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DEVELOPMENT OF AEROBIC GRANULES USING SEQUENCING BATCH REACTOR (SBR): A PROPOSED WORKFLOW

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Abstract

This study highlights on the development of aerobic granules using sequencing batch reactor (SBR). The development involves four phases; fill, aerate, settle, and draw in every cycle. In easing the understanding; the flowchart, schematic diagram, and list of equipment are presented in this paper. Sampling is another important stage in completing the process. In addition, the composition of synthetic wastewater including nutrients and trace elements are detailed out in this paper. In monitoring the development of aerobic granules, several parameters should be measured consistently. As a guideline, expected results have been listed in ensuring the smoothness of the proposed workflow.

Keywords: *aerobic granules; activated sludge; sequencing batch reactor (SBR)*

1.0 INTRODUCTION

Various types of treatments were implemented by the authorities to treat wastewater around the world in order to provide clean and fresh water. Wastewater treatment process is very important to reduce the risk of waterborne diseases such as typhoid and cholera in the human population (Ahmad et al., 2015). There are two main categories of wastewater treatments namely suspended growth (e.g.: activated sludge process) and attached growth (e.g.: rotating biological contactor) (Mara & Horan, 2003).

Basically, in the suspended growth method, the biological agents (microbes) are grown and move freely in the reactors to seize the pollutants in the wastewater. The microbes are settled at the bottom of the tank as flocs. These flocs later are kept in the reactors for the purpose of next wastewater treatment. In the attached growth method, the microbes are retained and grown on the provided mediums (e.g.: plastic, gravel and ceramic), as the wastewater flow through them. Then, the microbes will diminish over time (Westerling, 2014). In general, Dabi (2015) reported that the attached growth method is more energy competence as compared to the suspended growth method.

Thus, focus is given on sequencing batch reactor (SBR) which is available under the suspended growth process. In term of efficiency, SBR is better than conventional activated sludge method, in treating variation of wastewater (Mohan et al., 2005). For this study, the SBR will work as a tool in developing aerobic granules; the major component for wastewater treatment.

1.1 Sequencing Batch Reactor (SBR)

Recently, sequencing batch reactor (SBR) is a common wastewater treatment process and is extensively used worldwide (Kalbar et al., 2013). Lesser areas are required for SBR, contradicts to other wastewater treatment methods. As detailed out by Emadian et al. (2015) and Christgen et al. (2015), only a single tank is needed for SBR. In contrast, other conventional activated sludge processes need primary and secondary tanks. Hence, this shows that another term of efficiency needed for the SBR method.

The SBR reactor operates under a batch process in one container. The four phases started by filling, followed by aeration, settled and ended with withdraw. Timers are used to control these sequence processes. Aeration phase is important to provide enough oxygen for the activated sludge in the reactor. Besides that, the oxygen from air pump will cause the shear force to the granules in the reactor. The force from the diffuser will enhance the granulation process in the SBR. Tay et al. (2001), Liu & Tay (2002), Beun et al. (2002) and Tay et al. (2004) reported a positive correlation between shear force, formation of good settling ability of the granules and production of biofilms in the reactor. During the settle phase, high biomass retained at the bottom of the reactor, due to the increase of settling ability of the aerobic granules (Dutta et al., 2014; Halim et al., 2016).

1.2 Aerobic Granules

Aerobic granular method has been developed to treat wastewater in biological aspect (De Kreuk et al., 2005; Tay et al., 2001). In other studies; Dangcong et al. (1999) and Moy et al. (2002) unanimously agreed on the high capability of this granulation method for wastewater treatment. In ensuring this capability, formation of aerobic granules in the SBR is important. Therefore, there is a need in having ideal oxygen supply into the reactor using air diffuser.

The formation of granules is caused by aggregation of microbes during SBR process (Adav et al., 2008; Cui et al., 2014). Aerobic granules are known to have several advantages, especially in removing nutrients and easiness of settling at the bottom of the reactor (Yang et al., 2003; Adav et al., 2008). In addition, variations of microbes have been found in the aerobic granules (Liu & Tay, 2004; Liu et al., 2005). The variations of microbes in the granules are important in treating different type of chemicals exist in wastewater such as ammonia, phosphorus, herbicides, and phenols. There are three conditions exist in one aerobic granule such as aerobic, anoxic, and anaerobic which each condition acts differently (Yilmaz et al., 2008). Additionally, the formation of aerobic granules in SBR is influenced by other parameters such as the composition of food supply (substrate) and loading rate of the organic compound into the reactor (Adav et al., 2008).

