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Performance of Aerobic Granular Sludge for Domestic Wastewater Treatment

Laila Dina Amalia Purba, Norhayati Abdullah, Mohd Hakim Ab Halim, Ali Yuzir, Arash Zamyadi

Abstract**: *Aerobic granular sludge can be used to treat various types of wastewater, such as industrial, municipal and domestic wastewater. This study investigated the treatment of low-strength domestic wastewater while simultaneously developed aerobic granular sludge in a sequencing batch reactor (SBR). Activated sludge was used as the seeding for granulation. The results indicated good COD and ammoniacal nitrogen removal at 72% and 73%, respectively. Aerobic granular sludge was successfully developed with low sludge volume index (SVI_{30}) of 29 mL/g, which demonstrated an excellent settling property of aerobic granular sludge. Biomass concentration increased significantly compared to the seed sludge, indicating high biomass density in the SBR system. Settling velocity of aerobic granular sludge was significantly higher compared to the conventional activated sludge. This study showed the feasibility of aerobic granular sludge to be developed using low-strength domestic wastewater. Moreover, this study demonstrated the long-term application of aerobic granular sludge in domestic wastewater treatment.***

Keywords: Aerobic granular sludge, low-strength domestic wastewater, domestic wastewater treatment.

I. INTRODUCTION

Aerobic granular sludge has received more attention in wastewater treatment system as it possessed superior characteristics than the world-wide used conventional activated sludge [1]. Aerobic granular sludge is a microbial consortia that formed by various forces, including physical, chemical and microbial factors [2].

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***** Correspondence Author
Laila Dina Amalia Purba, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia. Email: purbalaila@gmail.com
Norhayati Abdullah*, Department of Environmental Engineering and Green Technology, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia. Email: norhayati@utm.my
Mohd Hakim Ab Halim, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia. Email: mohdhakim@utm.my
Ali Yuzir, Department of Environmental Engineering and Green Technology, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia. Email: muhdaliyuzir@utm.my
Arash Zamyadi, Water Research Australia and Australia Water Research Centre, School of Civil and Environmental Engineering, University of New South Wales (UNSW), Australia. Email : a.zamyadi@unsw@edu.au

A distinguished layer of aerobic and anoxic zone may be found in aerobic granules, thus allowing both aerobic and anoxic reactions to occur in a single system. Aerobic granular sludge exhibited better settling features due to high biomass density therefore reducing the needs for separate clarifier tank in a wastewater treatment plant.

Aerobic granules were successfully developed in various types of wastewater, such as piggery wastewater [3], high strength agro-based wastewater [4], municipal wastewater [5] and domestic wastewater [6]. Domestic wastewater is known to have lower organic content compared to the other types of wastewater. This factor has been a challenge to develop aerobic granular sludge using domestic wastewater. Low organic content has been proven to produce smaller granules with loose and porous structure [5].

First attempt of aerobic granulation using domestic wastewater demonstrated that long-start up period was required (up to 300 days) with intensive physical selective pressure to cultivate aerobic granular sludge [7]. Recently, application of aerobic granular sludge for low-strength domestic wastewater treatment was reported [8]. However, to enhance aerobic granulation process, external carbon source was introduced into the system. Moreover, metabolic selective pressure was applied to enhance COD uptake of aerobic granules. The results highlighted that 85% COD removal efficiency was achieved in a long-term operation of aerobic granular sludge system.

This study aims to analyze the domestic wastewater treatment while simultaneously cultivate aerobic granular sludge in a sequencing batch reactor (SBR) system. No selection pressure was applied in this study. SBR column was operated for 140 days to fully understand the performance of aerobic granular sludge in a long-term operation. Lastly, aerobic granular sludge was characterized in terms of the morphological and physical features.

