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WASTEWATER CHARACTERIZATION AND SEQUENCING BATCH REACTOR OPERATION FOR AEROBIC GRANULAR SLUDGE CULTIVATION

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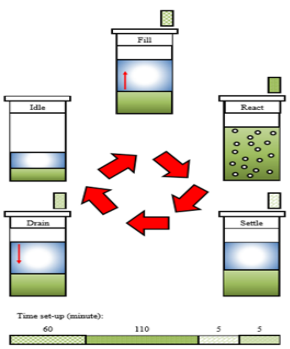
Graphical abstract



Abstract

Studying the possibility of forming aerobic granules on real domestic sewage was a logical step in the scaling-up process and development of Aerobic Granular Sludge (AGS) technology. It was noted that influent wastewater composition and Sequencing Batch Reactor (SBR) operation cycle time are important factors that can influence the formation of AGS. Therefore, this study aims to determine the suitability of influent wastewater from Bunus Wastewater Treatment Plant (WWTP) for AGS cultivation and then propose a proper SBR operation cycle time. In this study, wastewater characterization was done for the influent of wastewater treatment plant located in Bunus, Kuala Lumpur. The result was then analysed and compared with previous research to determine the suitability of AGS cultivation. The information on SBR from previous studies were also gathered to propose SBR operation cycle time that suit the Bunus WWTP influent. The findings indicate that the wastewater can be characterized as low strength domestic wastewater with low organic and nutrients content. The values of related parameters in this study have shown that influent wastewater of Bunus WWTP is suitable for cultivating AGS. For the proposed SBR operation, the cycle time is 3h, which consist of 60 min (fill), 110 min (aerate), 5 min (settle), and 5 min (discharge), respectively.

Keywords: Aerobic granular sludge, Sequencing Batch reactor, influent, cycle time, cultivation

1.0 INTRODUCTION

Modern technology has introduced more advance system in both biological and chemical method for wastewater treatment process. Nowadays, biological treatment becomes more preferable than additional of chemicals which provides more cost effective, simple and environmental friendly system for the treatment [1]. In the need for more compact biological treatment, there has been an evolution in the sludge discovery for the application of wastewater treatment. Biogranulation technology that based upon self-immobilised granulated biomass is seen as a preferable alternative than using activated sludge system in treating wastewater. Aerobic granular sludge (AGS), a major part of the biogranulation technology has risen as a promising treatment process for the wastewater treatment industry [2].

Gao *et al.* [3] stated that AGS is cultivated in aerobic conditions and commonly used for the degradation of organics. It is also undergoing removal of nitrogen under aerobic and anoxic conditions. According to Seow *et al.* [4], compare to conventional bioflocs, aerobic granular sludge offers advantages in the form of compact and dense microbial structure which exhibit good settleability and high retention of biomass. Moreover, AGS also achieves excellent rate of metabolism and resilience to shocks and toxins. This is due to the conservation by a matrix of extracellular polymeric substances (EPS). In this sense, AGS technology has played a decisive role as an innovative technology for wastewater treatment in the near future.

In order to improve and promote its application in global wastewater treatment industry, research on the fundamentals of aerobic granulation have been deeply executed. Most of the previous research on AGS have shown that the properties of AGS formed in SBR are influenced by many factors, including substrate composition and SBR operation cycle time [2]. However, it required a combination of several factor to form a successfully developed AGS. Adav *et al.* [5] in his study on AGS mentioned that there was a very small possibility for the successful cultivation of AGS. Under specific conditions, the desired granules could be formed".

The operation of SBR is a sequencing cycle consist of feeding, aeration, settling, and discharging of treated effluent. The time for each process have significant effect on the formation of AGS [6]. For substrate composition, many types of wastewater were used to developed AGS such as industrial, synthetic and domestic wastewater. Substrate composition influences the kinetic behaviour, stability, and morphology of granules [7]. Yang *et al.* [8] stated that studying the possibility of forming aerobic granules on real domestic sewage was a logical step in the scaling-up process and development of this technology. Therefore, it is important to determine the suitability of influent wastewater characteristics from Bunus WWTP for the cultivation of AGS.

