STARVATION AND REACTIVATION OF

PARTIAL NITRIFYING BACTERIA:

COMPARISON BETWEEN FLOCCULAR AND GRANULAR BIOMASS

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STARVATION AND REACTIVATION OF

NITROGEN REMOVING BACTERIA:

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by

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TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

AN	Ammonium Nitrogen
AOB	Ammonia Oxidizing Bacteria
ATP	Adenosine Triphosphate
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
EPS	Extracellular Polymeric Substances
FA	Free Ammonia
FNA	Free Nitrous Acid
H/D	Height/Diameter Ratio
HRT	Hydraulic Retention Time
MLSS	Mixed Liquor Suspended Solid
MLVSS	Mixed Liquor Volatile Suspended Solid
NOB	Nitrite Oxidizing Bacteria
OUR	Oxygen Uptake Rate
SAUR	Specific Ammonium Uptake Rate
SBR	Sequencing Batch Reactor
SOUR	Specific Oxygen Uptake Rate
SRT	Sludge Retention Time
SS	Suspended Solid
SVI	Sludge Volume Index
TOC	Total Organic Carbon
VER	Volume Exchange Ratio

LIST OF SYMBOLS

$NaHCO_3$	Sodium Bicarbonate
NH_4-N	Ammonium-Nitrogen
NH_4Cl	Ammonium Chloride
NH_4HCO_3	Ammonium Hydrogen Carbonate
$SOUR_{xc}$	Specific Oxygen Uptake Rate without carbon

KEBULURAN DAN PENGAKTIFAN SEMULA BAKTERIA NITRIFIKASI SEPARA: PERBANDINGAN ANTARA BAKTERIA JENIS FLOKULUS DAN BERBUTIR

Abstrak

Dalam kajian ini, nitrogen telah disingkarkan dari air sisa melalui penitritan separa dengan menggunakan kedua-dua bakteria flokulus dan berbutir. Tujuan kajian ini adalah untuk menyiasat akibat kebuluran terhadap bakteria penyingkiran nitrogen, penukaran bentuk bakteria ketika dalam keadaan kebuluran, dan kebolehan bakteria untuk pemulihan. Dua reaktor kelompok urutan (SBR) dengan kapasiti 8 L telah dijalankan untuk memperkayakan bakteria flokulus dan berbutir. Kedua-dua bakteria flokulus dan berbutir diperkayakan oleh air sisa sintetik yang mengandungi kandungan tinggi dalam SBR dengan keadaan yang sama kecuali nisbah tinggi/garis pusat (H/D) dan masa pengenapan. Nisbah H/D dalam reaktor kelompok urutan yang digunakan oleh bakteria jenis berbutir ialah 10, lebih tinggi berbanding dengan bakteria jenis flokulus (5). Masa pengenapan untuk bakteria berbutir dengan dikurangkan secara berperingkat dari 5 ke 1 minit untuk penambahan proses pembutiran. Bakteria berbutir yang dihasilkan mempunyai garis pusat purata 2 mm. Prestasi bakteria jenis flokulus dan berbutir jangka panjang adalah tekal dan keputusan menunjukan penitritan separa telah dicapai utuk kedua-dua bakteria jenis flokulus dan berbutir. Perbandingan antara bakteria jenis flokulus dan berbutir dalam kebuluran, pengaktifan semula, dan pengagihan tenaga. Kajian kebuluran (kebuluran karbon dan tenaga) telah dijalankan atas bakteria jenis flokulus dan berbutir. Kajian

