TREATMENT OF PALM OIL MILL EFFLUENT FROM POLISHING POND USING CALCINATED LIMESTONE ROUGHING FILTER

by

AREZOO FEREIDONIAN DASHTI

Thesis submitted in fulfilment of the
Requirements for the Degree of
Doctor of Philosophy

April 2017

TREATMENT OF PALM OIL MILL EFFLUENT FROM POLISHING POND USING CALCINATED LIMESTONE ROUGHING FILTER

AREZOO FEREIDONIAN DASHTI

UNIVERSITI SAINS MALAYSIA

2017

ACKNOWLEDGMENT

First of all, I would like to express my sincere appreciation to my supervisor Professor Ir. Dr. Mohd. Nordin Adlan for his invaluable advice, coaching, support, giving practical exposure and fruitful discussion throughout the project without which I would not have succeeded in carrying out this research.

I also would like to thank Professor Dr. Hamidi Abdul Aziz, the project co-supervisors for his invaluable guidance and inspiration throughout the project. Special thanks to Mr. Mohd Nizam, Mr Muhammad Zaini bin Mohd Zuki, Mr Muhammad Nabil bin Semail and all staff of civil engineering laboratory of USM for their help with the laboratory testing.

Also, would like to express my deepest gratitude to my parents, Parviz Fereidonian Dashti and Esmat Ahmadi for their endless love, motivation, support, patience and for standing by me through the toughest moments in my Ph.D. study that has resulted in this research.

Arezoo Fereidonian Dashti
April 2017

TABLE OF CONTENT

Page

ACKNOWLEDGMENT ii

TABLE OF CONTENTS iii

LIST OF TABLES viii

LIST OF FIGURES x

LIST OF PLATE xiv

LIST OF ABBREVIATIONS xv

LIST OF SYMBOLS xvii

ABSTRAK xx

ABSTRACT xxi

CHAPTER ONE: INTRODUCTION

1.1 Background of the study 1

1.2 Problem statement 4

1.3 Research objectives 5

1.4 Scope of the study 6

1.5 Thesis organization 7

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction 9

2.2 The production process of palm oil 10

2.3 Waste generation in palm oil mills 12

- 2.3.1 Liquid effluent 12
- 2.3.2 Solid waste 13
- 2.3.3 Gaseous emission 13

2.4 Environmental regulations of effluent discharge 13

2.5 Treatment technology of POME 14

- 2.5.1 Physical treatment 14
- 2.5.2 Chemical treatment 15
- 2.5.3 Biological treatment technologies 15

2.6 Background of roughing filter 16

- 2.6.1 Historical use of roughing filter 17

2.6.2 Classification of filters 18
2.6.3 Types of roughing filters 18
2.6.4 Filter materials 21
2.6.5 The theory of roughing filter 22
2.6.6 Flow rate 22
2.6.7 Removal mechanisms of roughing filter 23
2.6.7(a) Transportation mechanism 24
2.6.7(b) Hydrodynamic forces 27
2.6.7(c) Attachment mechanism 28
2.6.7(d) Transformation mechanisms 29
2.6.8 Factors affecting removal in roughing filter 30
2.6.9 Cleaning of roughing filter 31
2.7 Roughing filter for wastewater reuse 32
2.7.1 Removal capability of a roughing filter 32
2.7.1(a) Removal of turbidity 33
2.7.1(b) Removal of COD and colour 35
2.7.1(c) Suspended solid removal in a roughing filter 37
2.8 Adsorption 40
2.8.1 Types of adsorption 41
2.8.2 Factors influencing adsorption 41
2.8.2(a) Effect of dosage 42
2.8.2(b) Effect of adsorbent characteristics 42
2.8.2(c) Effect of pH 43
2.9 Adsorption Isotherm 44
2.9.1 Langmuir Isotherm 45
2.9.2 Freundlich Isotherm 47
2.10 Application of limestone 48
2.11 Calcinated limestone 50
2.11.1 Characteristics of calcinated limestone 50
2.11.2 Uses of calcinated limestone 53
2.12 Summary 54

