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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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_3BO_3	Boric acid
IA	Image analysis
IC	Ion Chromatography
K_2HPO_4	Dipotassium phosphate
KH_2PO_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_2EDTA	Ethylenediaminetetraacetic acid
$NaHCO_3$	Sodium bicarbonate
NaM_oO_4	Sodium molybdate
NH_4^+-N	Ammonium
NH_4Cl	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)
kgCOD/m^3/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
^{o}C	Temperature (degree Celsius)
pH	Measure of acidity or alkalinity
ppm	Parts per million

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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 pembentukkan 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 pengenapan 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/m^3/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/m^3/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