kebuluran menunjukan bahawa kubuluran karbon (ketiadaan sumber karbon, hanya membekal sumber tenaga) mempunyai kurang kesan terhadap aktiviti bakteria jenis flokulus dan berbutir jika dibandingkan dengan kebuluran tenaga (ketiadaan sumber tenaga, hanya membekal sumber karbon). Bakteria jenis berbutir mempunyai pembingkasan yang lebih baik terhadap kebuluran apabila dibandingkan dengan bakteria jenis flokulus disebabkan oleh pengurangan kadar pengambilan ammonium yang lebih rendah. Di samping itu, kajian pengaktifan semula terhadap bakteria jenis flokulus dan berbutir telah dijalankan selepas tempoh kebuluran yang tertentu (kebuluran karbon dan tenaga). Keputusan kajian pengaktifan semula menunjukan bahawa bakteria yang mengalami kebuluran karbon lebih senang diaktifkan semula berbanding dengan bakteria yang mengalami kebuluran tenaga. Bakteria berbutir yang mengalami kebuluran karbon mempunyai responsif yang lebih baik terhadap pengaktifan semula berbanding dengan bakteria jenis flokulus. Pengaktifan semula berpanjangan adalah diperlukan untuk mengaktifkan semula bakteria yang mengalami kebuluran tenaga. Bakteria jenis berbutir yang mengalami kebuluran tenaga memerlukan tempoh yang lebih singkat untuk pengaktifan semula berbanding dengan bakteria jenis flokulus yang mengalami kebuluran tenaga. Kajian pengagihan tenaga penyaraan telah dijalankan terhadap kedua-dua bakteria jenis flokulus dan berbutir. Kajian menunjukan bakteria jenis berbutir mempunyai tenaga penyaraan yang lebih tinggi (89%) berbanding dengan bakteria jenis flokulus ketika keadaan biasa. Pengagihan tenaga penyaraan untuk kedua-dua bakteria jenis flokulus dan berbutir tidak dijejaskan oleh kebuluran (70%). Namun demikian, pengagihan tenaga penyaraan yang serupa selepas kebuluran adalah dipercayai disebabkan pemecahan struktur berbutir selepas kebuluran yang mengakibatkan kelakuan yang serupa dengan bakteria jenis flokulus.

STARVATION AND REACTIVATION OF

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ABSTRACT

In this study, nitrogen was removed from wastewater via partial nitrification using both floccular and granular biomass. The purpose of this study is to investigate the effect of starvation on nitrogen removing bacteria, changes of biomass in term of structure during starvation, and recovery ability of biomass. 2 Sequencing Batch Reactor (SBR) with working volume of 8L were operated to enrich floccular and granular biomass. Both floccular and granular biomass were cultivated using high strength synthetic wastewater in SBR operating under similar parameters except height/diameter (H/D) ratio and settling time. The height/diameter ratio of SBR used to cultivate granular biomass was 10 which was higher than floccular biomass (5). The settling period of granular biomass was stepwise decreased from 5 to 1 minute for the enhancement of granulation. The cultivated granular biomass has an average diameter of 2mm. The long term performance of floccular and granular biomass were consistent and the results showed that partial nitrification was achieved for both floccular and granular biomass. Comparison was made between floccular and granular biomass in starvation, reactivation and energy distribution. Starvation studies (carbon starvation and energy starvation) were carried out on both floccular and granular biomass. The starvation studies showed that carbon starvation (absence of carbon source, only energy source is provided) has lesser impacts in the activity of both floccular and granular biomass as compared to energy starvation (absence of energy source, only carbon source is provided). Granular biomass was found to be

more resilient to the starvation as compared to floccular biomass due to slower rate of reduction in ammonium uptake. Furthermore, recovery study was carried out on both floccular and granular biomass after certain period of starvations (both carbon and energy starvations). The recovery study results showed that carbon starved biomass were able to recovery easily as compared to energy starved biomass. Carbon starved granular biomass was found to be more responsive to the recovery as compared to carbon starved floccular biomass. Prolonged recovery was required for energy starved biomass to reactivate. Energy starved granular biomass required shorter period to recover as compared to energy starved floccular biomass. Maintenance energy distribution study was carried out on both carbon starved floccular biomass and granular biomass. It was found out that granular biomass has higher maintenance energy distribution (89%) during normal condition as compared to floccular biomass (69%). The maintenance energy distribution of both floccular and granular biomass were not affected by the starvation (70%). However, it was believed that the disintegration of the granular structure after starvation induced similar behaviour to the floccular biomass, which was probably the reason behind the similar maintenance energy distribution after starvation.

CHAPTER 1

INTRODUCTION

1.1 Water

Water is an important resource on Earth which none of us would survive more than 5 days without drinking, whereas one could survive more than a week without food. Thus, quality of the water have to be preserved as much as possible so that clean water could be recycled naturally rather than applying tons of chemicals just to purify the water to drinkable level. Although applying tons of chemicals could solve the clean water crisis problem, but it creates other problems which are pollutions, either soil, water, or air pollution.

Besides that, water also used by many industries to serve multiple purposes such as washing the media in electronic industries, blending in food industries, fertilizer industries, and pharmaceutical industries. Thus, preservative of clean and usable water, either in term of drinking or industrial usage, become imperative from time and time.

