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Development of aerobic granular sludge using industrial latex wastewater

By

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DEDICATION

To dearest Muhammad and Madinah
Allah's greatest gift

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TABLE OF CONTENTS

	PAGE
THESIS DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	v
LIST OF FIGURES	x
LIST OF TABLES	xiii
LIST OF ABBREVIATIONS	xiv
LIST OF SYMBOLS	xvii
LIST OF APPENDICES	xviii
ABSTRAK	xx
ABSTRACT	xxi
CHAPTER 1 INTRODUCTION	
1.1 Overview	1
1.2 Significant of the study	6
1.3 Problem statement	7
1.4 Objectives of study	9
1.5 Scope of study	10
1.6 Thesis structure	11

CHAPTER 2 LITERATURE REVIEW

2.1	Rubber latex industry	14
2.2	Treatment methods	17
2.3	Alternative approach to an advanced biological treatment	20
2.4	The sequencing batch reactor	22
2.5	Aerobic granulation and treatment of contaminants	23
2.6	Formation of aerobic granules	24
2.7	Factors affecting the formation of aerobic granules	25
2.7.1	Influence of cycle time	26
2.7.2	Influence of settling time	30
2.7.3	Granulation in SBRs with different height/diameter (H/D) ratio (reactor configuration)	30
2.7.4	Effects of shear force	31
2.7.5	Formation of aerobic granular sludge in SBR with variable aeration	32
2.7.6	Effect of aeration rate on dissolved oxygen in granular sludge reactor	34
2.7.7	Investigation of dissolved oxygen (DO) on nitrification and denitrification in granular treatment	36
2.7.7.1	Effect of nitrogen removal on organic loading	38
2.7.8	Characterization of aerobic granules at various wastewater strength	40
2.7.8.1	Cultivation of aerobic granules using real wastewater	42
2.7.8.2	Cultivation of aerobic granules using synthetic wastewater	46
2.7.9	Substrate composition	50

CHAPTER 3 RESEARCH METHODOLOGY

3.1	Reactor design	52
3.2	Setting up of bioreactors	55
3.3	Inoculated seed sludge	57
3.3.1	Feed preparation	58
3.4	Analytical procedures	60
3.5	Scanning electron microscopy (SEM)	61
3.6	Bacterial isolation	62
3.6.1	Sample preparation	62
3.6.2	Nutrient agar preparation	63
3.6.3	Bacterial quantification by spread plate	63
3.7	Experimental stages	63
3.7.1	Granule formation on inconsistent F/M ratio with selection of suitable cycling time	63
3.7.2	Granulation formation using industrial latex wastewater	65
3.7.3	Granules cultivated using latex (inconsistent OLR) and synthetic wastewater (constant OLR)	67
3.7.4	The application of Different organic loading on reactor configuration (H/D) ratio	69

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1	Selection of cycling time for cultivation of aerobic granules in relation with inconsistent F/M ratio	71
4.1.1	Performance of reactor during granulation	72
4.1.2	Effect of inconsistent F/M ratio on granulation formation and physical characteristics of granules	76

4.2	Development of aerobic granules using real latex wastewater	82
4.2.1	Physical properties of granular biomass	83
4.2.2	Granules formation	89
4.2.3	Performance of granular biomass	94
4.3	Selection of a suitable latex dye for fabrication of synthetic wastewater and application to bioreactor	99
4.3.1	UV-Vis spectrum analysis of solvent concentration	99
4.3.2	Absorption curve of disperse orange dye without addition of solvent	101
4.3.3	The effect of organic solvent addition to disperse orange and black dye	102
	4.3.3.1 Absorption curve of disperse orange dye with addition of organic solvent	102
4.3.4	Absorption curve of methanol : water	103
4.3.5	Effect of methanol addition at different solvent to water ratio	105
4.4	Study on the time taken to achieve granulation with synthetic and real latex wastewater	106
4.4.1	Granules characteristics and reactors performance	106
4.4.2	Comparison of R1 granules and R2 granules	111
4.4.3	Effect of influent COD loadings on biomass growth	115
4.4.4	The effect of DO with substrate concentration on stability of aerobic granules developed in R1 and R2	118
4.4.5	Comparison of COD and nitrogen removal with and without supply of external carbon source	121