2.0 METHODOLOGY

This research determines the influent characteristics of domestic wastewater from wastewater treatment plant located in Bunus, Kuala Lumpur. The result was then analysed and compared with previous research for suitability of AGS cultivation. The information on SBR operation were collected from previous studies in order to propose SBR operation cycle time that can suit the Bunus WWTP influent.

2.1 Location of Study Area

The study area is Bunus, Kuala Lumpur city, Malaysia with the coordinate of 3°11'04.9"N 101°42'40.8"E. Wastewater treatment plant was classified as domestic according to the source of raw sewage and the samples were collected from the influent of Bunus treatment plant

Table 1 Measurement for wastewater characterization analysis

No	Measurement	Methods	Units	Time
1.	pH	Measured with a pH-meter (Thermo Orion S010169)		daily to weekly
2.	Dissolved oxygen (DO)	Measured with a DO-meter (Thermo Orion S005343)	mgL^{-1}	daily to weekly
3.	Temperature	Monitor together with DO-meter (Thermo Orion S005343)	^{o}C	daily to weekly
4.	Chemical oxygen demand, (COD),	Measured colorimetrically according to the Standard Methods [9] using HACH Spectrophotometer (DR5000)	mgL^{-1}	daily to weekly
5.	Total phosphorus (TP)	Similar as above	mgL^{-1}	daily to weekly
6.	Ammonium (NH_4^+-N) Nitrite (NO_2^+-N) Nitrate (NO_3^+-N)	Similar as above	mgL^{-1}	daily to weekly
7.	Total nitrogen(TN)	Similar as above	mgL^{-1}	daily to weekly
8	Total suspended solid (TSS)	24 h drying at 105^{o}C; Standard Methods [9]	mgL^{-1}	daily to weekly
9	Biochemical oxygen demand, (BOD)	Samples was kept in an incubator at 20^{o}C and left for five days Standard Methods [9]	mgL^{-1}	daily to weekly

2.2 Wastewater Characterization Data Collection

Collections of samples were done once every week for two month from 5 September 2017 to 31 October 2017. Grab samples of influent wastewater were collected in one day trips. The wastewater was collected by using a pail and then filled in sampling bottle through a funnel. All the samples were then transported to the laboratory for analysis.

3.0 RESULTS AND DISCUSSION

3.1 Wastewater Characterization

Bunus WWTP wastewater characterization sampling and analysis have been done according to related parameter; BOD, COD, NH_3-N, TN, NO_2-N, NO_3-N, TP, DO, TSS, Temperature and pH. The parameter was analyzed and determine for suitability in cultivating AGS.

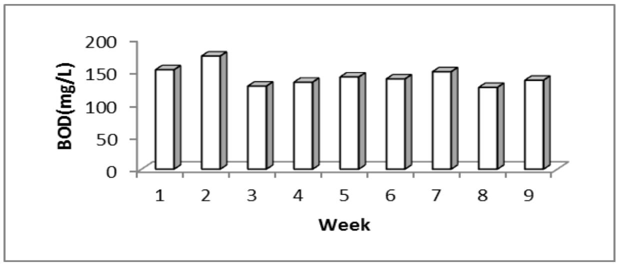


Figure 1 Variation of influent Biochemical Oxygen Demand (BOD) during the study period

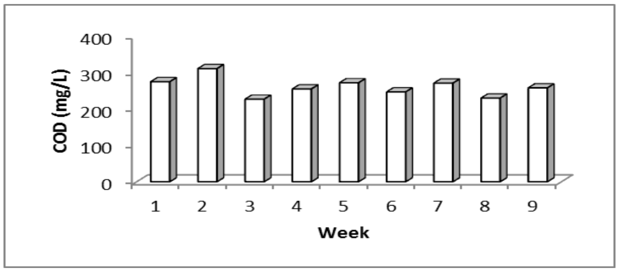


Figure 2 Variation of influent Chemical Oxygen Demand (COD) during the study period