1.2 Water pollution in Malaysia

Division of Environment of Malaysia was established on 15 September 1975 under Ministry of Local Government & Environment. Division of Environment was then renamed to Department of Environment (DOE) at 1983 and it was placed under Ministry of Natural Resources and Environment on 27 March 2004. The main objectives of the establishment of DOE are to (i) provide a clean, safe, healthy and productive environment for present and future generation, (ii) conservation of the country's unique and diverse cultural and natural heritage with effective participation by all sectors of society, and (iii) sustainable lifestyles and patterns of consumption and production (Department of Environment, 2014).

According to the Malaysia Environment Report 2013, among 473 rivers that were being monitored, 275 (58.1%) were found to be clean, 173 (36.6%) slightly polluted and 25 (5.3%) polluted as shown in Figure 1.1.The three major pollutants detected were Biochemical Oxygen Demand (BOD), Ammonium Nitrogen (AN), and Suspended Solid (SS). Among the 25 rivers that were classified as polluted rivers,23 (92%) were polluted with AN.Table 1.1(a) shows the 25 rivers that are being polluted with AN and (b) showsthe DOE water quality index classification (DOE, 2014).

Ammonium-Nitrogen (NH_4-N) is a component of nitrogen which is adopted as an indicator to determine pollution by water. The main sources of NH_3-N are from domestic sewage, industrial wastewater, and livestock farming. Ammonium-Nitrogen is important to be removed from the rivers because excessive of it will cause eutrophication. Eutrophication is a phenomena whereby algae in the river is overgrown due to excessive Ammonium-Nitrogenis being supplied. This will causes the oxygen level in the river decreased and will endanger other marine species in the river. Figure 1.2 shows a general trend of decrease in the number of clean river based on Ammonium-Nitrogen. Thus, it is important to reduce the concentration of Ammonium Nitrogen to the level that being enforced in the regulationas highlighted in Table 1.2(DOE, 2014)

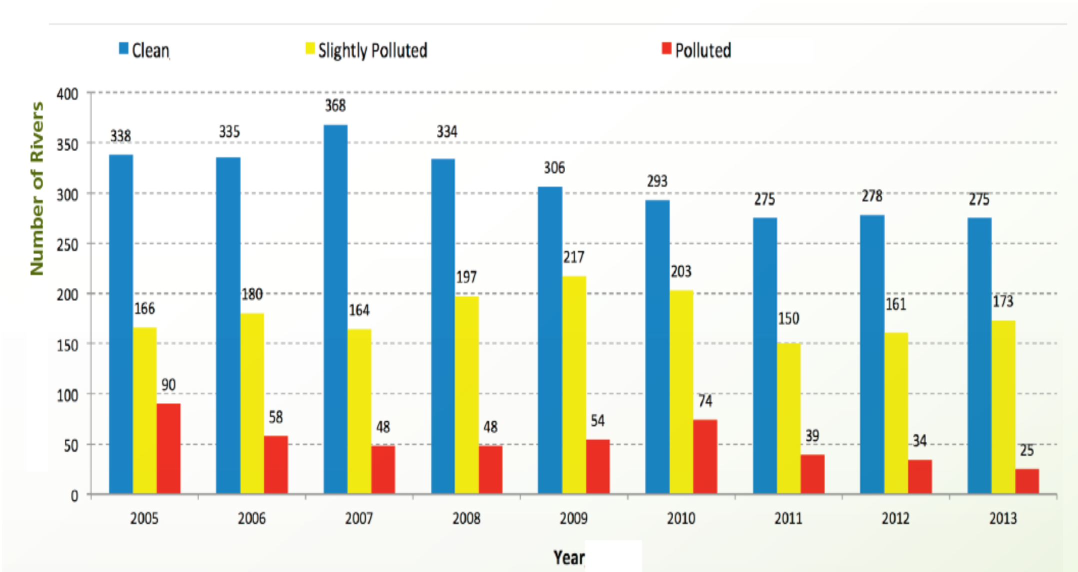

Figure 1.1 River Water Quality Trend in Malaysia (2005-2013)
(Source: Malaysia Environment Quality Report 2013. Department of Environment, Ministry of Natural Resources and Environment, Malaysia)