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction 56

3.2 Research procedure 56
3.3 Location of site 57
3.4 Sampling 58
3.5 Preparation of material 59
  3.5.1 Sieve analysis 59
  3.5.2 Limestone 60
  3.5.3 Calcination process of limestone 60
3.6 Determination of physical properties 62
  3.6.1 X-ray Fluorescence (XRF) 62
  3.6.2 Determination of void percentage 62
  3.6.3 Determination of media Density 63
  3.6.4 Surface area 63
  3.6.5 Scanning Electron Microscopy (SEM) 63
3.7 Analytical methods 64
  3.7.1 Measurement of pH 64
  3.7.2 Measurement of Turbidity 65
  3.7.3 Determination of COD 65
  3.7.4 Determination of Colour 66
  3.7.5 Determination of suspended solid 66
  3.7.6 Determination of Ammonia Nitrogen 67
3.8 Batch study 67
  3.8.1 Determination of optimum dosage 67
  3.8.2 Determination of optimum settling time 68
  3.8.3 Effect of initial PH 68
3.9 Adsorption Isotherm 69
3.10 Experimental setup 69
  3.10.1 Roughing filter 69
3.11 Experimental design 71

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Overview 73
4.2 Palm oil mill effluent characteristics 73
4.3 Characteristics of raw and calcinated limestone 74
4.4 Surface morphology 76

4.5 Batch experiment 80
    4.5.1 Determine of optimum dosage 80
    4.5.2 Determine of settling time 85
    4.5.3 Effect of initial pH 89
4.6 Adsorption Isotherm 94
    4.6.1 Adsorption isotherm of turbidity removal 95
    4.6.2 Adsorption isotherm of COD removal 98
    4.6.3 Adsorption isotherm of colour removal 101
    4.6.4 Adsorption isotherm of suspended solids removal 103
    4.6.5 Adsorption isotherm of NH3-N removal 105
4.7 Experimental design 107
    4.7.1 Mathematical modelling and statistical analysis 107
    4.7.2 Treatment of palm oil mill effluent using raw limestone 113
4.8 Numerical optimization 118
4.9 Experimental design for calcinated limestone 121
    4.9.1 Mathematical modelling and statistical analysis 123
    4.9.2 Turbidity removal of palm oil mill effluent using calcinated limestone 127
    4.9.3 COD removal of palm oil mill effluent using calcinated limestone 128
    4.9.4 Colour removal of palm oil mill effluent using calcinated limestone 131
    4.9.5 SS removal of palm oil mill effluent using calcinated limestone 132
    4.9.6 NH3-N removal of palm oil mill effluent using calcinated limestone 135
4.10 Numerical optimization for calcinated limestone 137

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and Conclusion 139
5.2 Recommendations and suggestion 141

REFERENCES 142

APPENDICES

APPENDIX A: Optimum Dosage for Removal Efficiency
APPENDIX B Optimum Settling Time for Removal Efficiency
APPENDIX C Optimum pH for Removal Efficiency
APPENDIX D Langmuir and Freundlich Figures
APPENDIX E Sieve Analysis
APPENDIX F Physical Characteristics for Medium Size Limestone
APPENDIX G Test Procedure
LIST OF PUBLICATIONS

LIST OF TABLES

Page

Table 1.1: Parameter limits for POME discharge into watercourses in Malaysia 3

Table 2.1: Characteristics of raw POME 12

Table 2.2: Standards of effluent discharge for crude palm oil mills 14

Table 2.3: Classification of filters 18

Table 2.4: Percentages of reduction in turbidity 34

Table 2.5: Percentages of reduction in colour 37

Table 2.6: Percentages of reduction in SS 39

Table 2.7: Research studies that are complied with Langmuir isotherm 46

Table 2.8: Research studies that complied with Freundlich isotherm 48

Table 3.1: Illustration of analytical methods 64

Table 3.2: Operational parameters of filters are show 71

Table 4.1: Palm oil mil effluent characteristics from a polishing pond 74

Table 4.2: Chemical characteristics of all types limestone 75

Table 4.3: Physical composition of all types limestone 75

Table 4.4: Surface area, pore volume and pore size of raw and calcinated Limestone (800°C, 600°C, 400°C) 76