II. METHODOLOGY

A. Experimental Set-Up

This study utilized an SBR column with 100 cm height and 6 cm inner diameter, resulting in H/D ratio of 17 as shown in Fig. 1. The SBR column was operated at 3-hours cyclic time with working volume of 1.5 L. SBR cyclic time consisted of 5 minutes feeding, 161 minutes aeration, 10 minutes settling, 2 minutes effluent withdrawal and 2 minutes idle periods. Aeration was introduced using a microsparger located at the bottom of the column with 2.5 L/min air-flow rate.

Activated sludge and domestic wastewater samples were collected from local wastewater treatment plant (WWTP). Activated sludge was used as the seeding for development of aerobic granulation. All samples were filtered to remove unwanted large debris that might clog the piping in SBR column.

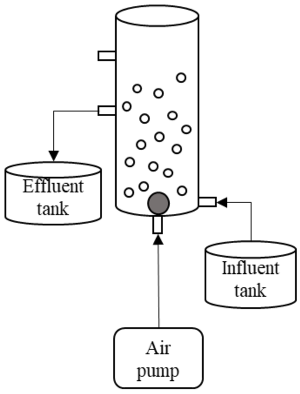

Fig. 1. SBR column used in this study

B. Analytical Methods

Analyses of influent and treated wastewater were performed for the COD and ammoniacal nitrogen concentration following the Standard Methods for the Examination of Water and Wastewater [9]. Development of aerobic granular sludge was observed from the value of mixed liquor suspended solid (MLSS) and sludge volume index (SVI_{30}). Development of aerobic granular sludge was indicated by a stable increase of MLSS and low SVI_{30}.

Developed aerobic granular sludge was observed using a stereomicroscope and field emission scanning electron microscope (FESEM, Jeol, FSM7800F, Japan) (Olympus SZX7, Japan). Moreover, the settling velocity of aerobic granules were analyzed by observing the average time taken for individual granules to settle at certain height of a glass column filled with tap water.

III. RESULTS AND DISCUSSION

A. Performance of SBR

Wastewater sample was characterized prior to be used in this study. The analysis revealed COD and ammoniacal nitrogen concentrations of 177 mg/L and 31.7 mg/L, respectively. The characteristics of domestic wastewater used in this study was found to be lower than previous reports [10]–[12]. Moreover, the concentration of organic content in domestic wastewater was found to be varied from time to time. This might be due to the rainy season and variance in local weather conditions. Moreover, since open pond system is widely used at local WWTP, heavy rainfall may directly affect the concentration of organic content in the wastewater stream. This posed a challenge to utilize actual domestic wastewater to develop aerobic granular sludge while maintaining high removal efficiency to meet the regulation of treated wastewater disposal to the environment.

Performance of SBR system using aerobic granular sludge was analyzed in terms of COD and ammoniacal nitrogen removal. COD removal was successfully achieved at 72% with effluent concentration of 47 mg/L. As can be seen in Fig. 2, COD removal was found to be stable throughout the experimental period. However, it can be noticed that increase in COD concentration occurred due to the varying concentration of wastewater stream. Moreover, mechanistic issue also occurred throughout the experimental period. This has caused unstable reactor performance since the system had to be shut down to address the issues. Nevertheless, the SBR system was able to maintain the performance after the operation was resumed.

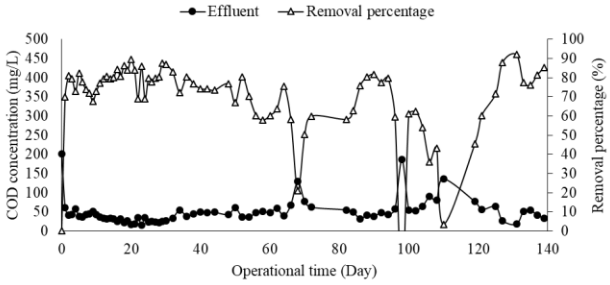

Fig. 2. COD removal using aerobic granular sludge

Performance of COD removal in this study was found to be lower than previous reports treating different types of wastewater, including industrial wastewater [4] and domestic wastewater [11]. This may be due to the concentration of COD in raw wastewater used in this study was much lower than the previous studies. Coma et al. (2012) utilized wastewater containing 326 mg/L COD concentration.