1.3 Objectives of the Study

In ensuring the success of the workflow, three objectives must be attained. The main objective is to grow aerobic granules by using activated sludge in the SBR at room temperature. Next objective is to analyse the characteristics of the created aerobic granules including physical, biological, biochemical, and removal performance. The last objective is to monitor the performance of the created aerobic granules, in term of elimination of nutrients and organics from wastewater.

2.0 MATERIALS AND METHODS

Five stages of workflow are proposed which it starts with the SBR design and set-up and ends with analytical process. The workflow is presented in Figure 1.

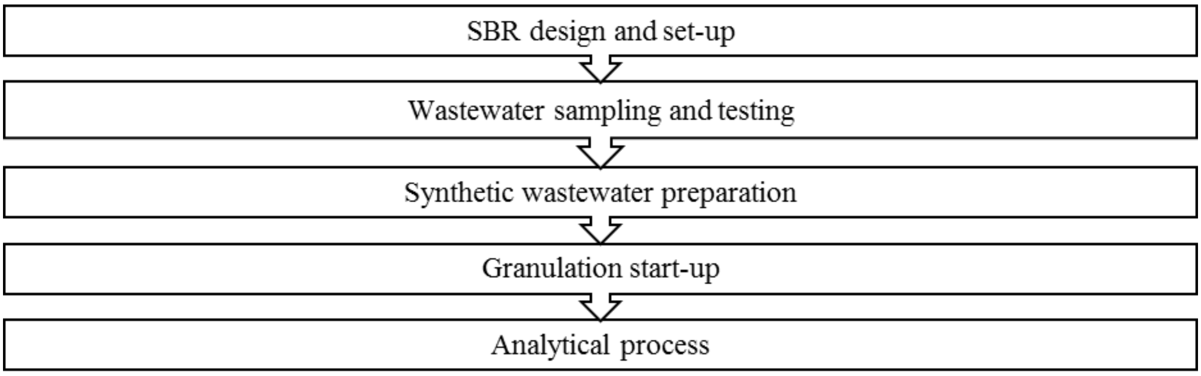

Figure 1 Proposed workflow for aerobic granules development in SBR

2.1 SBR Design and Set-Up

Referring to the first stage in Figure 1, reactor can be made using acrylic cylinder column, using a dimension of 2,500 ml for working volume, 0.095 m of internal diameter, and total height of 0.355 m. The equipment such as cylindrical column, air diffuser, silicone tube, and air flow meter will be needed during the set-up. On the other hand, timer, peristaltic pump, and aquarium air pump are electronic appliances needed to be attached to the reactor. All equipment is tabulated in Table 1. Figure 2 presents the schematic drawing for SBR in detailing out the assembly process.

The reactor has five sampling valves (number 1 – 5). Valve no. 5 works as an influx point, while valve no. 3 stands as outflux point for the reactor. The influx of synthetic wastewater is generated using peristaltic pump, controlled by timer. The wastewater is taken from the influent tank and the tank is attached to the reactor using silicon tube. Oxygen for microbes in the reactor will be supplied using air pump, controlled by another timer. For supplying fine air bubbles, air diffuser must be used and located at the bottom of the reactor. Air flow meter will be used to measure the supplied oxygen. The outflux works reversely as compared to the influx. The effluent is generated using peristaltic pump, controlled by timer, which the wastewater flows into the effluent tank.