Table 4.5: Separation factor (R_L) conditions 96

Table 4.6: Langmuir isotherm parameters for turbidity adsorption 96

Table 4.7: Freundlich isotherm parameters for turbidity adsorption 97

Table 4.8: Langmuir isotherm parameters for COD adsorption 99

Table 4.9: Freundlich isotherm parameters for COD adsorption 99

Table 4.10: Langmuir isotherm parameters for colour adsorption 102

Table 4.11: Freundlich isotherm parameters for colour adsorption 102

Table 4.12: Langmuir isotherm parameters for SS adsorption 104

Table 4.13: Freundlich isotherm parameters for SS adsorption 104

Table 4.14: Langmuir isotherm parameters for NH_3-N adsorption 106

Table 4.15: Freundlich isotherm parameters for NH_3-N adsorption 106

Table 4.16: Experimental design for treatment of POME using roughing filter and raw limestone 108

Table 4.17: ANOVA results for response parameter (COD, colour, turbidity, SS and NH_3-N removal) 111

Table 4.18: Constraints of each variable for numerical optimization of treatment efficiency of POME 120

Table 4.19: The responses at optimum condition for maximum removal 120

Table 4.20: Experimental design for treatment of POME using rouging filter and calcinated limestone 122

Table 4.21: ANOVA results for response parameters 124

Table 4.22: Constraints of each variable for numerical optimization of removal efficiency of POME treatment 138

Table 4.23: The value of each response at optimum condition 138

LIST OF FIGURES

		Page
Figure 2.1:	Typical fruit and production composition chart of a palm oil mill	11
Figure 2.2:	Diagram of Down- flow, Up-flow and Horizontal Roughing Filters	20
Figure 2.3:	Particle material removal mechanisms in HRF	24
Figure 2.4:	Screening of particles on filter media (a), sedimentation of filter media (b)	25
Figure 2.5:	Interceptions on filter media (a), hydrodynamic forces (b)	27
Figure 2.6:	Efficiency of a roughing filter in correlation to flow conditions	31
Figure 2.7:	Turbidity, TS and TSS removal in basalt, dolomite and calcite	33
Figure 2.8:	Turbidity behaviour of the GRF (on the left) and HRF (on the right) during rainy weather	34
Figure 2.9:	Combination of three different media size (12–18 mm, 8-12 mm & 4–8 mm) removal efficiency (%) of various parameters at 20 mL/min	35
Figure 2.10:	Changes of COD removal efficiency at filtration rates of 1 and 1.5 m/h	36
Figure 2.11:	Colour behaviour of the GRF (on the left) and HRF (on the right) during rainy weather	37
Figure 2.12:	Suspended solid removal with respect of flow rate	39
Figure 2.13:	Suspended solids behaviour of the GRF (on the left) and HRF (on the right) during rainy weather	40
Figure 2.14:	The effect of particle size on NH_3-N removal at different mixture ratios (conditions: shaking speed, 350 rpm; shaking time, 150 min; settling time, 120 min; LS–GAC, 25:15; pH, neutral)	43
Figure 2.15:	SEM pictures of pingdingshan limestone after high temperature	51

Figure 2.16: Swelling rate of limestone as a function of temperature 52

Figure 2.17: Axial stress-strain curves for limestone under high temperature 52

Figure 3.1: Flow chart of the methodology 57

Figure 3.2: Palm oil mill, Sungai Kecil Nibong Tebal, Pulau Pinang. 58

Figure 3.3: The aerial view of palm oil mill at Sungai Kecil Nibong Tebal, Pulau Pinang 58

Figure 3.4: Polishing pond in palm oil mill at Sungai Kecil Nibong Tebal 59

Figure 3.5: Schematic diagram of the experimental setup for calcinated limestone 61

Figure 3.6: Design of tube furnace 61

Figure 3.7: DR2100Q spectrophotometer 65

Figure 3.8: Images of (a) spectrophotometer and (b) COD reactor 67

Figure 3.9: Schematic of laboratory-scale roughing filter 70

Figure 3.10: Design expert process 72

Figure 4.1: Optimum dosage of turbidity removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 81

Figure 4.2: Optimum dosage of COD removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 82

Figure 4.3: Optimum dosage of colour removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 82

Figure 4.4: Optimum dosage of SS removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 83

Figure 4.5: Optimum dosage of NH_3-N removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 83

Figure 4.6: Optimum settling time of turbidity removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 86

Figure 4.7: Optimum settling time of COD removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 86

Figure 4.8: Optimum settling time of colour removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 87

Figure 4.9: Optimum settling time of SS removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 87

Figure 4.10: Optimum settling time of NH_3-N removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 88

