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Research paper

Biological Phosphorus Removal in Sequencing Batch Reactor at Longer Anaerobic Operating Period

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Abstract

Two lab scale sequencing batch reactors were operated to evaluate phosphorus removal at 12-hours cycle. Plastic media was used as packing media in SBR1 and SBR2, respectively. A 12-hours operation cycle of both SBRs consisted of six consecutive stages that include filling (2 min), anaerobic phase (120 min), aerobic phase (480 min), settling (120 min), draw (30 min) and idle (15 min) which a digital timer was used to control it. SBR 2 will undergo a total of 12 hrs operation cycle with longer anaerobic time (240 min) and shorter aerobic time (360 min). The scanning electron microscope (SEM) and energy diffusive x-ray (EDX) analyser were used to characterize the formation of biofilm formed. Performance of SBR in terms of Chemical Oxygen Demand (COD) removal was consistently greater than 90%, irrespective to the of changes in anaerobic operating period. The average removal efficiencies for COD and phosphate were recorded at 92.2% and 68.3%, respectively for SBR1, 90.2% and 80.9%, respectively for SBR2. A longer anaerobic period in SBR2 led to the formation of more compact sludge granules and higher settling rate. SEM analysis revealed that spherical and rod shaped were the dominant species of bacteria in the biofilm grown on the surface of the plastic media. This concluded that the activities of Phosphorus-Accumulating Organisms (PAOs) species were probably inhibited in the reactor.

Keywords: *Phosphorus removal, sequencing batch reactor, phosphorus accumulating organism.*

1. Introduction

High nutrient content in wastewater such as nitrates and phosphates compounds have caused increased eutrophication in natural water bodies such as rivers, lakes, coastal waters, estuaries and pose a potential threat to both ecosystem and human health.

The sequencing batch reactor (SBR) is one of the technologies that are mostly proposed due to its efficiency and applicability in the removal of organic carbon and nutrients. The SBR is a prominent technology in the modern world that is used in the treatment of sewage and industrial wastewater because of its practical usage and simple and flexible operational procedures [2]. The typical operational time for SBRs are 6-12h cycles for domestic wastewater treatment and is well documented [3,4].

The application of biological treatment in the removal of phosphorus by using biological treatment system is dependent on the activity of phosphorus-accumulating organisms (PAOs). The process is carried out by using operational phases of anaerobic, aerobic and sometimes anoxic conditions (absence of free oxygen but nitrate is present as electron acceptor) with biodegradable organic carbon available under anaerobic conditions [5].

Biological phosphorus removal depends on the uptake of excessive phosphorus by phosphorus-accumulating organisms (PAOs) and this is usually achieved by. The phosphorus-accumulating organisms (PAOs) that are often used to represent this group of bacteria and are considered as the predominant species in an activated sludge bacterial community that is associated with phosphorus removal is the groups of bacteria known as Acinetobacter, Pseudomonas [6,7] and Candidatus that hates bacteria as stated in [8,9]. Although there are still some studies that are unclear regarding the metabolism of PAOs, most researches have accepted that PAOs' ability to anaerobically take up volatile fatty acids (particularly acetic acid) and store them as PHAs (particularly poly-b-hydroxybutyrate or PHB) for later processing in anoxic or aerobic conditions thus giving these microorganisms an advantage over the competition for nutrients compared to other microorganisms [10].

Biological phosphorus removal requires the combination of different conditions and different microbial populations in the system. Different operating conditions of SBR were applied to evaluate treatment performances in phosphorus removal. The physical properties of the sludge (MLSS, sludge volume index, etc.) as well as the microbial activities (COD and phosphorus removal) were followed.

2. Materials and methods

2.1 Operating Conditions

Two lab-scale of SBR were carried out, each made of acrylic cylinder with height 24.5cm and diameter 30 cm, partially filled with plastic support materials, hanging at the center part of the reactor. The working volume for each unit was 5L with a sludge mixed liquid level of 20 cm. Fine air bubbles for aeration and mixing were supplied from air diffuser at the bottom of the reactor. After natural settling of the sludge, 3L of supernatant of the sludge was discharged which resulting in a volume exchange ratio of 60%.

The reactor operated sequentially in 12 hours cycle which was controlled by an automatic timer. Table 1 shows the operational characteristics of SBR and fast feeding was done to avoid long time air exposure to the activated sludge. The SBR worked at room temperature ranging from 16 ^{o}C to 37^{o}C.

Table 1: SBR Operational Characteristics.

