



JOURNAL OF BIOCHEMISTRY, MICROBIOLOGY AND BIOTECHNOLOGY

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Physicochemical Optimization of Granular Sludge in Rubber Industrial Wastewater

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History

Received: 28 September 2013
Received in revised form: 23 November 2013
Accepted: 2 December 2013
Available online: 25 December 2013

KEYWORDS

Aerobic granular sludge
SBR
Rubber industry wastewater

ABSTRACT

Aerobic granular sludge (AGS) technology is a novel and promising development in the field of biological wastewater treatment where it develops granulated sludge without any additional of supporting carrier material. Self immobilized granular sludge has high settling velocity and contribute to high efficiency of solid-liquid separation in wastewater. Current problem of rubber manufacturing wastewater are low solid:liquid separation ratio and therefore, this study aims to incorporate aerobic granulation technology into rubber industry treatment in order to improve the problems. Aerobic granules were developed in two identical sequencing batch reactors (SBRs) with different strategies for the enhancement of granulation. The characteristic of the microbial granular sludge were monitored throughout the study period and the results demonstrated good removal of COD and ammonia of 90% and 85%, respectively at the end of the study. Findings of this study show that granular sludge could be developed in rubber industry wastewater and is capable in treating the wastewater.

INTRODUCTION

Industries are major sources of pollution in all environments in our country, Malaysia. Depends on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations [1]. For rubber industry, wastewater is an unavoidable by-product of rubber processing where whatever processing procedures are used for preparing products from latex, which always have an aqueous liquid as a by-product. By releasing rubber industry wastewater straight into surface waters such as wells, streams, lakes or even the sea without any treatment, it will inevitably pollute that water and creates problems to the nature and human being.

The main problems of current treatment include large land area requirement in the factory, high energy consumption for the aerators, longer effluent treatment period, odour problems, and high operating and maintenance costs for the treatment process. Alternative method to solve these problems in rubber industry wastewater are the aerobic granular sludge (AGS) which is a novel environmental biotechnological process which tends to increase interest of researchers engaging in work in the area of biological wastewater treatment. Aerobic granulation is a self immobilization process in which microorganism agglomerate and developed to dense and compact biomass granules. AGS which is compact structured, biologically efficient aerobic with wide diverse microbial species and excellent settling capabilities is usually developed in sequencing batch reactors (SBR).

Granulation in aerobic systems has been extensively studied [2-5]. The "aerobic granule" was defined [6] as follows:

"Granules making up aerobic granular activated sludge are to be understood as aggregates of microbial origin, which do not coagulate under reduced hydrodynamic shear and which settle significantly faster than activated sludge flocs". Besides that, the biofilm particles developed on an inert carrier such as granular activated carbon, sand and others due to the attachment growth in fluidized bed reactors and other reactors cannot be considered as aerobic granules, although they appear as granular shape and have a high biomass density.

The aim of the study is to produce aerobic granular sludge in the sequencing batch reactor to treat rubber industry wastewater which can potentially replace the current treatment of rubber wastewater. Nutrient removal performance was also discussed to demonstrate the feasibility of using the aerobic granulation for treating the rubber industry wastewater. It is expected that the information derived from this work would be useful for the cultivation of aerobic granules and its further application for rubber industrial wastewater.

MATERIALS AND METHODS

Bioreactor Setup

Experiments were performed in a sequencing batch reactor (Figure 1) where it consisted of a rounded-bottom plastic vessel with a height of 34cm and diameter of 9.8cm. The bioreactor volume was 2.0 L and the working volume was 1.6 L. The height to the diameter ratio (H/D) being 3.5. The maximum level of the liquid was 25cm and the minimum level of 12cm after effluent withdrawal. The bioreactor is modified from a plastic Tupperware. Aeration was achieved during react by passing air through a fine bubble diffuser at the bottom of the bioreactor. Five water valves were available on the bioreactor, which two of them was used for

fill and draw, and other valve are used as various sampling points. Influent wastewater was introduced into the bottom of the bioreactor, and effluent was drawn at the middle of the reactor where the volumetric exchange ratio was 50%. Peristaltic pump were used to fill and to control the air pump which supply oxygen. The bioreactor was operated at room temperature (15-20°C).