4.5	Study on selection of a suitable size reactors in relation with the effect of organic loading	128
4.5.1	Progression of MLSS (biomass concentration) and SVI in four SBR	128
4.5.2	Granulation formation of sludge flocs with high (R1) and low (R3) H/D ratio using inconsistent organic loading	133
4.5.3	Granulation formation of sludge flocs with high (R2) and low (R4) H/D ratio using constant organic loading	135
4.5.4	Comparison of granule's performance cultivated under different H/D ratio with inconsistent organic loading	144
4.5.4.1	Conversion of ammonium (NH_4) to nitrite (NO_2) and nitrate (NO_3)	151
CHAPTER 5 CONCLUSION AND RECOMMENDATION		
5.1	Conclusion	159
5.2	Recommendation	161
REFERENCES		162
APPENDICES		177
PUBLICATIONS		209

LIST OF FIGURES

NO.		PAGE
2.1	Rubber plantation	14
2.2	Activated sludge plants	17
2.3	Conventional to advanced biological treatment	20
2.4	SBR cycle operation	23
2.5	Illustration of aerobic granules formation	25
3.1	Research flow chart	53
3.2	Detailed feature of R1 and R2	54
3.3	Detailed feature of R3 and R4	55
3.4	Operational mode of R1 (Phase I)	57
3.5	Operational mode of R1, R2, R3 and R4 (Phase II)	57
3.6	Schematic diagram of SBR	58
3.7	Operational parameters during 1 st stage of experiment	65
3.8	Operational parameters during 2 nd stage of experiment	67
3.9	Operational parameters during 3 rd stage of experiment	68
3.10	Operational parameters during 4 th stage of experiment	70
4.1	COD removal during granulation	73
4.2	Percentage of NH_4^+ -N removal by aerobic granules	74
4.3	Size distributions of granules in bioreactor	76
4.4	F/M ratio in SBR reactor throughout the experiment	77
4.5	MLSS and MLVSS in SBR column during granules development	79
4.6	Effect of granule size on settling velocity	81
4.7	Settling velocity (SV) of aerobic granules in reactor	84

4.8	Variations of SVI_{10} and SVI_{30} of the reactor in 220 days of operation	85
4.9	MLSS and MLVSS concentration	87
4.10	Measurement of DO concentrations in reactor	88
4.11	Images of sludge in SBR: (A) seed sludge; (B) sludge on day 30; (C) sludge on day 60; (D) sludge on day 120	89
4.12	Changing patterns of particle size distribution of sludge throughout 210 days of operation	91
4.13	Performance for continuous SBR operation with ammonia in influent, effluent and percentage of ammonia removal	94
4.14	Performance of reactor with COD influent, effluent and percentage of COD removal	95
4.15	Profiles of DO, pH and total microorganisms (CFUs/mL) concentration	96
4.16	Absorption curves of disperse orange dye without addition of organic solvent	101
4.17	(A) Absorption curve of disperse orange dye with methanol to water ratio of (40:60); (B) Absorption curve of disperse orange dye with methanol to water ratio of (20:80)	103
4.18	Absorption spectrum of Black EG disperse dye in methanol : water ratio of (40:60)	104
4.19	Absorption spectrum of Black EG disperse dye in methanol : water ratio of (10:90)	104
4.20	Micrographs of the formation and evolution of aerobic granules in (A) R1 and (B) R2	109
4.21	R2 microorganisms on 60 days of operation (400x magnification)	111
4.22	Particle size distribution in R2: (A) start of granulation from day 0 to 60, (B) and day 120 to 210	112
4.23	Particle size distribution in R1: (A) start of granulation from day 0 to 60, (B) and day 120 to 210 (steady state)	113