Figure 4.11: Effect of initial pH on turbidity removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 91

Figure 4.12: Effect of initial pH on COD removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 91

Figure 4.13: Effect of initial pH on colour removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 92

Figure 4.14: Effect of initial pH on SS removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 92

Figure 4.15: Effect of initial pH on NH_3-N removal (Condition: 350 rpm shaking speed; 2 hours shaking time; five hours settling time) 93

Figure 4.16: Plots of the predicted vs. actual values for removal of (a) COD, (b) SS, (c) turbidity, (d) colour, (e) NH_3-N (treatment using raw limestone in roughing filter) 112

Figure 4.17: Effect of process variables on responses for (a) COD, (b) SS, (c) turbidity, (d) colour, (e) NH_3-N (treatment using raw limestone in roughing filter). 116

Figure 4.18: The desirability of all responses at optimum condition 120

Figure 4.19: Pots of predicted vs. actual values for (a) COD, (b) SS, (c) turbidity, (d) colour, (e) NH_3-N (treatment using calcinated limestone and roughing filter). 126

Figure 4.20: Effect of process variables on turbidity removal by different flow rates using roughing filter: (a) 20 ml/min (b) 60 ml/min (c) 100 ml/min by roughing filter 128

Figure 4.21: Effect of process variables on COD removal by different flowrates using roughing filter: (a) 20 ml/min (b) 60 ml/min (c) 100 ml/min by roughing filter 130

Figure 4.22: Effect of process variables on colour removal by different flowrates using roughing filter: (a) 20 ml/min (b) 60 ml/min (c) 100 ml/min by roughing filter 132

Figure 4.23: Effect of process variables on SS removal by different flowrates using roughing filter: (a) 20 ml/min (b) 60 ml/min (c) 100 ml/min by roughing filter 134

Figure 4.24: Effect of process variables on NH_3-N removal by different flowrates using roughing filter: (a) 20 ml/min (b) 60 ml/min (c) 100 ml/min by roughing filter 136

Figure 4.25: The value of all responses at optimum condition 138

LIST OF PLATE

Page

4.1: SEM image of raw limestone 78

4.2 SEM image of calcinated limestone 400^{o}C 78

4.3 SEM image of calcinated limestone 600^{o}C 79

4.4 SEM image of calcinated limestone 800^{o}C 79

4.5 SEM image of calcinated limestone 800^{o}C after treatment 80

LIST OF ABBREVIATION

Ag SO_4	Silver Sulphate
ANOVA	Analysis of variance
APHA	American Public Health Association
AWWA	American Water Works Association
BET	Brunauer-Emmett-Teller
BOD	Biochemical oxygen demand
$CaCo_3$	Calcium Carbonate
CH_4	Methane
CLS	Calcinated limestone
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CPO	Crude palm oil
Cu	Copper
DO	Dissolved Oxygen
DOE	Department of environment
EFB	Empty fruit bunch
Fe	Iron
FFB	Fresh fruit bunch
F-Value	Fisher variation ratio
GRF	Gravity Roughing Filter
H_2SO_4	Sulfuric acid
HRT	Hydraulic retention times
HRF	Horizontal roughing filter

K_2Co_7	Potassium Dichromate
LOI	Loss of Ignition
LS	Limestone
NaOH	Sodium hydroxide
NH_3-N	Ammoniacal nitrogen
NTU	Nephelometric turbidity unit
pH	Potential of hydrogen
POME	Palm oil mill effluent
Rpm	Revolution per minute
RSM	Response surface methodology
SEM	Scanning electron microscopy
SS	Suspended solid
TS	Total solid
TSS	Total suspended solid
VSS	Volatile Suspended Solids
VRF	Vertical roughing filter
XRF	X-Ray Fluorescence

