction process using wet milling method	75
Figure 3.5	Flow diagram for floc formation and strength analysis	87
Figure 4.1	Effect of pH on the IEP point for DM-DSS and WM-DSS	99
Figure 4.2	Surface morphology of DM-DSS at magnification (a) 2K and (b) 5K	100

		Page
Figure 4.3	Surface morphology of WM-DSS at magnification (a) 2K and (b) 5K	101
Figure 4.4	EDX elementary results for (a) DM-DSS and (b) WM-DSS	103
Figure 4.5	Effects of pH on the (a) colour and (b) COD removal-PAC	104
Figure 4.6	Effects of pH on (a) suspended solids and (b) turbidity removal- PAC	105
Figure 4.7	Effects of pH on (a) colour and (b) COD removal-DM-DSS	107
Figure 4.8	Effects of pH on (a) suspended solids and (b) turbidity removal - DM-DSS	108
Figure 4.9	Surface morphology of DM-DSS coagulant after the treatment process	110
Figure 4.10	Effects of pH on (a) colour and (b) COD removal-WM-DSS	111
Figure 4.11	Effects of pH on (a) suspended solid removal and (b) turbidity removal-WM-DSS	112
Figure 4.12	Surface morphology of WM-DSS coagulant after the treatment process.	113
Figure 4.13	Effects of PAC dosages on the contaminants removal	115
Figure 4.14	Effects of PAC dosages on the floc size and zeta potential	116
Figure 4.15	Effects of DM-DSS dosages on the contaminants removal	118
Figure 4.16	Effects of DM-DSS dosages on the floc size and zeta potential	120
Figure 4.17	Effects of WM-DSS dosages on contaminants removal	121
Figure 4.18	Effects of WM-DSS dosages on the floc size and zeta potential	123
Figure 4.19	Effects of IAP dosages to the contaminants removal	124
Figure 4.20	Effects of IAP dosages to the floc size and zeta potential	126

	Page	
Figure 4.21	Surface morphology of DSS before (a) crosslinking and (b) after crosslinking	127
Figure 4.22	Effects of CWM-DSS dosages on the contaminants removal	129
Figure 4.23	Effects of CWM-DSS dosages on floc size and zeta potential	130
Figure 4.24	Effects of PAC dosages on contaminants removal at best dosage of CWM-DSS flocculants (0.4 g/L)	131
Figure 4.25	Flocculation analysis of floc formation and floc strength	134
Figure 4.26	Microscopic images of PAC flocs at magnification of (a) 430 and (b) 450	136
Figure 4.27	Microscopic images of PACDM-DSS flocs at magnification of (a) 430 and (b) 450	138
Figure 4.28	Microscopic images of PACWM-DSS flocs (a) 430 and (b) 450	140
Figure 4.29	Microscopic images of PAC-IAP flocs at magnification (a) 430 and (b) 450	142
Figure 4.30	Schematics showing starch structures of (a) starch polymer and (b) crosslinked starch	143
Figure 4.31	Microscopic image of PACCWM-DSS floc at magnification (a) 430 and (b) 450	144
Figure 4.32	Analysis of sludge resistance in filtration (SRF) with addition of flocculants	146
Figure 4.33	Analysis of sludge volume index with the addition of flocculants	147
Figure 4.34	Analysis of settling velocity with the addition of flocculants	148
Figure 4.35	Sludge surface morphology images of (a) PAC (b) PACDM-DSS (c) PACWM-DSS (d) PACIAP and (e) PACCWM-DSS at magnification of 5K	150
Figure 4.36	The linear graph of predicted values versus actual experimental contaminants removal of (a) colour (b) COD (c) suspended solids and (d) turbidity	158

	Page	
Figure 4.37	Response surface plot for contaminants removal for (a) colour (b) COD (c) suspended solids and (d) turbidity	160
Figure 4.38	Response surface plot for contaminants removal of (a) COD contour model and (b) turbidity factor interaction	161
Figure 4.39	Sketch diagram for the operation flow design of mixing and sedimentation process	165