Both terms of BOD_5 and COD are commonly used to measure the organic matter. The result shows the values of influent BOD_5 range from 125 to 173 mg/L while the values of influent COD range from 227 to 311 mg/L for nine weeks of the study period as shown in Figure 1 and 2. The average value of the influent BOD_5 and COD are 142 and 261 mg/L respectively. The value represents low strength domestic sewage, which an indicator of low content of organic matter. According to de Kreuk *et al.* [10], type of substrate and COD are important parameters for cultivating AGS. Liu *et al.* [11] stated that AGS can be cultured in a range of organic loading rate (OLR) from 2.5 to 15 kg COD m^{-3} day. In the case of OLR lower than 1 or 2 kg COD m^{-3} day, the development of AGS would be a failure. Meanwhile, if the OLR is too high, unstable granules would appear [12]. In previous AGS study, COD is the only parameters mentioned while BOD_5 is rarely found. The COD value in this study is comparable to previous studies that proved to cultivate the AGS; Su *et al*. [13], Jungles *et al*. [14] and Derlon *et al.* [15]. It was reported that the AGS were formed within 8 to 55 days and the size were around 0.8 to 4mm. Therefore, this range of influent COD is suitable in order to develop AGS.

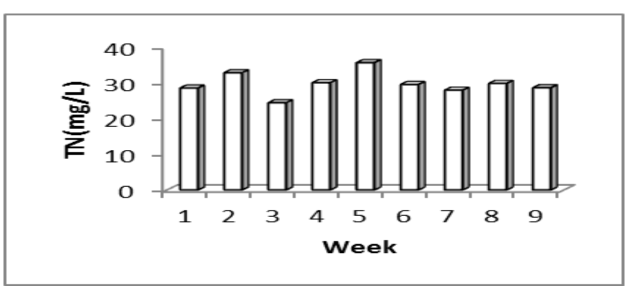


Figure 3 Variation of influent Total nitrogen (TN) during the study period

Nitrogen in wastewater can be found in four major forms, and each major form is generally analyzed as a separate component, with Total Nitrogen calculated from the sum of the four forms. The result shows the concentration of total nitrogen is range from 24.4 to 35.6 mg/L as shown in Figure 3. The average value of the total nitrogen is 29.7 mg/L. In general, nitrogen concentration on the formation of AGS often related with N/COD ratio. According to Muda [12], the development of AGS with the presence of nitrogen and carbon sources have resulted with the co-existing of heterotrophic, nitrifying and denitrifying microniches within the granules. The activity in the microniches was controlled by the substrate N/COD ratio. Yang *et al*. [8] state that slow-growing nitrifying bacteria were enriched at high substrate N/COD ratios which lead to a development of good settleability and strong structure of AGS. This statement is supported by Li *et al.* [35] that proved 30/100 N/COD ratio considered as high ratio had formed a compact AGS with good stability. Moreover, the presence of nitrogen in SBR also can lead to a better granulation by boosting the aggregation process under aerobic condition [16]. In this study, the result of total nitrogen is corresponding to previous studies. Study executed by Ni *et al.* [17] and Wagner and da Costa, [18] proved to form AGS with influent concentration of total nitrogen ranged from 12 to 50 mg/L. Both of them have a similar granules size in the ranged of 0.2 to 1.3 mm. Meanwhile, the aerobic granules appeared after 80 and 28 days respectively. In other study, Derlon *et al*. [15] also managed to cultivate AGS with total nitrogen concentration ranged from 28 to 38 mg/L in 55 days. Therefore, the total nitrogen concentration found in this study was relevance for the cultivation of AGS.