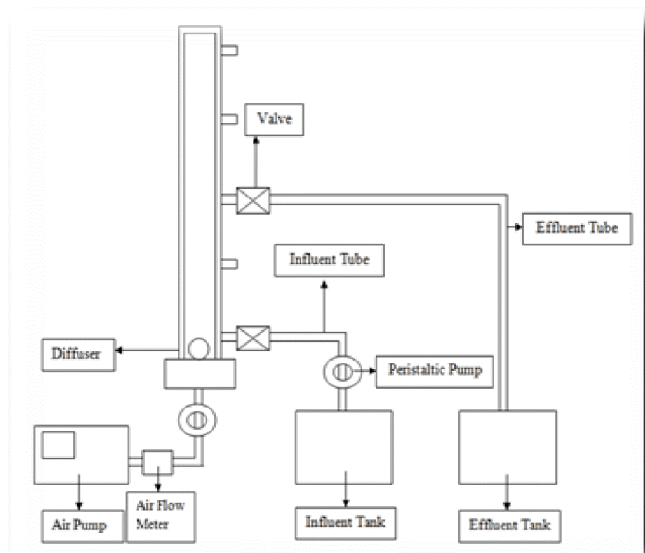


Figure 1. Schematic diagram of the SBR

Analytical Method

Collected samples were analyzed using methods described in Standard Methods for the Examination of Water and Wastewater (APHA, 1998). pH of the samples was determined using a Hanna portable pH meter and Dissolved oxygen was determined using DO meter. The effluent sample was analyzed for concentration of Chemical Oxygen Demand (COD), using the standard method and Ammoniacal Nitrogen concentration was measured by Nesslerization Method (4500-NH₃) using a HACH DR/2010 Spectrophotometer set at 425 nm wavelength. The sludge sample was analyzed for mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids, and sludge volume index (SVI) which was measured in a 100ml graduated cylinder. Sludge morphology observation was measured regularly by using by using an optical microscope with an attached with digital camera.

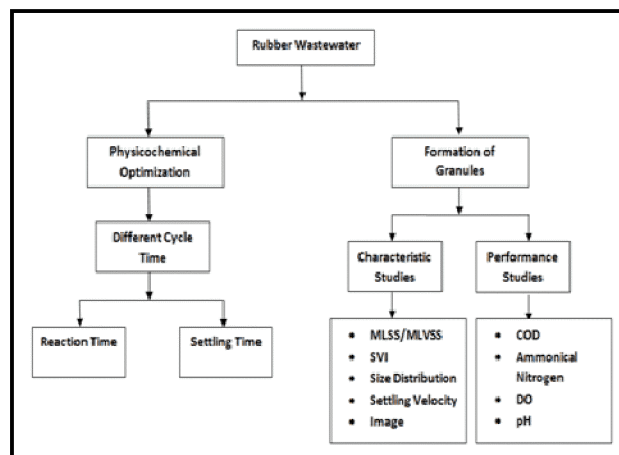


Figure 2: Process flow of the experiment

RESULTS AND DISCUSSION

The main goal of this experiment was to demonstrate granule formation on rubber industry wastewater in a SBR system which was collected from Shorubber (M) Sdn Bhd. In order to do so, the reactors which are R1 and R2 was started up with the influent from the WWTP of the company and inoculated with the company's activated sludge. The granulation process was investigated using two different strategies in each SBR. One of the physicochemical studies which are cycle time was modified in this study. Phase one focused on different aeration mode and second phase focused on different settling time. Cycle time is associated with the washout frequency of SBR, which can be regarded as a kind of hydraulic selection pressure. Sound understanding of the role of SBR cycle time in aerobic granulation would helpful for the optimization and design of large-scale aerobic granular sludge SBR.

Formation Of Aerobic Granules

The evolution of the activated sludge in this SBR, as shown in figure 2, was observed using image analysis for about 50 days (100days). The seeding sludge had a fluffy, irregular and loose-structure morphology, as shown in figure for both reactors. The colour of the activated sludge changed from brown to grayish brown and then light green with the progress of the experiment. For R1 and R2, during the start-up period for phase one, there was no significant change of morphology of the sludge except that the colour changes turned from brown to grayish brown slowly and it continue to be same until the end of phase one. Granulation is not achieved in the phase one due to the longer cycle hour where only typical bioflocs were cultivated in the SBR (Tay et al., 2002). Throughout the phase one, flocculent sludge was dominant in the reactor, and it showed fluffy, irregular and loose structure morphology. This is due to the fact that the SBR cycle time represents the frequency of solid discharge through effluent withdrawal, and it is related to the HRT. This indicates that the long cycle time would result in the lowest selection pressure and as a result, no granulation was occurred in the SBR run at the cycle time of 24 hours. But however, if the SBR is run at an extremely short cycle which is less than 3 hours, the sludge loss due to hydraulic washout from the system cannot be compensated

for by the growth of the bacteria. Due to that, biomass can't be retained in the system, and complete washout of sludge blanket occurs and eventually leads to failure in granulation process (Tay et al., 2002).

But in phase two where the cycle time was 4 hours, granulation started to occur in both reactors where activated sludge gradually change to aerobic granular. Aerobic granules is a gradual process from seed sludge or activated sludge to compact aggregates, further to granular sludge and finally to mature granules. Figure shows that, on day 1, the colour of sludge was straw yellow and there is no flocs formed in the Petri dish. On day 7th, some of the activated sludge changed to tiny particles or flocs where the colour is darker than the raw sludge.