## LIST OF PLATES

		Page
Plate 4.1	The extracted powder of DM-DSS	96
Plate 4.2	The extracted powder of WM-DSS	96
Plate 4.3	Centrifuged layer of WM-DSS extraction	97

## LIST OF TABLES

		Page
Table 2.1	List of Constituents for Each Leachate Components	16
Table 2.2	Health Risks Caused by Metal Bioaccumulation	19
Table 2.3	Comparison of Physico-chemical Methods for Leachate Treatment	25
Table 2.4	Degree of Coagulation as a Function of Zeta Potential	32
Table 2.5	Application of Natural Flocculants for Waste Water Treatment	44
Table 2.6	Starch Granules Properties	48
Table 2.7	Starch-Based Flocculants Modifications	50
Table 2.8	Comparison of Wet Milling Method for Seeds Starch Extractions	58
Table 2.9	Application of Natural Flocculants for Landfill Leachate Treatment.	63
Table 3.1	List of Materials, Chemicals, and Reagents	71
Table 3.2	Experiment Runs for the Effect of PAC Dosage	80
Table 3.3	Experiment Runs for the Effect of Flocculants Dosage	81
Table 3.4	Experiments Design for the Effect of PAC CWM-DSS Flocculant Dosage	81
Table 3.5	Experiment Designs for Floc Formation and Strength	86
Table 3.6	Actual Coded Values of Variables for Optimisation Design	89
Table 3.7	Actual Experimental Design for the Optimization of PAC CWM-DSS Flocculant in Leachate Treatment	90
Table 4.1	Characteristics of Matang Landfill Leachate	92
Table 4.2	Physico-chemical Properties of Extracted Starch	95

Table 4.3	FTIR analyses for DM-DSS and WM-DSS	98
Table 4.4	Best pH Values for Different Contaminants Responses in PAC-Leachate Coagulation	106
Table 4.5	Best pH Values for Different Contaminants Responses in DM-DSS -Leachate Coagulation	109
Table 4.6	Best pH Values for Different Contaminants Responses in PAC-Leachate Coagulation	113
Table 4.7	Effect of Coagulant (PAC) Dosage on colour, COD, Suspended Solids and Turbidity Removal	114
Table 4.8	Effect of Flocculants (DM-DSS) Dosage on Colour, COD, Suspended Solids and Turbidity Removals	118
Table 4.9	Effect of Flocculants (WM-DSS) Dosage on Colour, COD, Suspended Solids and Turbidity Removal WM-DSS	121
Table 4.10	Effect of Flocculants (IAP) Dosage on Colour, COD, Suspended Solids and Turbidity Removal	124
Table 4.11	Effect of Flocculants (CWM-DSS) Dosage on Colour, COD, Suspended Solids and Turbidity Removal CWM-DSS	128
Table 4.12	Determination of Best Dosage for CWM-DSS Flocculants on Contaminants Removal	131
Table 4.13	Experimental for Central Composite Design (CCD) of Process parameter	152
Table 4.14	Model Summary Statistics for (a) Colour, (b) COD,(c) Suspended Solids and (d) Turbidity Removals	152
Table 4.15	Analysis of Variance (ANOVA) for Response Surface Quadratic Model for Colour Removal	155
Table 4.16	Analysis of Variance (ANOVA) for Response Surface Quadratic Model for COD Removal	155
Table 4.17	Analysis of Variance (ANOVA) for Response Surface Quadratic Model for Suspended Solids Removal	155
Table 4.18	Analysis of Variance (ANOVA) for Response Surface Quadratic Model for Turbidity Removal	156

Table 4.19	Constraints Data of Process Variables for Contaminants Removal Optimization	162
Table 4.20	Removal Percentages for Colour, COD, Suspended Solid and Turbidity Optimizations	163
Table 4.21	Data Verification for Process Optimization	163
Table 4.22	Typical Design Criteria for Mixing and Settling Tank	164
Table 4.23	Design Calculation for Batch Type Mixing Tank	165
Table 4.24	Design Calculation for Batch Type Settling Tank for PAC Coagulant	167
Table 4.25	Design Calculation for Batch Type Settling Tank for PAC coagulant	168
Table 4.6	Treatment Cost Calculation for PAC coagulant and PACCWM-DSS	168