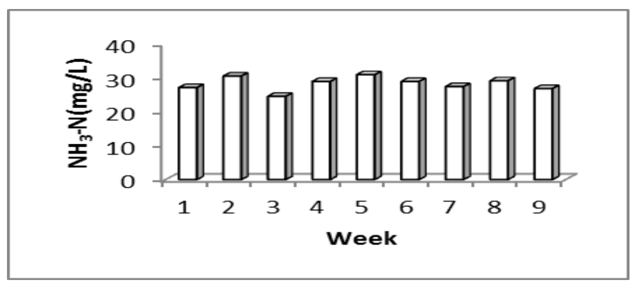


Figure 4 Variation of influent Ammonia nitrogen (NH_3-N) during the study period

Ammonia (NH_3) is part of nitrogen compounds that is categorized as nutrients matter in wastewater. The results show that the values of NH_3-N fluctuate from 24.6 to 31 mg/L as shown in Figure 4. The average value of the influent NH_3-N is 28.3 mg/L. It has been mentioned by de Kreuk *et al*. [10] that NH_3-N is one of the important parameters in formation of AGS. According to Pronk *et al.* [7], ammonium substrates promoted good granulation process. The conversion of ammonia with oxygen by slow growing bacteria leads to a denser biofilm formation. In AGS systems, substrates that encourage slow growth of bacteria aerobically are normally accomplish a stable granulation. This study indicated the range values of NH_3-N shown in Figure 4 above are complementary to previous AGS study. In previous AGS study, Liu *et al.* [19] have successfully cultivated AGS in 22 days with NH_3-N values ranged from 12 to 88 mg/L. In addition, Su *et al.* [13] and Ni *et al.* [17] also achieved AGS formation with NH_3-N value ranged from 10 to 40 mg/L. The granulation rates for both studies are 80 days and 8 days respectively. Another study conducted by Wagner and da Costa, [18] with influent NH_3-N ranged from 12 to 50 mg/L also succeeds to form AGS in 28 days. In conclusion, the range NH_3-N value in this study is relevance for the cultivation of AGS.

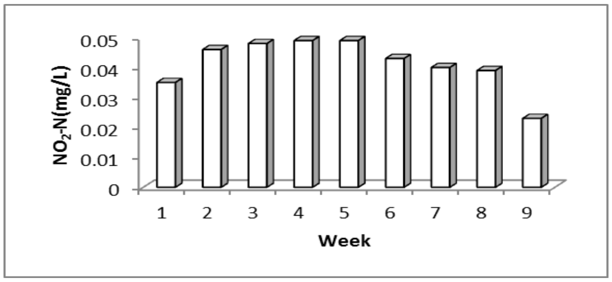


Figure 5 Variation of influent Nitrite (NO_2-N) during the study period

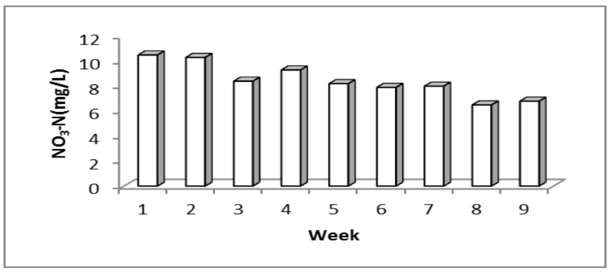


Figure 6 Variation of influent Nitrate (NO_3-N) during the study period

Nitrite (NO_2-N) and Nitrate (NO_3-N) are part of nitrogen compounds that is categorized as nutrients matter in sewage. The result of influent NO_2-N and NO_3-N of this study are displayed in Figure 5 and 6 respectively. The influent concentration of NO_2-N varies from 0.023 to 0.049 mg/L with an average of 0.041 mg/L while influent concentration of NO_3-N is range from 6.5 mg/L to 10.5 mg/L with an average value of 8.4 mg/L. According to Wan and Sperandio, [20] nitrite and nitrate are common contaminant that can influence the settling characteristics of AGS. Experiment using nitrate-fed reactors conducted by Wan and Sperandio shows a compact, dense and excellent settling behavior of AGS. Study done by Suja *et al*. [21] indicated the addition of nitrate and nitrite can speed up AGS formation in SBR. In this study, the ranged value of NO_2-N and NO_3-N are comparable to previous AGS studies. Rocktäschel *et al.* [22] have successfully formed AGS with influent NO_2-N was ranged from 0.015 to 2 mg/L and NO_3-N from 7 to 18 mg/L. The granulation rate was rapid, 13 days and the size of the granules was 1 to 1.8 mm. Derlon *et al.* [15] in low strength wastewater pilot scale study, also formed AGS with NO_2-N of 0.3 mg/L and NO_3-N of 7 mg/L for 55 days. Another study conducted by Long *et al.* [23] achieved the AGS formation in 21 days with NO_2-N of 0.2 mg/L and NO_3-N of 10 mg/L. Thus, the range values of nitrite and nitrate in this study are applicable for the cultivation of AGS.