Table 1 Equipment for SBR

Equipment	Explanation
	Cylindrical column (reactor)

	Timer
	Peristaltic pump
	Aquarium air pump
	Air diffuser
	Silicone tube
	Air flow meter

Source: All pictures (except cylindrical column) were taken from Amazon.com

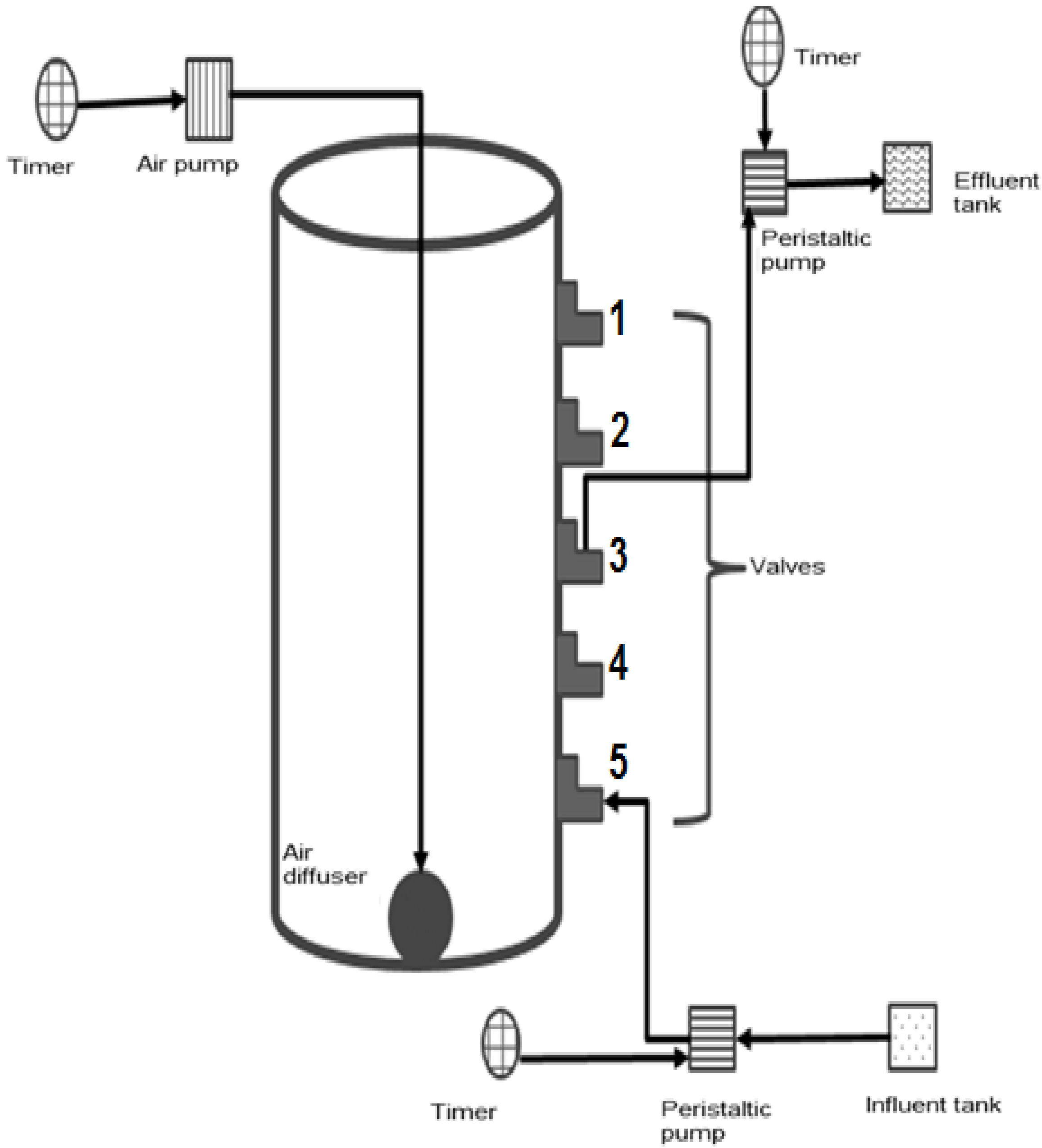

Figure 2 Schematic diagram for SBR

2.2 Wastewater Sampling and Testing

The second stage is wastewater sampling and testing. At this stage, the wastewater will be taken from wastewater treatment plant by using plastic sampling bottles. About 1,000 mL of activated sludge can be used as a starter. In determining the characteristics of sample, several parameters can be tested on the wastewater. The seven parameters suggested are pH, dissolved oxygen (DO), chemical oxygen demand (COD), mixed liquor suspended solid (MLSS), mixed liquor volatile suspended solid (MLVSS), biological oxygen demand (BOD5), and ammoniacal nitrogen (AN) as illustrated in Figure 3. The sample can be tested using standard method applied by American Public Health Association (APHA, 2012).