## LIST OF ABBREVIATIONS

<b>ANOVA</b>	Analysis of Variance
<b>APHA</b>	American Public Health Association
<b>BOD</b>	Biochemical Oxygen Demand
<b>COD</b>	Chemical Oxygen Demand
<b>CCD</b>	Central Composite Design
<b>CWM-DSS</b>	Crosslinking Wet Milling Durian Seed Starch
<b>DM-DSS</b>	Dry Milling Durian Seed Starch
<b>DSS</b>	Durian Seed Starch
<b>DO</b>	Dissolved Oxygen
<b>EDX</b>	Energy Dispersive X-ray
<b>FESEM</b>	Field Emission Scanning Electron Microscopy
<b>FI</b>	Flocculation Index
<b>FTIR</b>	Fourier Transform Infrared
<b>IAP</b>	Industrial Anionic Polymer
<b>ICP</b>	Inductive Couple Plasma
<b>IEP</b>	Isoelectric Point
<b>MLS</b>	Matang Landfill Site
<b>NTU</b>	Nephelometric Turbidity Unit
<b>PAC</b>	Polyaluminium Chloride
<b>PACDM-DSS</b>	Polyaluminium Chloride Dry Milling Durian Seed Starch
<b>PACWM-DSS</b>	Polyaluminium Chloride Wet Milling Durian Seed Starch
<b>PACCWM-DSS</b>	Polyaluminium Chloride Crosslinking Wet Milling Durian Seed Starch
<b>PACIAP</b>	Polyaluminium Chloride-Anionic Polymer
<b>pH</b>	Hydrogen Ions
<b>PDA</b>	Photometric Dispersion Analyser
<b>PtCo</b>	Platinum Cobalt
<b>RSM</b>	Response Surface Methodology
<b>SEM</b>	Scanning Electron Microscopy
<b>SRF</b>	Specific Resistance in Filtration
<b>SS</b>	Suspended Solid

<b>SVI</b>	Sludge Volume Index
<b><math>S_{SW}</math></b>	Solid Waste Water Stored
<b>TKN</b>	Total Kjeldahl Nitrogen
<b>WM-DSS</b>	Wet Milling Durian Seed Starch
<b><math>W_{A(R)}</math></b>	Rainfall Water
<b><math>W_{B(L)}</math></b>	Bottom Leaving Water
<b><math>W_{CM}</math></b>	Cover Material Water
<b><math>W_E</math></b>	Water Evaporation
<b><math>W_{LG}</math></b>	Landfill Gas Loss Water
<b><math>W_{SW}</math></b>	Solid Waste Water
<b><math>W_{TS}</math></b>	Treated Sludge Water
<b><math>W_{WV}</math></b>	Water Vapor

**PENGGUMPAL SEMULAJADI DARIPADA KANJI BIJI *Durio zibethinus***  
**UNTUK OLAHAN LARUT LESAP KAMBUS TANAH SISA PEPEJAL**  
**PEMBANDARAN**

**ABSTRAK**

Penggunaan penggumpal polialuminium klorida (PAC) sangat menonjol di dalam olahan larut lesap kambus tanah. Aplikasi PAC di dalam proses penggumpalan telah terbukti di antara penggumpal yang efektif untuk olahan larut lesap kambus tanah. Walaubagaimanapun, PAC dikenal pasti berpotensi menghasilkan lebih toksik aluminium kepada persekitaran akuatik. Sebagai alternatif, kombinasi bersama penggumpal tambahan semulajadi boleh mengurangkan dos dan pergantungan kepada PAC. Di dalam kajian ini, penggumpal tambahan berasaskan bahan semulajadi daripada kanji biji durian (*Durio zibethinus*) telah digunakan untuk olahan larut lesap kambus tanah. Sampel larut lesap kambus tanah tapak telah diambil dari tapak pelupusan Matang yang terletak di Taiping, Perak. Kanji biji durian telah diekstrak menggunakan kaedah pengekstrakan kering dan kaedah pengekstrakan basah. Kanji terbaik yang diperolehi, diubahsuai dengan kaedah persilangan cantuman penggumpal kanji untuk memperbaiki proses rawatan. Keadaan eksperimen dalam penyikiran warna, keperluan oksigen kimia (COD), pepejal terampai dan kekeruhan telah dioptimumkan lagi menggunakan kaedah statistik tindak balas permukaan (RSM). Di samping itu juga nilai kelajuan pemendakan (SV) dibandingkan dan digunakan untuk reka bentuk pengiraan tangki campuran dan tangki pemendakan. Berdasarkan pada hasil eksperimen, penggunaan penggumpal tambahan dari kanji pengekstrakan basah (WM-DSS) telah meninggikan peratus penyikiran bagi warna, pepejal terampai dan kekeruhan

