



## **SEQUENCING BATCH REACTORS OPERATION AT HIGH TEMPERATURE FOR SYNTHETIC WASTEWATER TREATMENT USING AEROBIC GRANULAR SLUDGE**

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### **ABSTRACT**

In this research, the formation and development of aerobic granular sludge (AGS) for domestic wastewater treatment application in hot climate conditions was studied using a sequencing batch reactor (SBR). The performance of the developed AGS in the removal of organic matter and nutrients from wastewater was also investigated. The operation of the reactor was based on the sequencing batch system with a complete cycle time of 3 hours that included feeding, aeration, settling, discharging and idling. The reactor was seeded with sludge collected from the municipal wastewater treatment plant in Madinah city, Saudi Arabia and operated at a temperature of 40°C using synthetic wastewater as influent. Results showed that granular sludge was developed after an operation period of 30 days. The developed granular sludge had a good settling ability with an average size of 2.42 mm. The removal efficiency of chemical oxygen demand (COD), ammonia nitrogen (NH<sub>3</sub>-N) and total phosphorus (TP) were 87.31%, 91.93% and 61.25% respectively. These results show that AGS can be developed at elevated temperatures and it is a promising technique to treat domestic wastewater in hot and low humidity climate conditions such as those encountered in Saudi Arabia.

**Keywords:** Aerobic granular sludge, hot climate, sequencing batch reactor, domestic wastewater treatment.

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## **1 INTRODUCTION**

Biological treatment of wastewater uses controlled biological population to biodegrade waste from either municipal or industrial sources or a mix of the two types of wastewater sources. Basically, these methods use microorganisms to remove organic matters and nutrients present in wastewater which result in a better quality effluent. Activated sludge is one of the methods of biological treatment that had been practiced for well over a century. In countries with hot and low humidity climate (e.g. Saudi Arabia) water availability challenges are faced as these countries are located within arid and semi-arid areas, and fresh water resources are limited. In Saudi Arabia, the wastewater treatment system is still at early stages as the main treatment method is the conventional activated sludge system, which is still in use in other countries as well. Generally, these systems require large surface areas for treatment and biomass separation due to poor settling properties. Therefore, improved and effective technology in treating wastewater are needed so treated wastewater can be reused in different beneficial uses which can contribute to solving the problem of limited water resources.

Aerobic granulation sludge is a new and promising technology that has increasingly gained the interests of researchers engaged in the area of biological wastewater treatment. The formation of aerobic granulation takes place by the process of microbial-self immobilization which results in a more compact aggregate than conventional activated sludge. Sludge in a granules form are packed with different species of microorganisms which plays different roles in removing organics matter and nutrients and able to treat a wide variety of wastewater. As reported by previous researchers, compared to conventional aerobic wastewater treatment systems, the aerobic granulation sludge system has several advantages, such as compact physical structure, dense, high settling ability of the granules, high biomass retention for solid-effluent separation, greater ability to withstand shock loadings as well as reduced space demand. To increase the efficiency of treatment system, aerobic granular sludge technology had been approached. Additional advantages of aerobic granular sludge as compared to traditional system include significant lower use of energy and chemicals, compactness and lower investment and operational cost which will make it more applicable in the future of wastewater treatment.

Extensive research has been performed in order to investigate the important factors affecting aerobic granular sludge formation. In term of temperature influence, most of the research was done at low temperature of 8 - 20°C [6] and ambient temperature of 20 - 25°C [14]. However, there is still limited information about the formation of granules at high temperature. A number of studies conducted granulation experiments at 27 - 30°C [2], [9] and 35°C. (Z. Song, N. Ren, K. Zhang, and L. Tong) reported the optimum temperature for mature aerobic granules cultivation is 30°C, where the granules had excellent settleability, more compact structure and higher bioactivity as compared to granules developed at 25°C and 35°C. The percentage removal of chemical oxygen demand (COD) and total phosphorus (TP) achieved was 97% and 75% respectively.

The objective of this study is to investigate the possibility of developing aerobic granular sludge in SBR system at a temperature of 40°C by using synthetic wastewater and activated sludge taken from the Madinah city, Saudi Arabia municipal wastewater treatment plant. Another objective is to assess the removal efficiency of organic matter and nutrients by aerobic granules in the SBR system and to characterize the aerobic granular sludge developed under such conditions. This study is expected to contribute further understanding of the mechanism of aerobic granulation at high temperature.