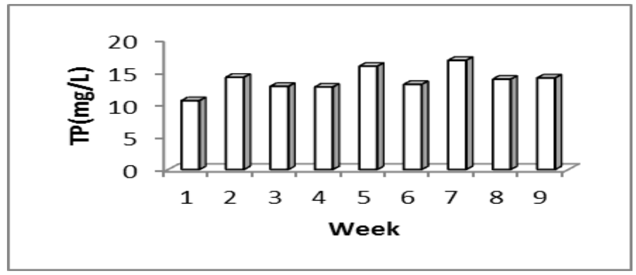


Figure 7 Variation of influent Total Phosphorus (TP) during the study period

Another nutrient matter in domestic sewage is phosphorus compound. The results show that the total phosphorus values were ranged from 10.6 to 16.8 mg/L as shown in Figure 7. Generally, phosphorus may be found in several forms in wastewater, including dissolved form (orthophosphate), inorganic form and organically bound forms. Total Phosphorus is the sum of reactive, condensed and organic phosphorous. In the formation of granules, Zhang *et al.* [24] stated that the aerobic granules are accumulated by phosphorus via chemical precipitation and denitrification in the existence of filamentous Thiothrix. Study done by Huang *et al.* [25] on the phosphorus distributions in AGS reactor noted that approximately 73% of phosphorus was accumulated in microbial cells. The formation of AGS by the phosphorus concentration also related to P/COD ratio. Lin *et al.* [26], conducted an experiment on cultivation of aerobic granules at different substrate P/COD indicated that smaller microbial granules developed at higher substrate P/COD ratios. Moreover, the structure of the granules also became more compact and denser as the substrate P/COD ratio increased. Based on Figure 7 above, the ranged value of total phosphorus was comparable to previous AGS study. Su *et al.* [13] conducted a pilot scale study on AGS and formed aerobic granules with total phosphorus concentration ranged from 6 to 13 mg/L in 8 days. Coma *et al*. [27], with the total phosphorus ranged from 10-12 mg/L also successfully cultivated AGS in 40 days. So, the range value of total phosphorus in this study is satisfactory for the cultivation of AGS.

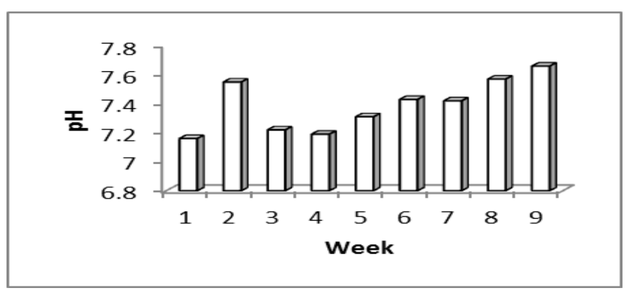


Figure 8 Variation of influent pH during the study period

pH value also known as potential of hydrogen, is a numeric scale used to specify the acidity or basicity of an aqueous solution. The result indicates the influent pH value range from 7.16 to 7.66 with an average pH value of 7.4 as shown in Figure 8. According to Khan *et al.* [16], pH is an important factor for aerobic granulation. Granulation is difficult to achieve at pH above 8.5 while a slight alkaline pH (7.5) is suitable for appropriate granulation. Based on the result of this study, the ranged pH value of this study was slightly alkaline. Therefore, it can be concluded that the pH value of Bunus WWTP influent is suitable for AGS cultivation.

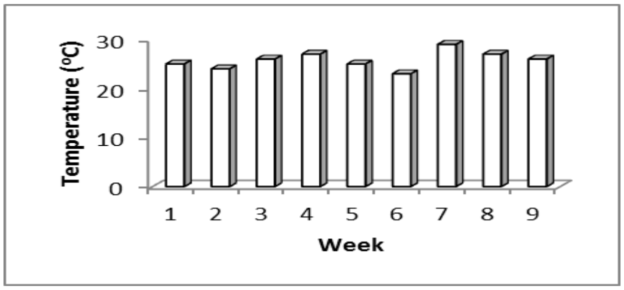


Figure 9 Variation of influent Temperature during the study period

The result of influent temperature is shown in Figure 9. The temperature varies from 23 to 29°C with an average of 26°C. Khan *et al.* [16] mentioned that influent wastewater temperature can affect the performance of AGS system. If the temperature was too low (26°C) or too high (41°C), it will reduce the biomass, which is crucial to cultivate AGS. It was also reported that the temperature of wastewater inside the SBR must be between 28 and 35°C for optimum activity of microbes. In previous study, Sarma *et al.* [28] noted that the temperature inside SBR of 25°C, have successfully cultivated AGS in 7 days. Thus, it is relevance for cultivation of AGS with this study influent temperature.