4.24	Influent COD concentration in R1 and R2	115
4.25	Growth of MLSS concentrations	116
4.26	DO concentration profiles for R1 and R2	118
4.27	COD removal under observed in bioreactor 1 and 2 (R1): without the supply of an external carbon source; (R2): with supply of an external carbon source	122
4.28	Comparison between changes of granule size in reactor fed with synthetic and latex wastewater	123
4.29	SEM image of aerobic granules cultivated in bioreactor 1 (R1) using latex wastewater	125
4.30	SEM image of aerobic granules cultivated in bioreactor 2 (R2) using synthetic wastewater	125
4.31	Comparison of granule size developed in R1(A) and R2(B)	126
4.32	Changes of MLSS throughout investigation time	129
4.33	SVI value in R1, R2, R3 and R4	131
4.34	Size distributions of granules in R1 and R3 during granules development	133
4.35	Size distributions of granules in R2 and R4 during granules development	135
4.36	Changes in Settling velocity of granule in R1 and R3 with the effect of various organic loading	138
4.37	Settling velocity of granules in R2 and R4	142
4.38	Profile of organic removal in R1 and R3	144
4.39	COD profiles in R2 and R4 with constant supply of organic loading under different H/D ratio	147
4.40	NH_4^+ -N removal by granules cultivated using (R1): high H/D ratio and (R2): low H/D ratio	153
4.41	Profiles of nitrification occurrence observed cultivated under constant organic loading with (R2): high H/D ratio; (R4): low H/D ratio	156

4.42	Decolourization of disperse dye, comparison of different reactor configuration (R2): high H/D ratio; (R4): low H/D ratio	158
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LIST OF TABLES

NO.		PAGE
2.1	Current rubber wastewater treatment method	16
2.2	Advantages and disadvantages of physical, chemical and biological treatment	18
2.3	Characteristics of aerobic granule and activated sludge	21
2.4	List of contaminants and types of wastewater treated by aerobic granulation process in SBR	24
2.5	SBR operating time	27
3.1	Detailed experimental features of all bioreactors	55
3.2	Synthetic wastewater recipes	59
3.3	Composition of the industrial latex wastewater	60
4.1	Comparison of SVI value utilizing several types of wastewater	86
4.2	Comparison of an average granules size achieved	93
4.3	Treatment efficiency and granule characteristics of aerobic granules under different COD loadings	107
4.4	Composition of elements in aerobic granules developed in R1 and R2 using two different carbon source	127
4.5	Variations of organic loading rate in R1 and R3 throughout granulation	140
4.6	Comparison of four reactors for cultivation of aerobic granules	149

LIST OF ABBREVIATIONS

2,4-D	2,4-dichlorophenoxyacetic
2-CP	2-chlorophenol
AOB	Ammonium oxidizing bacteria
CaCl ₂	Calcium chloride
CO ₂	Carbon dioxide
CoCl ₂	Cobalt chloride
COD	Chemical oxygen demand
CuSO ₄	Copper sulphate
DCM	Dichloromethane
DO	Dissolved oxygen
EGSB	Expanded granular sludge bed
EPS	Extracellular polymerase sacharide
F/M	Food to microorganisms ratio
FeCl ₃	Iron chloride
FeSO ₄	Iron sulphate
GAC	Granular activated carbon
H/D	Height to diameter ratio
H ₃ BO ₃	Boric acid
IA	Image analysis
IC	Ion Chromatography
K ₂ HPO ₄	Dipotassium phosphate
KH ₂ PO ₄	Monopotassium phosphate
KI	Potassium Iodide