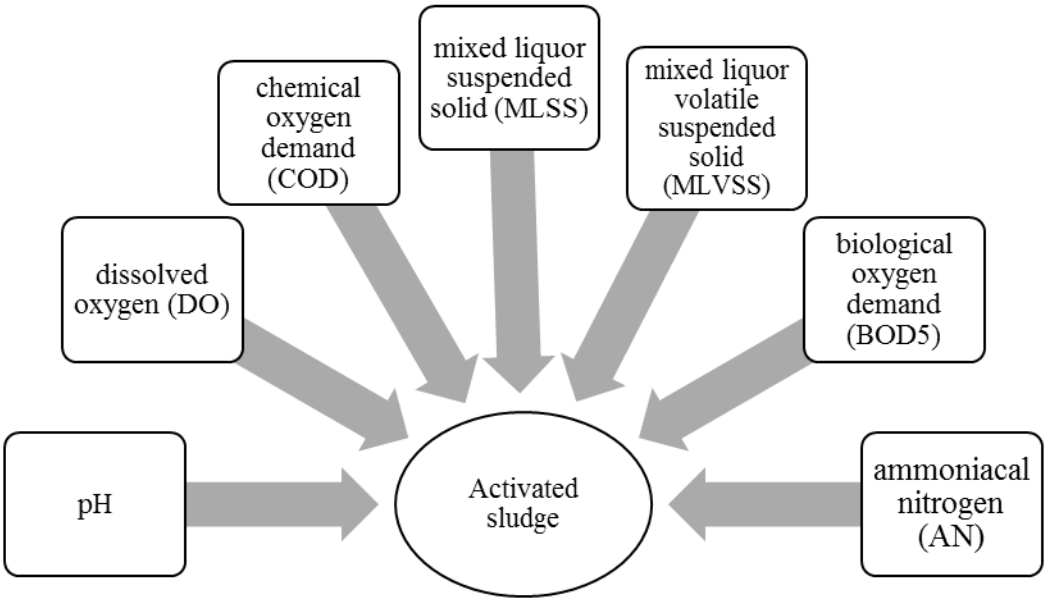

Figure 3 Characteristics of wastewater

2.3 Synthetic Wastewater Preparation

In the preparation process, the recipe for synthetic wastewater which consists of medium X, medium Y, and trace elements can be taken from Nor-Anuar (2008). Sodium acetate is the main ingredient in this synthetic wastewater together with other chemicals such as ammonium chloride, potassium chloride, and dipotassium phosphate as shown in Table 2. Solutions of medium X and Y are mixed together with water and later added with a small amount of trace elements. Synthetic wastewater works as a food supply for microbes in the reactor.

Table 2 Medium X, Y and trace elements compositions

Medium X	Medium Y	Trace elements
• sodium acetate • magnesium sulfate heptahydrate • potassium chloride	• ammonium chloride • dipotassium phosphate • potassium dihydrogen phosphate	• ethylenediaminetetraacetic acid • zinc sulphate heptahydrate • calcium chloride dehydrate • manganese (ii) chloride tetrahydrate • iron (ii) sulphate heptahydrate • copper(ii) sulphate pentahydrate • cobalt(ii) chloride hexahydrate

2.4 Granulation Start-Up

At the stage of granulation start-up, four phases of SBR operation (fill, aerate, settle, and draw) per cycle is suggested, as shown in Table 3. Three hours are the proposed time for each cycle. The cycle started with the fill phase by filling the synthetic wastewater into the SBR. It takes about 0.50 hour per cycle. Oxygen will be streamed into the SBR for 2.00 hours per cycle during aerate process. Then, the SBR will let to settle for about 0.08 hour, before the draw process takes place. The cycles will continue until the granules achieved the desired sizes, as suggested in Liu et al. (2012), Abdullah et al. (2013) and Li et al. (2014) which those may take about one month or more of the cycle duration. Tay et al. (2001) for instance, have developed granules in two weeks using acetate and the matured granules were seen after a month in SBR.