Table 1.1(a) The Polluted Rivers and Classes Based on BOD, AN and SS and (b) DOE Water Quality Index Classification in Malaysia, 2013 (Source: Malaysia Environment Quality Report 2013. Department of Environment, Ministry of Natural Resources and Environment, Malaysia)

(a)

STATE/ NEGERI	RIVER BASIN/ LEMBANGAN SUNGAI	RIVER/ SUNGAI	STATUS 2013		CLASS BASED ON:/ KELAS BERDASARKAN:		
			WQI/ IKA	CLASS/ KELAS	BOD	AN	SS
SELANGOR/ WPKL	KLANG	SG. BUNOS	59	III	V	IV	I
SELANGOR/ WPKL	KLANG	SG. TOBA	59	III	V	V	II
JOHOR	RAMBAH	SG. RAMBAH	58	III	V	II	II
JOHOR	KAW. PASIR GUDANG	SG. PEREMBI	58	III	IV	IV	II
MELAKA	SERI MELAKA	SG. SERI MELAKA	57	III	IV	IV	I
P.PINANG	JURU	SG. RAMBAI	57	III	IV	IV	II
SARAWAK	MIRI	SG. DALAM	57	III	V	V	II
JOHOR	TEBRAU	SG. TAMPOI	57	III	V	IV	II
P.PINANG	JAWI	SG. JAWI	55	III	IV	IV	III
P.PINANG	JURU	SG. JURU	55	III	V	IV	II
JOHOR	KAW. PASIR GUDANG	SG. MASAI	54	III	IV	IV	I
P.PINANG/KEDAH	PERAI	SG. KEREH	52	IV	V	V	II
JOHOR	SEGGET	SG. SEGGET	52	IV	V	V	II
JOHOR	AIR BALOI	SG. AIR BALOI	49	IV	V	I	III
JOHOR	KEMPAS	SG. KEMPAS	49	IV	V	V	II
P.PINANG	PERAI	SG. PERTAMA	48	IV	V	IV	III
JOHOR	TEBRAU	SG. SEBULUNG	48	IV	V	IV	I
SELANGOR/ WPKL	KLANG	SG. UNTUT	48	IV	V	V	I
JOHOR	KAW. PASIR GUDANG	SG. BULUH	48	IV	V	IV	II
JOHOR	DANGA	SG. DANGA	47	IV	V	V	II
MELAKA	MERLIMAU	SG. MERLIMAU	45	IV	V	V	II
JOHOR	KAW. PASIR GUDANG	SG. TUKANG BATU	38	IV	V	V	II
JOHOR	TEBRAU	SG. SENGKUANG	37	IV	V	V	II
P.PINANG	PINANG	SG. JELUTONG	35	IV	V	V	II
JOHOR	PONTIAN BESAR	SG. AYER MERAH	32	IV	V	IV	I

(b)

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	> 5.0
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

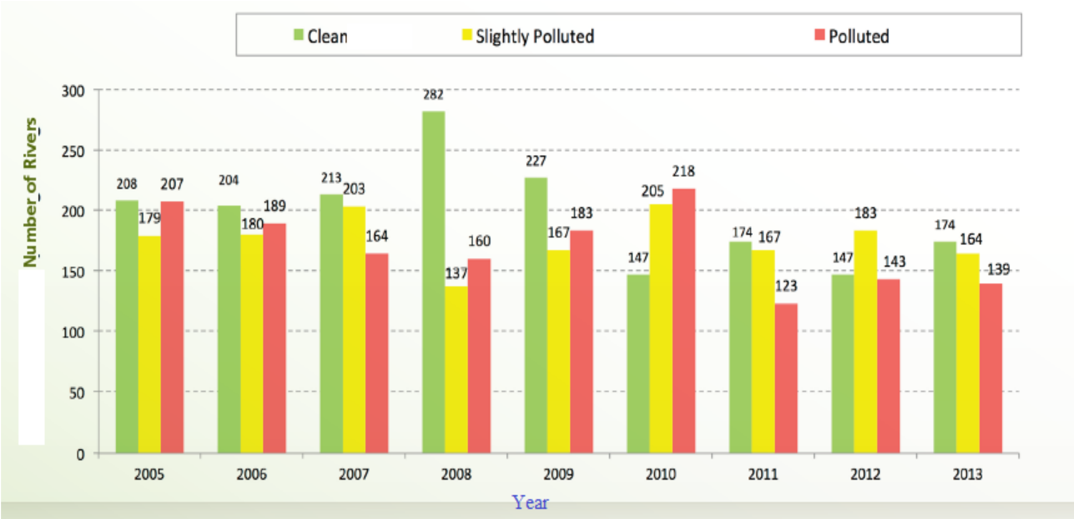

Figure 1.2 River Water Quality Trend based on AN sub-index in Malaysia (2005-2013)