LIST OF SYMBOLS

^{o}C	Degree Celsius
1/n	Freundlich intensity parameter
A	Area
C_0	Initial concentration of adsorbate
C_e	Final equilibrium concentration of adsorbate after adsorption has occurred
e_i	The error
H	Height
k	The number of studied factors
K_f	Freundlich capacity factor
L	Litter
m	Mass of adsorbent
mg	milligram
mm	millimeter
Q	Volumetric flow rate
R^2	Correlation Coefficient
R_L	Separation factor for Langmuir Isotherm
V	Settling velocity
V	Volume of liquid sample
V_F	Filtration rate
W	Width
x	Amount of solute adsorbed
X_iX_j	Variables

y	Response
B_0	A constant coefficient
B_{ij}	The interaction coefficient of second order terms
B_j	The interaction coefficient of linear
B_{jj}	The interaction coefficient of quadratic
R^2	Correlation Coefficient
Q	Adsorption capacity
b	The Langmuir constant (L/mg)
μ	Fluid viscosity
p_w	Fluid density
P_p	Particle density
d	Diameter of particle
g	Acceleration due to gravity
V	Settling velocity

RAWATAN EFLUEN MINYAK KELAPA SAWIT DARIPADA KOLAM RAWATAN AKHIR MENGGUNAKAN PENAPIS KASAR BATU KAPUR BAKAR

ABSTRAK

Rawatan untuk air sisa adalah salah satu masalah utama yang dihadapi oleh pengusaha kilang minyak sawit. Salah satu industri kilang minyak sawit terdapat di Sungai Kecil, Nibong Tebal, Pulau Pinang. Kilang kelapa sawit di Malaysia mengalami kepekatan COD, warna, kekeruhan, pepejal terampai dan nitrogen berammonia yang tinggi dalam efluen yang akhir selepas rawatan biologi yang melebihi had pelepasan piawai. Tujuan kajian ini adalah untuk mengenal pasti kesesuaian penggunaan batu kapur mentah (LS) dan batu kapur kalsin (CLS) sebagai media turasan berkos rendah bagi pasca rawatan efluen terawat dengan menggunakan turasan kasar mendatar. Rawatan fiziko-kimia yang digunakan dalam kajian ini telah dipilih berbanding kaedah lain kerana lebih ringkas, mudah diselenggara dan mudah bagi kawalan kualiti. Kolam akhir bagi rawatan efluen kilang minyak sawit adalah kolam penyudah dimana efluen terus dilepaskan ke dalam sungai. Efluen dalam kolam penyudah telah dipilih menjadi sampel dalam kajian ini. Julat kepekatan minima dan maksima bagi kekeruhan, COD, warna, pepejal terampai dan nitrogen berammonia dalam kolam penyudah adalah masing-masing 200 - 650 NTU, 2,200 – 3,300 mg/L, 3,000 – 5,000 PtCo, 400 - 730 mg/L dan 190 – 300 mg/L. Saiz partikel bagi batu kapur iaitu 4, 12 dan 20 mm;kadar aliran seperti 20mL/min, 60mL/min, dan 100mL/min; dan suhu iaitu 400 ˚C, 600 ˚C dan 800 ˚C, telah digunakan dalam kajian ini. Hasil menunjukkan partikel media bersaiz kecil (4mm) lebih berkesan daripada partikel bersaiz besar (20 mm) kerana partikel bersaiz kecil mempunyai luas permukaan yang lebih tinggi yang menyebabkan kapasiti penjerapan tinggi. Selain itu, kadar aliran rendah menyebabkan masa penepuan tinggi, manakala kadar aliran tinggi memendekkan masa penepuan turus dan menunjukkan penyingkiran yang kurang berkesan. Kajian menunjukkan bahawa batu kapur kalsin pada suhu 800 ˚C mempunyai kecekapan penyingkiran yang paling tinggi bagi kekeruhan, COD, warna, pepejal terampai dan nitrogen beramonia (66%, 50%, 52%, 60%, 75%, masing-masing) pada media turasan bersaiz kecil (4 mm) dan pada kadar aliran 20 mL/min berbanding batu kapur kalsin pada suhu berbeza dan juga batu kapur mentah. Hasil kelompok menunjukkan dos optimum bagi batu kapur kalsin pada suhu 800 ˚C untuk menyingkir kekeruhan, COD, warna, pepejal terampai dan nitrogen beramonia (69.23%, 48.23%, 40.13%, 70.81%, 50%, masing-masing) adalah 85 g dos batukapur; manakala masa pengenapan optimum adalah 5 jam. Kecekapan penyingkiran paling tinggi diperolehi pada keadaan berasid bagi semua parameter, tetapi NH_3-N disingkirkan dengan berkesan pada pH 10 (58.17%) bagi batu kapur kalsin pada suhu 800 ˚C. Data penjerapan keseimbangan untuk kekeruhan, COD, warna, pepejal terampai dan nitrogen beramonia (0.959, 0.916, 0.935, 0.909, 0.977, masing-masing) lebih padan dengan isoterma Langmuir berbanding isoterma Freundlich kerana nilai R^2 lebih tinggi.