MgSO ₄	Magnesium Sulphate
Milli-Q	Ultrapure water
MLSS	Mixed liquor suspended solids
MLVSS	Mixed liquor volatile suspended solids
MnCl ₂	Manganese Chloride
N=N	Nitrogen double bond
Na ₂ EDTA	Ethylenediaminetetraacetic acid
NaHCO ₃	Sodium bicarbonate
NaM _o O ₄	Sodium molybdate
NH ₄ ⁺ -N	Ammonium
NH ₄ Cl	Ammonium chloride
NO ₂	Nitrite
NO ₃	Nitrate
NOB	Nitrifying oxidizing bacteria
NTA	Nitrilotriacetic acid
OLR	Organic loading rate
PHB	Poly-β-hydroxybutyrate
PO ₄ ³⁻	Phosphate ion
R1	Reactor 1
R2	Reactor 2
R3	Reactor 3
R4	Reactor 4
SAV	Superficial air velocity
SBAR	Sequencing batch airlift reactor
SBR	Sequencing batch reactor

SEM	Scanning electron microscope
SND	Simultaneous nitrification denitrification
SRT	Sludge retention time
SV	Settling velocity
SVI	Sludge volume index
TSS	Total suspended solids
UASB	Upflow anaerobic sludge blanket
UV-Vis	Ultraviolet visible
WWTP	Wastewater treatment plant
ZnSO ₄	Zinc sulphate
ρ_{ow}	Octanol-water partition coefficient

LIST OF SYMBOLS

%	Percentage
μm	Micrometer (size of cell)
cm	Centimetre
cm/s	Centimetre per second
g/L	Gram per litre (Mass concentration)
$\text{kgCOD}/\text{m}^3/\text{d}$	Organic loading rate
L	Litre
L/min	Litre per minute
m	Metre
m/hr	Metre per hour
mg/L	Milligram per litre
mgCOD/L	Milligram COD per litre
mgCOD/mgSS d	Milligram COD per milligram suspended solids per day (F/M unit)
min	Minute
mL/g	Millilitre per gram
nm	Nanometre
$^{\circ}\text{C}$	Temperature (degree Celsius)
pH	Measure of acidity or alkalinity
ppm	Parts per million

LIST OF APPENDICES

NO.		PAGE
APPENDIX A		
A.1	SEM image of granules cultivated in R1	177
A.2	Elemental composition of granules cultivated in R1	177
APPENDIX B		
B.1	SEM image of granules cultivated in R2	178
B.2	Elemental composition of granules cultivated in R2	178
APPENDIX C		
C.1	R3 microorganisms on 60 days of operation (400x magnification)	179
C.2	R3 microorganisms on 120 days of operation (400x magnification)	179
APPENDIX D		
D.1	R4 microorganisms on 60 days of operation (400x magnification)	180
D.2	R4 microorganisms on 120 days of operation (400x magnification)	180
APPENDIX E		
E.1	Schematic diagram of R1, R2, R3 and R4	181
APPENDIX F		
F.1	Actual experimental reactor setup of R1, R2, R3 and R4	182
APPENDIX G		
G.1	Removal efficiency of organic substrate and dye by granules cultivated in R2	183

NO.		PAGE
APPENDIX H		
H.1	Chromatogram of standard anions	184
APPENDIX I		
I.1	Composition of anions in R1 effluent	185
I.2	Composition of anions in R2 effluent	186
I.3	Composition of anion in R3 effluent	187
I.4	Composition of anion in R4 effluent	188
APPENDIX J		
J.1	Data	189