Table 3 Four phases of SBR

Process	Period (hours)
Fill	0.50
Aerate	2.00
Settle	0.08
Draw	0.42

2.5 Analytical Process

Similar to paragraph 2.2, seven types of parameters will be measured on the created aerobic granules. The tests involved are pH, dissolved oxygen (DO), chemical oxygen demand (COD), mixed liquor suspended solid (MLSS), mixed liquor volatile suspended solid (MLVSS), biological oxygen demand (BOD5), and ammoniacal nitrogen (AN); as shown in Table 4. The pH and DO values will be taken using portable devices. At the same time, the COD and AN readings can be analysed using spectrophotometer (DR2800-HACH). In measuring MLSS for example, samples will be dried for one hour in the oven at a temperature of 105 °C. Later, the dry samples will be heated in muffle furnace for 15 minutes at a high temperature (550 °C), in determining MLVSS level. In contrast, BOD5 is the only testing that can be done after five days of incubation at a temperature of 20 °C. Details on all these measurements are made available in APHA (2012).

Table 4: List of analysis

Parameters	
• pH	• settling velocity
• dissolved oxygen (DO)	• sludge volume index
• chemical oxygen demand (COD)	• granules monitoring
• mixed liquor suspended solid (MLSS)	• removal performance
• mixed liquor volatile suspended solid (MLVSS)	
• biological oxygen demand (BOD5)	
• ammoniacal nitrogen (AN)	

The settling velocity of the aerobic granules can be measured using a stopwatch. Time taken for the aerobic granules in reaching the bottom of 1,000 mL measuring cylinder, is counted on average basis, as suggested by Rosman et al. (2014). The sludge volume index value is calculated based on De Kreuk et al. (2005). Besides, granules monitoring is important in analysing structure and morphology of the aerobic granules. For the structure, optical light microscope with digital camera is the appropriate tools, while scanning electron microscope (SEM) is the most suitable in viewing inner part of the aerobic granules. In valuing removal performance, a comparison between influx and outflux, in term of COD and AN, must be calculated. All collected data will then be processed using Microsoft Excel and Statistical Package for the Social Science (SPSS).

3.0 EXPECTED RESULTS

In this proposed workflow, there are three expected results, as presented in Table 5.

Table 5 Expected results of this research

Expected result	Explanation
Granules development	The fluffy flocs of activated sludge will change to granular shapes after more than two weeks in SBR.
Granules characteristics	The value of MLSS and MLVSS are expected to fluctuate due to the condition of SBR.
Granules performance	Chemical oxygen demand and ammoniacal value are expected to decrease due to the ability of granules to remove nutrient in SBR.

In earlier stage, the activated sludge will appear in loose-structure, fluffy, and irregular shape. Presence of filamentous bacteria in bulk is the possible reason as highlighted in Halim et al. (2016). At the end, the flocs will be gone and replaced by the small granules. The average diameter of aerobic granules is ranged from 1.80 mm to 2.00 mm that caused by existence of non-filamentous bacteria in the aerobic granules as demonstrated in Rosman et al. (2014).

Secondly, the characteristics of the aerobic granules such as MLSS and MLVSS are expected to decrease at the beginning of the development. Biomass washout from the reactor is the expected reason. After the aerobic granules start to form, the settling time increase and MLSS as well as MLVSS will reach their steady state in the reactor as shared by Ebrahimi et al. (2010) and Halim et al. (2016).

In general, aerobic microbes use oxygen for respiration and growth. At the same time, microbes are capable in nitrifying ammonia into nitrites or nitrates. In the granulation process, the microbes' population are expected to increase over time. Consequently, more oxygen will be consumed and more ammonia will be converted. These reductions which will happen in the synthetic wastewater indicate the third objective of the SBR system.

4.0 CONCLUSIONS

It is a hope that this proposed workflow will give an initial understanding to the researchers in the related field. Furthermore, with the existence of the flowchart, schematic diagram, lists of equipment and parameters, relevant images, and expected results may provide a clear cut guideline in developing aerobic granules using sequencing batch reactor (SBR).

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