masing-masing melebihi sebanyak 0.4 %, 2.9 % dan 13.2 % berbanding PAC sahaja (88.8%, 65.9 %, 90.7 % dan 80.5 %). Malahan indeks kelajuan pemendakan juga bertambah baik dari 531.3 mL/g kepada 158.1 mL/g. Sebaliknya, penggunaan penggumpal tambahan daripada kanji pengekstarakan kering (DM-DSS) telah menurun dan mengurangkan peratus penyingkiran bagi warna, pepejal terampai dan kekeruhan masing-masing melebihi sebanyak 25 %, 1.6 % dan 2.8 % berbanding PAC sahaja (90.2 %, 59.6 % 97.2 % dan 95.0 %). Dalam hal ini, ia jelas menunjukkan aplikasi pengekstrakan secara lembab boleh diyakini untuk digunakan sebagai kaedah pembangunan penggumpal tambahan berasaskan kanji. Pada masa yang sama, modifikasi persilangan cantuman penggumpal kanji (CWM-DSS) telah meninggikan peratus penyingkiran bagi warna, COD, pepejal terampai dan kekeruhan masing-masing melebihi sebanyak 1.7 %, 5.1 %, 14.8 %, and 14 % berbanding PAC sahaja (94.4 %, 55.8 %, 70.4 % dan 81.1 %). Tambahan pula, modifikasi persilangan cantuman kanji ini telah mampu mengurangkan 0.557 g/L dos PAC. Malahan, penggunaan CWM-DSS ia telah berjaya mengurangkan bilangan tangki pemendakan dari 6 kepada 3 unit tangki dan meningkatkan isipadu aturan olahan larut lesap kambus tanah yang telah dirawat dari 2376 m<sup>3</sup>/hari kepada 2404.08 m<sup>3</sup>/hari. Oleh yang demikian, ini sangat jelas dapat diperhatikan bahawa penggunaan penggumpal CWM-DSS dapat digunakan di dalam proses rawatan olahan larut lesap kambus tanah.

# NATURAL FLOCCULANT FROM *Durio zibethinus* SEED STARCH FOR MUNICIPAL SOLID WASTE LANDFILL LEACHATE TREATMENT

## ABSTRACT

The used of polyaluminium chloride (PAC) coagulant is prominent in landfill leachate treatment. PAC coagulant is proven to be among the effective coagulants for landfill leachate treatment. However, it was found that PAC coagulant has a toxic potential of aluminium residual to the aquatic environment. As an alternative, the combination of natural flocculants with inorganic coagulants could reduce the dosage and dependence on the PAC coagulant and improved the flocculant properties. In this study, natural based flocculants from durian seed starch were used for landfill leachate treatment. The landfill leachate samples were collected from Matang landfill located at Taiping, Perak. The durian seed starches were extracted using dry milling and wet milling extraction method. The best starch obtained was further modified by crosslinking modification method to improve the treatment process. The experimental condition in removing colour, Chemical Oxygen Demand (COD), suspended solid and turbidity were further optimized statistically using Response Surface Method (RSM). The settling velocity values were compared and used for mixing and settling tanks calculation design. According to the results, the use of wet milling durian seed starch (WM-DSS) as a flocculants increased the removal percentage of colour, suspended solids and turbidity by 0.4 %, 2.9 %, and 13.2 % compared to PAC coagulants alone (88.8%, 90.7 % and 80.5 %). Besides, the sludge velocity index (SVI) was also improved from 531.3 mL/g to 158.1 mL/g. In contrast, the use of dry milling durian seed starch (DM-DSS) flocculants had decreased the removal percentage of chemical oxygen demand (COD), suspended solids and turbidity by 25 %, 1.6 %, and 2.8 % compared to PAC coagulants alone (59.6 % 97.2