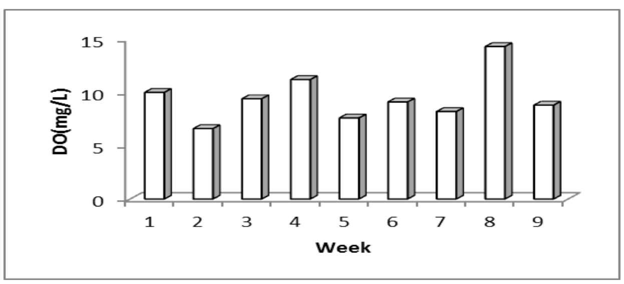


Figure 10 Variation of influent Dissolved Oxygen (DO) during the study period

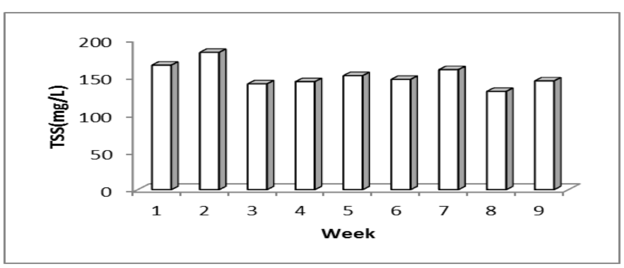


Figure 11 Variation of influent Total Suspended Solid (TSS) during the study period

The result shows the influent concentration of dissolved oxygen (DO) fluctuate from 6.6 to 14.3 mg/L as shown in Figure 10. While the influent TSS range from 131 to 183 mg/L as shown in Figure 11. The average values for both parameters are 9.5 and 152 mg/L respectively. In general, influent DO and TSS are parameters that are rarely discussed in the formation of AGS. However, both DO level and TSS are important factors that must be taken into consideration during the process in the bioreactor. Influent DO and TSS does not influence the AGS formation as there will be aeration process and biomass mixed inside the bioreactor. Therefore, it can be considered that influent DO and TSS values in this study do not give significant effect towards the formation of AGS.

Table 2 Average value of related parameter for Bunus WWTP influent wastewater

Parameter	Average value
BOD_5	142 mg/L
COD	261 mg/L
TN	29.7 mg/L
NH_3-N	28.3 mg/L
NO_2-N	0.041 mg/L
NO_3-N	8.41 mg/L
TP	13.8 mg/L
pH	7.4
Temperature	26°C
DO	9.5 mg/L
TSS	152 mg/L

Several parameters were considered to evaluate the characteristic of influent wastewater at Bunus WWTP. The results of the parameter shown in Table 2 above represent low strength domestic sewage, which an indicator of low content of organic matter and nutrients. The value of each parameter was compared to previous studies in order to determine the suitability of the influent wastewater for AGS cultivation. The parameter such as COD, TP, TN, NO_2-N, NO_3-N, NH_3-N and pH are the criteria that affect the cultivation of AGS, whereas DO and TSS do not influence the process. All the parameter that influenced the formation of AGS is comparable with previous AGS study. The average value of each parameter is relevance for the cultivation of AGS. Therefore, it is expected that AGS can be formed with the influent wastewater of Bunus WWTP if proper loading rate was applied during the SBR operation.