## 2 MATERIALS AND METHODS

### 2.1 BIOREACTOR SET-UP

The schematic diagram of bioreactor set-up is shown in Fig. 1. The bioreactor column was designed for a working volume of 1800 mL in SBR mode with internal diameter of 5 cm and total height of 35 cm. The bioreactor was operated continuously in cycles of 3 hours, including 5 min of influent filling, 155 min of aeration, 5 to 15 min of settling, 5 min of effluent discharge and 2 min of idle. A programmable logic controller (PLC) was used to control influent, effluent and aeration pumps by setting time at each phase. The influent was introduced through ports located at the bottom and air was introduced through the bottom by a fine bubble aerator. The effluent discharge occurred through an outlet port located at the middle of the bioreactor height which resulted in a volumetric exchange ratio of 50%. The bioreactor was operated at a temperature of  $(40 \pm 1)$  °C and at a dissolved oxygen level of 2 to 5 mg/L while the pH was observed to vary in the range of 6 to 8, and the substrate load was 1.6 g COD / L.d.

## 2.2 SYNTHETIC WASTEWATER COMPOSITIONS

According to previous study as in [A. Nor-Anuar], the aerobic granular sludge was successfully developed in synthetic wastewater. The composition of synthetic wastewater had been prepared in a similar way to that reported as which consists of two medias, namely medium A and medium B. The compositions medium A are 65.1 mM NaAc, 3.7 mM  $MgSO_4 \cdot 7H_2O$  and 4.8 mM KCl, while medium B consisted of 35.2 mM  $NH_4Cl$ , 2.2 mM  $K_2HPO_4$ , 4.4 mM  $KH_2PO_4$  and 10 mL of trace elements solution as in [W. Vishniac, and M. SanteR].

## 2.3 SEED SLUDGE

An activated sludge taken from an aeration tank of Madinah Municipal Wastewater Treatment Plant was used as seed sludge. The city is located within an arid climate region that experiences high temperature and low humidity conditions. Before adding into bioreactor, the sludge was sieved to remove large debris and inert impurities. The amount of seed sludge used was about 900 mL, with a mixed liquor suspended solid (MLSS) concentration of 3.7 g/L and mixed liquor volatile suspended solid (MLVSS) concentration of 7.1 g/L.