% and 95.0 %). In this respect, wet milling extraction method was effective to be used for starch flocculants synthesis. In fact, the crosslinking modification of the wet milling starch flocculants (CWM-DSS) further increased the removal percentage of colour, chemical oxygen demand (COD), suspended solids and turbidity by 1.7 %, 5.1 %, 14.8 %, and 14 % compared to PAC alone (94.4 %, 55.8 %, 70.4 % and 81.1 %). Moreover, this starch modification had able to reduce 0.557 g/L concentration of PAC coagulant for landfill leachate treatment. Besides, the used of CWM-DSS flocculants able to reduce the number of settling tank from 6 to 3 units and increased the volume of treated leachate from 2376 m<sup>3</sup>/day to 2404.08 m<sup>3</sup>/day. Therefore, it was clearly observed that the used of CWM-DSS flocculants is effective to be used for landfill leachate treatment process.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Overview

Landfilling is the most extensively employed method for municipal solid waste (MSW) disposal system in Malaysia. It is preferred in tackling solid waste disposal due to its simple operational procedure and cost-effectiveness (Aziz et al., 2007). The demand for the landfilling method keeps on increasing due to the increase in population and economic growth experienced in urban and rural areas (Ofori et al., 2013). In Malaysia, there are more than one hundred of landfills that are still operates (Ogboo and Hussain, 2013). In Malaysia, landfill operations are still active and generating more than 30000 tons per day of solid wastes (Fauziah and Agamuthu, 2012).

Although landfilling is broadly recognised as a proper waste disposal method, the environmental pollution caused by the MSW landfill leachate has been one of the drawbacks of the system. In Malaysia, each ton of MSW generates 150 litres of leachate (Agamuthu and Fauziah, 2008). Based on daily MSW generation rate in 2010, it is estimated that over than 3.0 million litres of leachate is produced every day in Malaysia (Agamuthu and Masaru, 2010). Therefore, it is important to estimate the production of leachate during the life span of the landfills for environmental monitoring and potential risk management (Hannu, 2015).

Leachate is a polluted liquid that is produced from the water percolation through solid waste (Hassan et al., 2016). This percolated water contains dissolved and suspended materials from various disposed materials and bio-decomposition process. Commonly, landfill leachate is a high-strength wastewater with extreme

levels of pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), inorganic salts and toxicity (Aziz et al., 2004). These contaminants are influenced by the waste biodegradation process (Hassan et al., 2016). In fact, the characteristics of leachate for each particular landfill are different depending on the time waste composition, landfilling practice, climatic conditions, landfill's conditions and the operation period of the landfill (Aziz et al., 2004). Nevertheless, contaminants like organic matters, ammoniacal-nitrogen, heavy metals and colour are normally the measured parameters in leachate quality assessment.

As a matter of fact, the treatment of leachate is necessary due to the contaminants that present in leachate. The leakage of untreated leachate into the environment will cause potential risks to water bodies. In fact, landfill leachate has been identified as a potential source of surface and groundwater contamination (Yang et al., 2013). Even worse, the leachate contaminants can also affect human physical and mental health (Tsarpali and Dailianis, 2012). Therefore, the understanding and management of landfill leachate are crucial. In this regards, feasible treatment methods for landfill leachate are gaining more and more attention.

## **1.2 Problem statement**

Different methods have been developed for landfill leachate treatment. Generally, physical, chemical and biological methods are the common methods that are usually used for leachate treatment. Nevertheless, it is difficult to obtain effectiveness and satisfactory treatment in a single approached. In order to ensure satisfactory quality, landfill leachate requires multiple stages of treatment. Integrated treatment system combining physical, chemical and biological methods has gained a greater interest in treating the landfill leachate (Moreira et al., 2015; Wang et al., 2014; Del Moro et al., 2013). One of the methods is physico-chemical treatment