TREATMENT OF PALM OIL MILL EFFLUENT FROM POLISHING POND USING CALCINATED LIMESTONE ROUGHING FILTER

ABSTRACT

Treatment of wastewater is one of the major problems faced by palm oil mill operators. One of the palm oil mill industries in Sungai Kecil Nibong Tebal, Pulau Pinang, Malaysia is experiencing a high concentration of turbidity, COD, colour, suspended solid and ammoniacal nitrogen in the final effluent after biological treatment that exceeds the standard discharge limit. The purpose of the present study is to investigate the suitability of using raw and calcinated limestone as low cost filter media for the treatment of treated effluent by using horizontal roughing filter. The physico-chemical treatment adopted in this study is preferred over other methods because of its simplicity, easy maintenance and quality control. The last treatment pond of palm oil mill effluent is the polishing pond where wastewater is directly discharged to the river. The polishing pond was selected for sampling in this study. The minimum and maximum concentrations of turbidity, COD, colour, suspended solid, and ammoniacal nitrogen in the polishing pond were 200 - 650 NTU, 2,200 – 3,300 mg/L, 3,000 – 5,000 PtCo, 400 - 730 mg/L, and 190 – 300 mg/L respectively. The parameters used in this study were particle sizes of limestone of 4, 12 and 20 mm, flowrates of 20 mL/min, 60 mL/min, and 100 mL/min and temperatures of 400 ˚C, 600 ˚C and 800 ˚C. Results indicated that a smaller particle size of limestone (4 mm) was more effective than a larger particle size of limestone (20 mm) because smaller sized particles of filter media have higher surface area which leads to high adsorption capacity. In contrast, a low flow rate (20mL/min) results in higher column saturation time, while higher flow rate results in shorter column saturation time and shows low removal efficiency. The study indicated that calcinated limestone at 800 ˚C has the highest removal efficiency for turbidity, COD, colour, SS and NH_3-N (66%, 50%, 52%, 60% and 57% respectively) at smaller sized filter media (4 mm) and lower flow rate (20 mL/min) compared to calcinated limestone at different temperature and raw limestone. The batch results showed that the optimum dosage of calcinated limestone at 800 ˚C for removing turbidity, COD, colour, SS and NH_3-N (69.23%, 48.23%, 40.13%, 70.81%, 50% respectively) was 85 g, whereas the optimum settling time was 5 hours. High removal efficiency was obtained in acidic phase for all parameters, but NH_3-N was removed efficiently at pH 10 (58.17%) for calcinated limestone at 800 ˚C. The equilibrium adsorption data for turbidity, COD, colour, SS and NH_3-N (0.959, 0.916, 0.935, 0.909, 0.977 respectively) was well-fitted with the Langmuir isotherm compared to that of Freundlich isotherm, indicated by high R^2 value for small sized calcinated (800 ˚C) limestone.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Palm oil is known as the most suitable harvest product in Malaysia and Indonesia (Najafpour et al., 2006). The total area oil palm plantation has increased in the last few years, with a consequent boost in palm oil production. As a result, palm oil waste which is a by-product of the milling process will also increase. The palm oil production process in mills consists of several unit operations. The processing of fresh fruit bunches of oil palm results in the generation of different types of residue. Among the waste generated, Palm Oil Mill Effluent (POME) is considered the most harmful waste for the environment if discharged untreated. Palm oil mill effluent is a thick brownish liquid that contains high solids, oil and grease, COD and BOD values. Several treatment technologies have been used for POME treatment, since the direct discharge of POME to water resource may adversely affects the environment (Rupani et al., 2010). With the rapid increase of the palm oil industry and the intensified awareness of the public on preventing environmental pollution, it has become an obligation for the industry to be socially and aesthetically responsible to treat its effluent before discharging it. In 1977, some standards for POME discharge into watercourses have been proposed and legalized by the Malaysian Government (Oswal et al., 2002). Since then, palm oil mills operators are required to treat their POME prior to discharging it into streams and rivers. The history of parameter limits for POME discharge into watercourses in Malaysia is summarized in Table 1.1.