Table 3 Guideline of cultivation of AGS and its characteristic in room temperature by using real domestic wastewater based on previous literature

Scale	Volume (L)	Strength of domestic wastewater				SBR Operation			Granulation rate	Diameter (mm)	Settling Velocity (m/h)	Reference
		Class	COD	NH_3	TP	Fill		Aeration				
						Anoxic	Anaerobic					
Lab scale	2.5L	Low	<200 mg/L	<40 mg/L	-	5 min	-	220-220 min	12 days	0.4-0.6	-	[19]
	2-3L	Medium	200-400 mg/L	40-90 mg/L	8-12 mg/L	0.5-60 min	60-100 min	100-224 min	28-90 days	0.3-1.3	10-12.5	[18, 27, 32]
	2L	High	>400 mg/L	100-250 mg/L	5-12 mg/L	10	-	120 min	7 days	0.2-0.3	20-39	[33]
Pilot scale	1000L	Low	<200 mg/L	10-40 mg/L	-	5 min	-	185-200 min	80 days	0.2-0.8	35	[17]
	11-85L	Medium	200-400 mg/L	10-40 mg/L	4-13 mg/L	10 min	90 min	140 min	8-55 days	0.3-0.8	12-16	[13, 15]
	4000L	High	>400 mg/L	40-60 mg/L	6-8 mg/L	15 min	-	128-138 min	13 days	1.0-1.8	-	[22]

Table 4 Guideline of cultivation of AGS and its performance in room temperature by using real domestic wastewater based on previous literature

Scale	Volume (L)	Strength of domestic wastewater				SBR Operation			COD removal (%)	N removal (%)	P removal (%)	Reference
		Class	COD	NH_3	TP	Fill		Aeration				
						Anoxic	Anaerobic					
Lab scale	2.5L	Low	<200 mg/L	<40 mg/L	-	5 min	-	220-220 min	91	90	-	[19]
	2-3L	Medium	200-400 mg/L	40-90 mg/L	8-12 mg/L	0.5-60 min	60-100 min	100-224 min	92-99	82-99	94-98	[18, 27, 32]
	2L	High	>400 mg/L	100-250 mg/L	5-12 mg/L	10	-	120 min	70	85	-	[33]
Pilot scale	1000L	Low	<200 mg/L	10-40 mg/L	-	5 min	-	185-200 min	90	95	-	[17]
	11-85L	Medium	200-400 mg/L	10-40 mg/L	4-13 mg/L	10 min	90 min	140 min	80-92	81-96	85-99	[13, 15]
	4000L	High	>400 mg/L	40-60 mg/L	6-8 mg/L	15 min	-	128-138 min	-	99	99	[22]

3.2 Proposed SBR Operation Cycle Time

Table 3 and 4 shows the guideline of AGS cultivation that specifically using real domestic wastewater at room temperature based on previous literature. both of the tables classify the strength of domestic wastewater according to their COD values. Table 3 indicates the relationship between the strength of influent wastewater and the characteristic of granules. Meanwhile, Table 4 indicates the relationship between strength of influent wastewater and the SBR performance. The influent Bunus WWTP was classified as medium strength domestic wastewater. In general, this guideline provides a brief overview on SBR operation cycle time for different class of influent based on proven previous AGS research.

3.2.1 Fill

The first process of SBR is Fill where the influent wastewater was filled into the tank either by using pump or gravity. In the cultivation of AGS, Liu *et al.* [11] noted that if the feeding period is short, it causes the microbes to experience a rapid high concentration of toxic substrates. This condition makes it unfavorable for aerobic granulation. The quick change of the reaction condition reduces the biomass activity [16]. Usually, fill process takes place in anoxic or anaerobic condition as the foods are fed to the microbes in large quantity with none or very little amount of oxygen. Based on Table 3 and 4 above, this study influent wastewater is characterized as medium concentration of COD for domestic wastewater. It was reported that the fill period for lab scale study range from 0.5 to 60 min while for pilot scale study, the period was 90 min.

3.2.2 Aeration

The second process of SBR is aeration. According to Show *et al*. [2], the aeration period in SBR operation consists of two stages; a degradation stage in which substrate is depleted followed by aerobic starvation stage where substrate is no longer available. Starvation stage initiates the aerobic granules formation cooperated by shear force. It was reported in starvation stage, the bacteria become more hydrophobic and promotes adhesion or aggregation to formed granules. The aggregation is regarded as a strategy of cells against starvation [29]. Moreover, a liquid media with high substrate concentrations also facilitates the formation of granules [30]. In Table 4, this study influent wastewater is classified as medium concentration of COD for domestic wastewater. The aeration period that has been used for lab scale study in this type of wastewater varies from 100 to 224 min. Meanwhile, 140 min aeration period was used for pilot scale study.