LIST OF APPENDICES

APPENDIX	PAGE
A	176
B	177
C	178
D	179
E	180
F	181
G	182
H	183
I	184
J	185
K	186
L	187
M	188

Penghasilan Granul Aerobik Menggunakan Air Sisa Industri Getah

ABSTRAK

Menerusi kajian ini, usaha untuk menghasilkan granul aerobik menggunakan enapcemar daripada industri air sisa getah telah dijalankan. Pengoptimuman kitaran masa telah dikaji dan penilaian kesan turun naik muatan organik telah dijalankan terlebih dahulu. Selepas itu diikuti pula dengan penyiasatan ciri-ciri fizikal penghasilan granul aerobik yang stabil di bawah muatan organik yang tidak konsisten dan berterusan. Analisa diteruskan dengan menganalisis impak nisbah ketinggian pada diameter reaktor (K/D) dengan nisbah K/D sebanyak 2.7 dan 14. Eksperimen telah dijalankan dalam reaktor R1, R2, R3 dan R4 dengan kitaran masa sebanyak 4 jam, setelah pemilihan kitaran masa yang sesuai telah dijalankan berdasarkan penyiasatan awal. Dengan itu, empat kumpulan eksperimen telah dijalankan untuk menyokong objektif kajian ini. Floks enapcemar yang mempunyai ciri-ciri yang sama telah dikultur kepada semua empat reaktor dengan konfigurasi reaktor 2.7 dan 14, bersama-sama dengan pelbagai kadar muatan organik. Air sisa susu getah telah dimasukkan ke dalam R1 dan R3 dengan pelbagai bebanan organik kimia (BOK) dari serendah 0.01-0.28 kg BOK/m³/d. Walau bagaimanapun, granul dalam R1 telah dihasilkan dengan halaju cetek udara (HCU) sebanyak 4.25 cm/s, manakala granul R3 digunakan HCU sebanyak 1.1 cm/s. R2 dan R4 telah diberikan air sisa sintetik dengan bebanan BOK konsisten 0.07 kg BOK/m³/d, tetapi dengan aplikasi HCU yang berbeza. Kesemua empat reaktor mencapai pembentukan granul. Walaupun granul yang dihasilkan di R1 dan R3 adalah lebih besar dan lebih padat daripada granul yang dihasilkan dalam R2 dan R4. Tetapi jika dibandingkan dengan granul yang terhasil dalam R1 dan R3, granul R2 dan R4 yang terhasil adalah kurang padat dan lebih kecil dan hanya boleh mencapai saiz 0.2-0.6 mm dalam tempoh 210 hari, berbanding dengan R1 dan R3 granul yang boleh terhasil sehingga saiz granul mencecah 4.75 mm dalam tempoh 150 hari. Keputusan ini menunjukkan perbezaan yang signifikan antara granul yang terhasil dalam R1 dan R3 dengan R2 dan R4. Seterusnya menunjukkan BOK menjadi faktor penting untuk penghasilan granul. Apabila granul yang terhasil dalam R1 dibandingkan dengan granul yang terhasil di dalam R3, terdapat perbezaan yang jelas dari segi ciri-ciri granul yang dapat diperhatikan dengan aplikasi purata halaju pengenaan tinggi (HPT) yang berbeza antara R3 dan R1. Walaubagaimanapun, R2 dan R4, tidak mempamerkan penghasilan granul yang stabil sepanjang eksperimen ini dijalankan. Akan tetapi prestasi reaktor stabil selepas pembentukan granul di dalam R2 dan R4. Kesimpulannya, penggunaan bebanan organik yang berkadar rendah tidak berjaya menghasilkan pembentukan granul yang stabil. Walaupun dengan mengaplikasikan K/D yang tinggi bertujuan untuk meningkatkan HCU di dalam reaktor supaya penghasilan granul yang lebih stabil dan padat dapat diperolehi.