As shown in Fig. 3, concentration of ammoniacal nitrogen was relatively stable throughout the experimental period. By the end of the study, concentration of ammoniacal nitrogen in the effluent was 8.5 mg/L with removal percentage of 73%, respectively. Nitrogen presents in wastewater in the form of ammoniacal nitrogen (NH_3-N) and oxidized into nitrite in a process called nitrification [2]. Nitrite is furthermore oxidized into nitrate and nitrogen gas and lastly released to the environment [13]. The result in this study indicated that ammonia oxidizing and nitrification occurred in the SBR system. However, further study is required to understand the removal of total nitrogen in the SBR system.

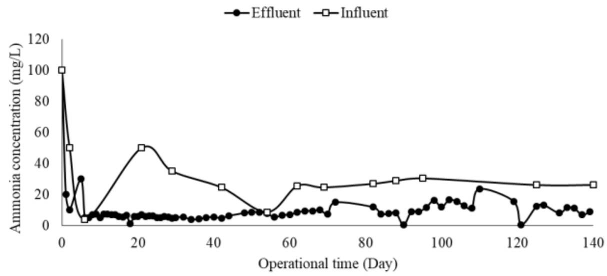

Fig. 3. Concentration of ammoniacal nitrogen in SBR effluent

B. Cultivation of Aerobic Granular Sludge

Aerobic granular sludge was developed in the SBR column by utilizing activated sludge as the seeding. The MLSS and SVI_{30} of the seed sludge were 1,700 mg/L and 147 mL/g, respectively. This indicated a poor settling properties and biomass density of the seed sludge. Unstable MLSS and SVI_{30} in the reactor may be observed during the acclimatization period until day-60.

To maintain biomass concentration in the reactor, settling time was prolonged from 10 to 15 minutes in the first 30 days of experimental period. Settling time was gradually decreased after stable MLSS concentration was observed. During biomass washout, fluffy and less dense sludge was withdrawn from the column. Remaining sludge then started to flocculate and form small granules.

After 140 days of experimental period, matured aerobic granular sludge was formed with SVI_{30} value of 29 mL/g. Meanwhile, the MLSS increased to 7,000 mg/L, indicating an excellent biomass accumulation in the system. Moreover, low SVI_{30} value indicated better settleability as compared to the seed sludge (Table-I).

Table-I: Changes of MLSS and SVI_{30} of granular sludge

Sample	MLSS (mg/L)	SVI_{30} (mL/g)
Seed sludge	1,700	147
Aerobic granular sludge	7,000	29

C. Characteristics of Aerobic Granular Sludge

Developed aerobic granular sludge was analyzed to reveal the morphological and physical characteristics of the granules. As shown in Fig. 4, diameter of the largest aerobic granules were 6.2 mm. Moreover, analysis of aerobic granules using FESEM showed that cocci-shaped bacteria dominates the outer layer of the granules. Cocci-shaped bacteria play major roles to support microbial attachment process in aerobic granulation [14]. Micropores or sometimes referred as cavities were also found on the granular surface. Micropores are important as a medium of transportation of substrates into the inner layer of granular sludge [15].

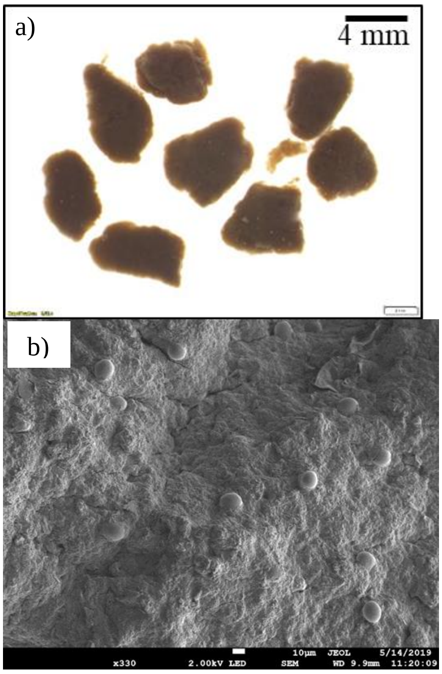

Fig. 4. a) Matured aerobic granular sludge observed using stereomicroscope and b) cocci-shaped bacteria on outer layer of granular sludge