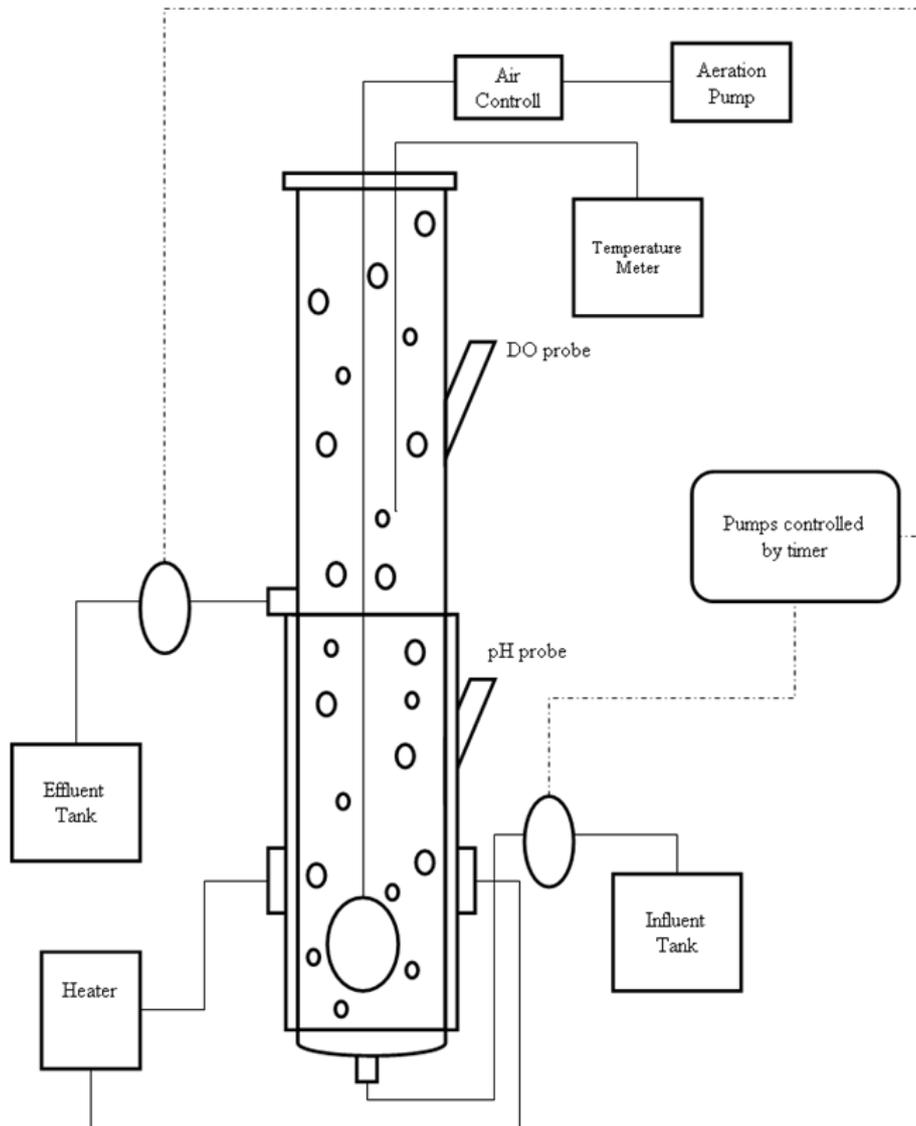


Figure 1. Schematic Layout of the SBR system

## 2.4 ANALYTICAL METHODS

Measurements of the parameters such as chemical oxygen demand (COD), total phosphate (TP), ammonia nitrogen ( $\text{NH}_3\text{-N}$ ), MLSS, MLVSS and settling velocity were conducted according to the method stated in Standard Methods for the Examination of Water and Wastewater [APHA]. The pH and DO were continuously monitored by using pH/DO meter (Orion 4-Star Benchtop pH/DO Meter). The morphological and structural observations of granular sludge were carried out by using a stereo microscope equipped with digital image processing and analyzer (PAX-ITv6, ARC PAX-CAM).

## 3 RESULTS AND DISCUSSION

### 3.1 FORMATION OF GRANULES

Aerobic granules development was observed by using a stereo microscope and the initial seed sludge was seen in the form of fluffy flocs, with loose and irregular structure. Microscopic observation shows that the shape of the mature granules was close to spherical which was obviously different from the seed sludge and the activated sludge flocs as well. After two weeks, the sludge flocs gradually disappeared and were replaced by granules with an average diameter of 1.03 mm. In contrast, the granules were larger and irregular. They formed by self aggregation of bacteria and had a settling velocity of 25.02 m/h. Subsequently, the small granules change to more regular shape and slowly increased in size in the next following days. After 30 days of operation, a large amount of granules that were close to spherical shape structure appeared in the bioreactor with an average size of 2.42 mm. The mature granular sludge had a compact structure with good settling ability (settling velocity about 31.27 m/h). The developed granules at 15 and 30 days are shown in Fig. 2.

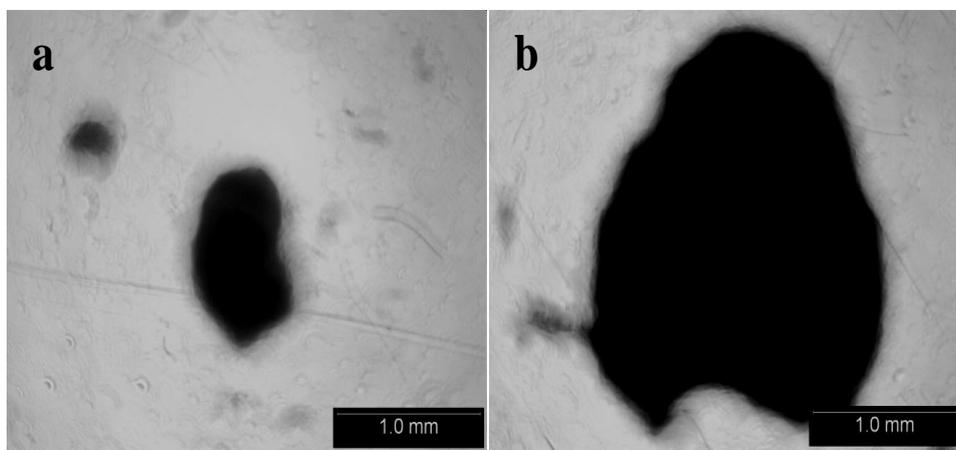


Figure 2. Stereo microscope images of granules (a) after 15 days and (b) after 30 days

### 3.2 BIOMASS PROFILE AND SETTLING CHARACTERISTICS OF GRANULES

Fig. 3 represents the profile of biomass concentration in the SBR system from the start-up until the end of the study. At the beginning of experiment, the reactor experienced a large amount of seed sludge wash out from the bioreactor due to poor settling properties, which caused a rapid decrease in the biomass concentration. During the start-up, the MLSS reduced from 3.7 g/L to 1.7 g/L mainly due to short settling time applied in the system. On the 9th day, the MLSS reduced from 10.2 g/L to 7.5 g/L apparently due to transition from

flocculating sludge to granular form. When aerobic granular sludge appeared in the bioreactor on day 15, the concentration of MLSS had improved and it was about 10.8 g/L on the day 30. This trend is similar to trend of MLVSS concentration which was about 6.1 g/L at the beginning stage and 8.2 g/L on the day 30. The MLVSS and MLSS ratio is about 0.81. A stable condition of biomass concentration shows a good accumulation of biomass in the bioreactor.