3.2.3 Settle

The third process of SBR is Settle. Khan *et al.* [16] mentioned that settling time plays an important role to create hydraulic selection pressure on the sludge particles in SBR. The pressure caused the particles that could settle down within a given time period, would be retained in the reactor while the rest would be washed out of the system. It is also noted that the settling time should be in the range of 2 to 10 min for a model laboratory SBR. Since SBR are available in different sizes, consideration on settling velocity (rate) is crucial for aerobic granulation as it exerts hydraulic selection pressure. The settling velocity should be greater than 10 m/h [16].

3.2.4 Discharge

Lastly, the fourth process is Discharge. This process allows the treated wastewater to flow out of the reactor. The time dedicated to this process can be set from 2 to 30% of the total cycle time. However, it must not be extended too much because of possible rising sludge problems.

3.2.5 Total Cycle Time

Based on Table 3, Table 4 and previous discussion, it is suggested that the period for fill, aerate, settle and discharge are 60 min, 110 min, 5 min, and 5 min respectively. The duration of every process followed Nor Anuar *et al.* [36]. The total cycle time is 3 hours. According to Lee *et al*. [31] a short cycle time resulted in a short hydraulic retention time (HRT), which was favorable for rapid granulation. Study done by Show *et al.* [2] reported that when a cycle time increased from 1.5 to 8 h, the specific biomass growth rate of granular sludge decreased from 0.266 to 0.031 d^{-1}, while the corresponding biomass growth yield decreased from 0.316 to 0.063 g g^{-1} COD. Moreover, the size of granules cultivated at 1.5 h cycle time were the biggest while the granules cultivated at 4 h cycle time were the most compact compared to others. Most of the previous studies that have a comparable influent characteristic of domestic wastewater with this study, applied a total cycle time of 3 h; [13, 32]. Therefore, a total cycle time of 3 h is expected to suit the SBR treatment process and Bunus domestic wastewater for cultivating AGS.

3.3 Expected AGS Characteristic and Performances

Table 5 indicates the expected AGS characteristic and performances based on Bunus WWTP influent wastewater characteristic and proposed SBR cycle time in this study. The consideration was for both lab scale and pilot scale study. The granules characteristic and performance are forecasted in this study by comparing the influent values and SBR operation with previous studies that have the same class of COD concentration (Table 3 and 4). The granules are expected to form in 8 to 90 days with diameter of 0.3 to 1.3 mm. In term of performances of AGS in SBR, it is expected that COD and TN removal are more than 80% as the proposed feeding and aeration time is 60 min and 110 min respectively. While, settling velocity with 10 to 16 m/h is forecasted as the proposed settling time is 5 min.

Table 5 Expected AGS characteristic and performances based on Bunus influent wastewater characteristic and proposed SBR cycle time

Bunus influent Parameter	SBR Process Time (min)	Expected granules characteristic	Expected performance
BOD_5: 142 mg/L COD: 261 mg/L TN: 29.7 mg/L NO_2-N: 0.041 mg/L NO_3-N: 8.41 mg/L NH_3-N: 28.3 mg/L TP: 13.8 mg/L pH: 7.4 Temperature: 26°C DO: 9.5 mg/L TSS: 152 mg/L	Fill: 60 Aerate: 110 Settle: 5 Discharge: 5 Cycle time: 180 (3 h)	Granulation rate: 8-90 days Diameter: 0.3-1.3 mm	COD removal: >80% TN removal: >80% Settling velocity: 10-16 m/h

4.0 CONCLUSION

In this study, the influent wastewater characteristic of Bunus WWTP was determined according to the standard parameter. The wastewater was characterized as medium strength domestic wastewater with low organic and nutrients content. The result of related parameters have shown that influent wastewater of Bunus WWTP was suitable for cultivating AGS. It was noted that influent DO and TSS do not have significant effect on the formation of AGS. All the parameter that influenced the formation of AGS is comparable with previous AGS study and therefore relevance for AGS cultivation. Moreover, the proposed SBR operation cycle time was 3h, consist of 60 min (fill), 110 min (aerate), 5 min (settle), and 5 min (discharge). By this proposal, AGS is expected to be cultivated with an optimum granules characteristic and performance.

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