In comparison with activated sludge, the developed granular sludge possessed higher settling velocity at 59 m/h. Meanwhile, the seed sludge had settling velocity of 11 m/h. The settling velocity of granular sludge in this study was significantly higher than previous report [16]. Rosman et al. (2013) developed aerobic granules with settling velocity of 33 m/h using rubber wastewater. This result indicated a significant improvement on settleability as compared to the seed sludge.

IV. CONCLUSION

Aerobic granular sludge was successfully developed using domestic wastewater in the SBR system. COD and ammoniacal nitrogen removal were achieved at more than 70% for 140-days of experimental period, indicating a stable operation of aerobic granular sludge system for long-term application. Moreover, matured granular sludge exhibited better settling properties compared to the conventional activated sludge.

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AUTHORS PROFILE

Laila Dina Amalia Purba, B.Sc. is a candidate for Master of Philosophy in Malaysia-Japan International Institute of Technology (MJIIT), UTM Kuala Lumpur. She obtained her degree in Biology Industry from Universiti Teknologi Malaysia. Her current research focuses on treatment of domestic wastewater, aerobic granulation, microalgae-bacteria granular consortia, bioenvironmental engineering and molecular biotechnology.

Assoc. Prof. Dr. Norhayati Abdullah is an Associate Professor at Malaysia-Japan International Institute of Technology (MJIIT), UTM Kuala Lumpur. She obtained her PhD in Environmental Biotechnology from Universiti Teknologi Malaysia and Newcastle University, UK. Her research focuses on wastewater treatment system for industrial and domestic wastewater, bioenvironmental engineering, biodegradation and molecular biotechnology. Her research focus also includes the resource recovery and sustainability, specifically the environmental impact assessment of palm oil production. She is fellow of the International Water Association (IWA) and received numerous awards globally. Her publications include both critical review articles and original research articles. She has also been serving as a reviewer for a number of reputed journals.

Dr. Mohd Hakim Ab Halim is currently a researcher at Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia Kuala Lumpur (UTM KL). He obtained his PhD in Environmental Biotechnology, from Department of Water and Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia Johor Bahru (UTM JB). He has published several papers in reputed journals and has been serving as a reviewer for a number of reputed journals. His research interests focus on domestic and agro-based wastewater treatment, water quality, water pollution control, bioenvironmental engineering, wastewater treatment technology, bioremediation and biodegradation, sequencing batch reactor system, environmental microbiology, biological process engineering and aerobic biogranular sludge technology.

Assoc. Prof. Dr. Muhamad Ali Muhammad Yuzir is an Associate Professor at MJIIT, UTM Kuala Lumpur. He obtained his PhD in Environmental Engineering from Newcastle University, UK. His research interests focus on environmental engineering, wastewater treatment technology, water quality, emerging micro-pollutant, anaerobic digestion, disaster preparedness and disaster risk management. His publications include both original research articles and critical review articles and he has been a reviewer for many reputed journals. He is an active member of International Water Association (IWA) and Board of Engineers Malaysia (BEM). He currently serves as deputy director of disaster preparedness and prevention centre (DPPC) in UTM Kuala Lumpur.

Arash Zamyadi, B.Sc., M.Sc., Ph.D. is an Associate Professor at School of Civil and Environmental Engineering, University New South Wales (UNSW). His research interests focus on bioenvironmental engineering, water quality and water treatment system, cyanobacteria and cyanotoxins. He has also broadened his research focus to the use of microalgae for “energy” and “food” production since if treated properly, cyanobacterial and algal species can be a valuable resource to produce energy and food. His research also focuses on water treatment using combined microbial/chemical contaminants and reuse opportunities. He is fellow of the International Water Association (IWA). His publications include both critical review and original research articles.