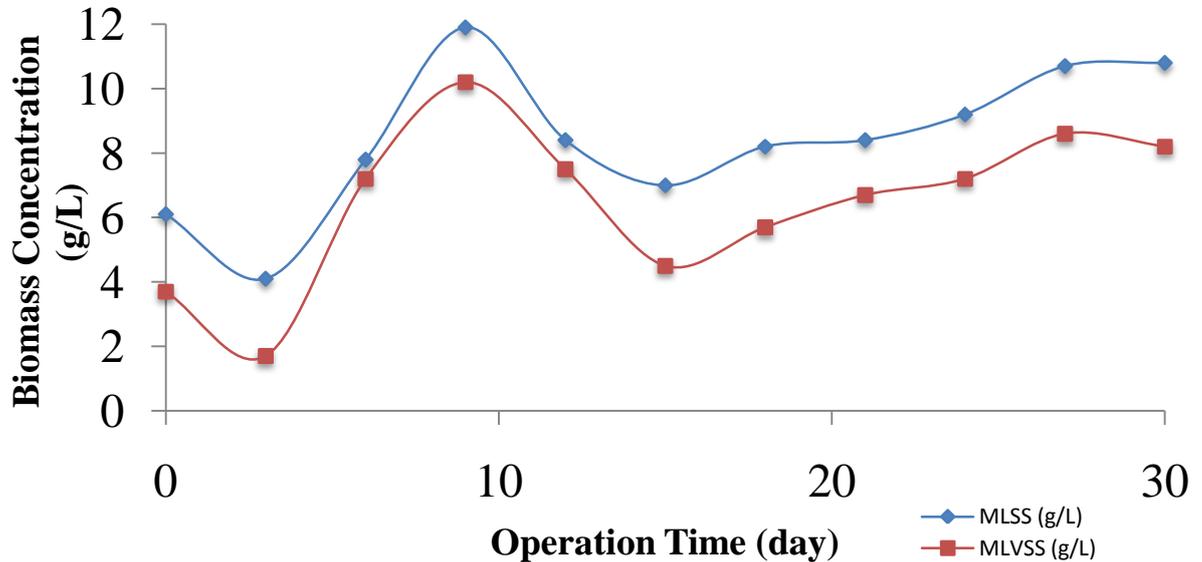


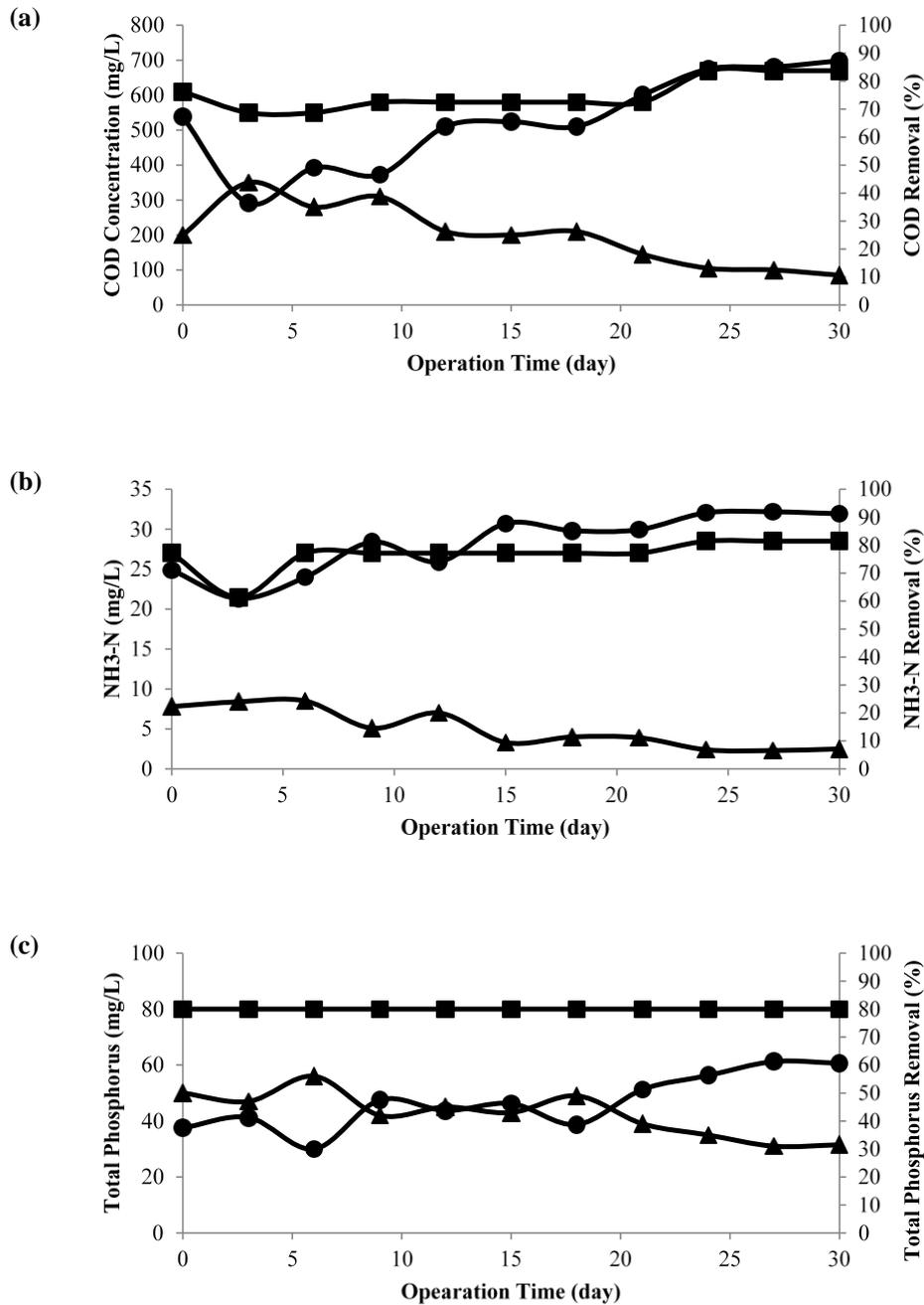
Figure 3. Profiles of biomass concentrations for 30 days of experiment

### 3.3 REMOVAL EFFICIENCY OF GRANULES

The COD,  $\text{NH}_3\text{-N}$  and TP contents of effluent were regularly monitored during the 30 days of development. The performance of the reactor system from beginning until day 30 is given in Fig. 4. At the initial stage of operation, the percentage removal for COD was 67.21% and decreased to 36.36% mainly due to the adapting process of the sludge with synthetic wastewater. The removal efficiency of COD was fluctuating and unsatisfactory as the percentage removal of COD was about 60% to 65%. After day 15, the percentage removal of COD was increased since the aerobic granules appeared in the bioreactor with average diameter size of 1.03 mm. The degradation ability of the granules and thus the removal efficiency of COD had improved up to 87.31%.

At the beginning of bioreactor start-up, the percentage removal of ammonia nitrogen was 71.11% and decreased to 60.93%. The percentage removal of ammonia nitrogen fluctuated until day 15 and remained stable after day 15 when the formation of granules started. The concentration of ammonia nitrogen in the effluent was significantly low as the concentration remained below 10 mg/L which indicated a good ammonia nitrogen removal efficiency (above 90%).

During the initial stage, the percentage removal of TP was 37.50% and then became fluctuated until the formation of aerobic granules appeared. The percentage removal of TP increased steadily up to 61.25%. However, in order to reach steady state and become stable with removal efficiency above 80%, aerobic granular sludge needed a longer period of time as many researchers reported more than 30 days [Z. Song, N. Ren, K. Zhang, and L. Tong], [A. Nor-Anuar,].



**Fig. 4 Profiles of removal performances in the SBR system within 30 days for (a) COD, (b) NH<sub>3</sub>-N and (c) TP. (■) Influent concentration; (▲) Effluent concentration; (●) Percentage removal.**

#### 4 CONCLUSION

Aerobic granular sludge was successfully developed after 30 days in SBR fed with synthetic wastewater and operated at 40°C. The mature granules were observed in the bioreactor with a good settling ability and an average diameter size of 2.42 mm. The removal efficiency results showed that aerobic granules are capable of removing organic matter and nutrients (COD, ammonia nitrogen and TP) with percentage removal of 87.31%, 91.93% and

61.25%, respectively. Thus, aerobic granular sludge can be developed at high temperature of 40°C and is capable of treating domestic wastewater at hot climate and low humidity conditions such as in Middle East countries (e.g. Saudi Arabia).

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