In the subsequent half month, on the day 11-15, tiny granular started to appear at R1 and their average diameter increased gradually. At this stage, small grey granules and flocs were both present at a mixture in the reactor one, R1. Figure illustrates that small yellow granules were dominant in the SBR, the same colour aerobic granules was reported by Tsuneda et al. (2003). The small granules had a regular round-shaped outer space. On the day 40, it can be viewed that, dark colour granules grew faster and the sludge concentration increased again. Increasing numbers of large-sized yellow granules vanished gradually in the reactor. At this stage, large granular was dominating the reactor and no flocs could be observed in R1. Short cycle time of SBR favors the development of the large granules (Liu, Y. 2002).

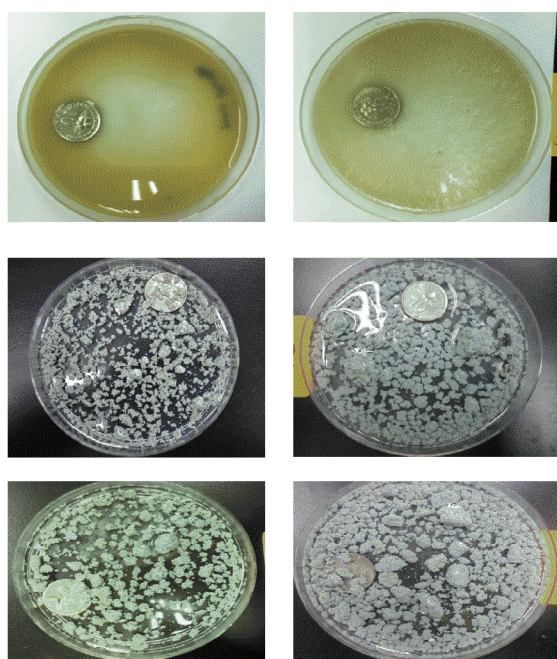


Figure 3: Evolution of the seed sludge

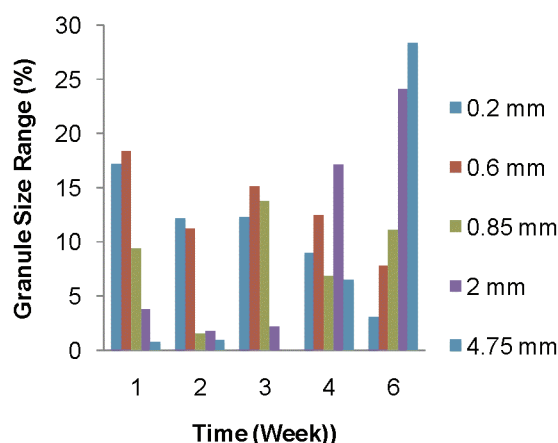


Figure 4: Size Distribution of the granular sludge

In reactor two, R2 the process of granulation is almost similar to the reactor one where at first, the flocculent sludge was dominant in the reactor, and it showed fluffy, irregular and loose structure morphology. After carrying out the experiment for few days, the flocculent sludge started to form in to small tiny aerobic granules and the average diameter increased gradually. At this stage, small granules and flocs were both present as a mixture in the reactor. On the final day of the experiment, it can be observed that, tiny granules have become larger. It have regular round shape, homogenous and clear outer morphology compared to reactor one. At this stage, large size granules were dominated and no flocs could be observed.

This proves that, in shorter cycle time and shorter settling time, aerobic granular could be developed in the SBR system. AGS formed in phase two compared to phase one which only dominated by matured flocs. It is proven by the image taken from image analyzer. Overall, reactor two, R2 has larger diameter compared to reactor one due to different settling time where reactor two has shorter settling time of 15minutes compared to 30 minutes for reactor one.

CONCLUSIONS

As a conclusion, this study has proved that AGS can be developed in rubber industry wastewater which is novelty of the research. Shorter cycle time which favour granulation results in a shorter hydraulic retention time (HRT), which provides a stronger selective pressure. Besides that, short settling time is also crucial for AGS since it preferentially selects for the growth of rapid settling bacteria and the sludge with a poor settling ability is washed out. The research study revealed that the AGS has high potential to be used as alternative treatment system since when compared to conventional activated sludge flocs, it is well known for their regular, dense, and strong microbial structure, good settling ability, high biomass retention, and great ability to withstand shock loadings. AGS can be developed into a sustainable business but due to lack of sufficient resources and experience, it is better for AGS to be commercialized by wastewater solution providers which are more experienced and have better reputation which would increase the confidence of consumers in granulation technology.

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