(Source: Malaysia Environment Quality Report 2013. Department of Environment, Ministry of Natural Resources and Environment, Malaysia)

Table 1.2 Acceptable Conditions for Discharge of Industrial Effluent for Mixed Effluent of Standard A and B (Extracted from Environment Quality (Industrial Effluents) Regulation 2009 (PU (A) 434))

FIFTH SCHEDULE
[Paragraph 11(1) (a)]

ACCEPTABLE CONDITIONS FOR DISCHARGE OF INDUSTRIAL EFFLUENT FOR MIXED EFFLUENT OF STANDARDS A AND B

	Parameter	Unit	Standard	
			A	B
	(1)	(2)	(3)	(4)
(i)	Temperature	°C	40	40
(ii)	pH Value	-	6.0-9.0	5.5-9.0
(iii)	BOD_5 at 20°C	mg/L	20	40
(iv)	Suspended Solids	mg/L	50	100
(v)	Mercury	mg/L	0.005	0.05
(vi)	Cadmium	mg/L	0.01	0.02
(vii)	Chromium, Hexavalent	mg/L	0.05	0.05
(viii)	Chromium, Trivalent	mg/L	0.20	1.0
(ix)	Arsenic	mg/L	0.05	0.10
(x)	Cyanide	mg/L	0.05	0.10
(xi)	Lead	mg/L	0.10	0.5
(xii)	Copper	mg/L	0.20	1.0
(xiii)	Manganese	mg/L	0.20	1.0
(xiv)	Nickel	mg/L	0.20	1.0
(xv)	Tin	mg/L	0.20	1.0
(xvi)	Zinc	mg/L	2.0	2.0
(xvii)	Boron	mg/L	1.0	4.0
(xviii)	Iron (Fe)	mg/L	1.0	5.0
(xix)	Silver	mg/L	0.1	1.0
(xx)	Aluminium	mg/L	10	15
(xxi)	Selenium	mg/L	0.02	0.5
(xxii)	Barium	mg/L	1.0	2.0
(xxiii)	Fluoride	mg/L	2.0	5.0
(xxiv)	Formaldehyde	mg/L	1.0	2.0
(xxv)	Phenol	mg/L	0.001	1.0
(xxvi)	Free Chlorine	mg/L	1.0	2.0
(xxvii)	Sulphide	mg/L	0.50	0.50
(xxviii)	Oil and Grease	mg/L	1.0	10
(xxix)	Ammoniacal Nitrogen	mg/L	10	20
(xxx)	Colour	ADMI*	100	200

ADMI- American Dye Manufactures Institute

1.3 Problem Statement

In modern age, people lives with a luxury lifestyle and having expensive technology. On the positive side, it helps the economy to grow. On the negative side, industrial produce a lot of waste due to the increasing of production in order to cope with the demand in the market. There are three types of wastesfrom industrial area which are solid, liquid and gas. Gas waste required filtration system that can be installed in the chimney to remove any greenhouse gases and other toxic gases using suitable absorption materials before the gases are being released to the environment. Solid waste does not require a big space for temporarily storage and disposal of the solid waste can be arranged with certain agency that specialized in handling the solid waste. However, liquid waste requires a big reservoir for temporarily storage. Thus, compared to storage, it is more feasible to treat the wastewater as it requires smaller reservoir due to continuous process and it reduces the cost of operation(Wan et al., 2013).

On the other hand, the discharge quality of the effluent of the industrial wastewater treatment plant is bounded by regulation as listed in Table 1.2. Under normal situation, various production lines produce various type of wastewater and they are collected in an equalizer tank whereby various sources of wastewater are mixed before the treatment begins Thus, a series of processes would normally be applied until final discharge can meet the requirements as amended in the regulation. The processes involve pre-treatment, primary treatment, and secondary treatment. Tertiary (or advance treatment) treatment is applied if necessary. Primary treatment is usually chemical treatment which apply chemical in order to extract certain ion and form a precipitate so that it can be settled and extracted from the wastewater easily. Secondary treatment is biological treatment which apply biomass (ammonia