Development of Aerobic Granular Sludge Using Industrial Latex Wastewater

ABSTRACT

In this study, an attempt of developing aerobic granules using industrial latex wastewater sludge was conducted. Optimization of cycling time were investigated and assessment of the effect of fluctuating organic loading was performed. Subsequently followed by investigation of physical characteristics of a stable aerobic granules under inconsistent and constant organic loading. Finally, aerobic granular sludge produced was then characterized by a height to diameter ratio (H/D) of 2.7 and 14. Experimental investigation was conducted in sequencing batch reactors R1, R2, R3 and R4 with cycling time of 4 hours after selection of cycling time was conducted based on preliminary investigation. Four batches of experiment were performed to support the objectives of this study. Similar size of sludge flocs was inoculated to all four reactors with reactor configuration of 2.7 and 14 together with various organic loading rate. R1 and R3 was introduced to real latex wastewater with varying chemical oxygen demand (COD) loadings from as low as 0.01 to 0.28 kgCOD/m³/d. However, granules in R1 were cultivated with superficial air velocity (SAV) of 4.25 cm/s, whereas granules R3 utilized SAV of 1.1 cm/s. R2 and R4 was fed with synthetic wastewater with consistent COD loadings of 0.07 kgCOD/m³/d but with different application of SAV. All four reactors achieve granulation, although granules developed in R1 and R3 is bigger and denser than in R2 and R4. But when compared to granules grown in R1 and R3, R2 and R4 granules were less compact and smaller in size. R2 and R4 granules can reach granule size of 0.2 to 0.6 mm within 210 days, compared to R1 and R3 granules that can only developed up to 4.75 mm within 150 days. This result shows significant difference between R1 and R3 with R2 and R4 granules, and that COD loadings appear to be a crucial factor for complete granulation. When R1 granules were compared to granules in R3, an apparent difference of granules characteristics were observed with a high average settling velocity (SV) value in R3 than in R1. On the other hand, R2 and R4, displayed unstable development of granules throughout the study but stable reactor performance after formation of granules. Utilization of a constantly low organic loading rate (OLR) does not seem to favour a stable granules formation, although high height to diameter ratio was applied to enhance the SAV within the reactor in order to intensify shear force optimizing the formation of a more stable and compact granules.

CHAPTER 1

INTRODUCTION

1.1 Overview

Over the past years, biological method appear to be an effective method for the treatment of latex wastewater in Malaysia (Mohammadi et al., 2010). Biological methods are considered to be inexpensive and capable of removing organic contaminants particularly ammonium that appear to be abundant in latex wastewater. Numerous biological treatment has been applied including aerobic, anaerobic and facultative ponds, due to area limitation mechanical treatments are utilized (Mohammadi et al., 2010).

Treating industrial latex wastewater can be difficult due to varying contaminant level of latex wastewater. Iyagba et al. (2008) investigated in his study, latex processing pose higher contamination due to chemicals added for concentrating process. Rubber effluent contain high level of ammonia and various nutrients creating conventional biological treatment seems irrelevant. Moreover, the production of latex products generate large amount of water. Adding more demands in search of practical and viable technology suitable for treating varying pollution level in latex wastewater particularly treatment within industrial compound with limited area. For that reason, investigation of an effective method to overcome several obstacle of treating latex wastewater is discussed in this chapter by applying aerobic granule technology that is capable of treating high organic wastewater and only utilizes small compound area. Hence, this

study applies recent technology of biological treatment using aerobic granules for the treatment of industrial latex wastewater.

Aerobic granules has been applied extensively for the treatment of industrial wastewater including, wastewater from palm oil mill (Gobi et al., 2011), mixed wastewater with high level of toxic organics (Liu et al., 2011), and petrochemical (Zhang et al., 2011). Application of aerobic granules in treating domestic wastewater has been improved by culturing vorticella and rotifers fed with real domestic wastewater (Li et al., 2013). Whilst, Coma et al. (2012) enhanced granulation by inoculating crushed granules for treatment of biological nutrient. Liu et al. (2011) on the other hand further removed nitrogen and COD in domestic wastewater. This demonstrate that treatment of wastewater using aerobic granular has been applied for treating industrial, domestic, and even livestock wastewater from a cattle farm (Othman et al., 2013).

Since aerobic granule was essentially made out of microorganism clustered together to form a dense aggregate (Sheng et al., 2010; Yuan and Gao, 2010), and is solely depend on the availability of sufficient organic substrate for rapid growth of biomass. Treatment of latex wastewater using aerobic granules seems suitable due to high content of organic contaminants particularly ammonium. High organic substrate is favourable for granules development in reactor and has been successfully cultivated with high organic concentration of more than 1000 mg/L d (Li et al., 2011). However, only a few researcher developed aerobic granules using low strength wastewater. Li et al. (2011) developed aerobic granules with COD concentration of 200 mg/L whilst Ni et al. (2009) achieved granulation by applying low strength municipal wastewater ranging from 100 to 400 mgCOD/L. Both researchers developed granules using synthetic and real wastewater respectively. Although Li et al. (2011) achieved granulation by adding