Operational characteristics	
Reaction volume	7 L
Operation days	30
Daily number of cycles	2

A 12 h operation cycle of both SBRs consisted of six successive phases including filling (2 min), anaerobic phase (2 h), aerobic phase (8 h), settling (2 h), draw (30 min) and idle (15 min) which were controlled by a digital timer. SBR 2 will undergo total 12 h operation cycle with longer anaerobic time (4h) and shorter aerobic time (6h).

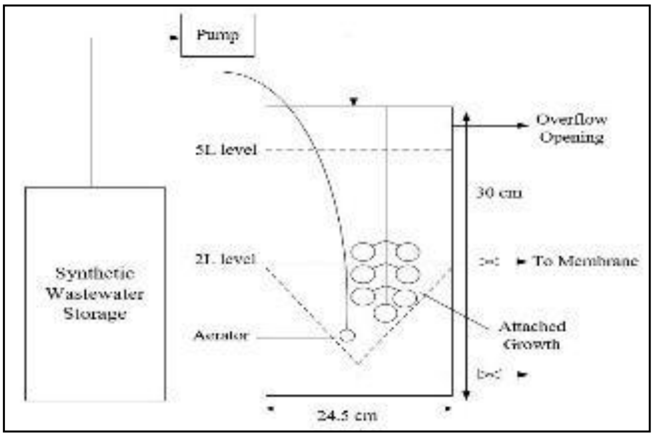


Figure 1: Schematic Diagram of SBR Experimental Setup.

Figure 1 shows the schematic diagram of the experimental setup used in this study. Table 2 shows the detailed experimental conditions during detailed operational stages for both reactor.

Table 2: SBR Cycle

Phase	SBR 1 (time)	SBR 2 (time)
Filling	2 min	2 min
Anaerobic	120 min	240 min
Aeration	480 min	360 min
Settling	120 min	120 min
Draw	2 min	2 min
Idle	15 min	15 min

Figure 2 shows the actual experimental setup used in this study. A certain volume of sludge (50ml) were periodically taken from the SBR and stored at -4^{o}C for further investigation.

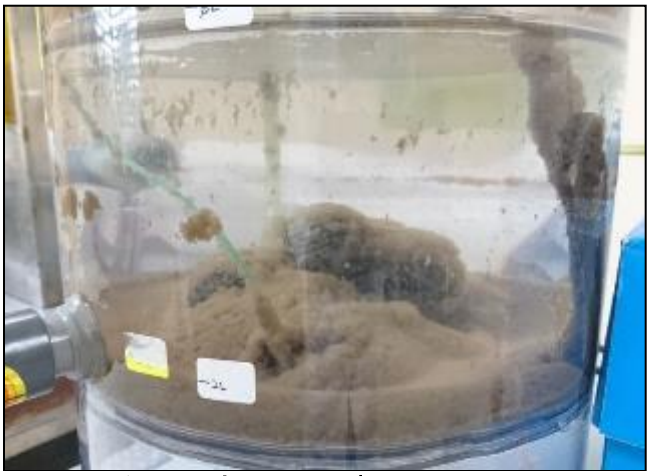


Figure 2: Laboratory Setup for SBR Experiment.

2.2 Feed wastewater characteristics

The heterogeneous seeding microbes used in SBR system were obtained from a domestic sewage treatment plant near Kota Damansara, Malaysia. The nutrient media had the following composition as presented in Table 3, resulted in a COD of influent of 400 mg/L. The effluent was stored inside a refrigerator at 5^{o}C to maintain its characteristics throughout the experiment.

Table 3: Composition of Synthetic Wastewater (mg/L)

Glucose	513.0
Peptone	128.3
Sodium carbonate	100.8
Potassium phosphate	43.5
Ammonium chloride	96.3
Sodium bicarbonate	100.8
Magnesium sulfate	5.0
Ferric chloride	1.5
Calcium chloride	5.0
Mangan chloride	1.0

The reactor was filled with a low-strength synthetic wastewater containing protein, carbohydrates and minerals and the reactor performance were evaluated through dynamic substrate concentration profiles during 12-hours batch cycles. During the acclimatisation period, the substrate was replaced every 24 hours.

2.3 Analytical method

During the operation, the feed, effluent and sludge from the SBR were sampled regularly for analysis. COD, TP, PO_4^{3-}, and MLSS were determined according to the standard methods [1]. The pH value and dissolved oxygen (DO) were measured by using pH meter (WalkLab Microprocessor) and dissolved oxygen meter (WalkLab).

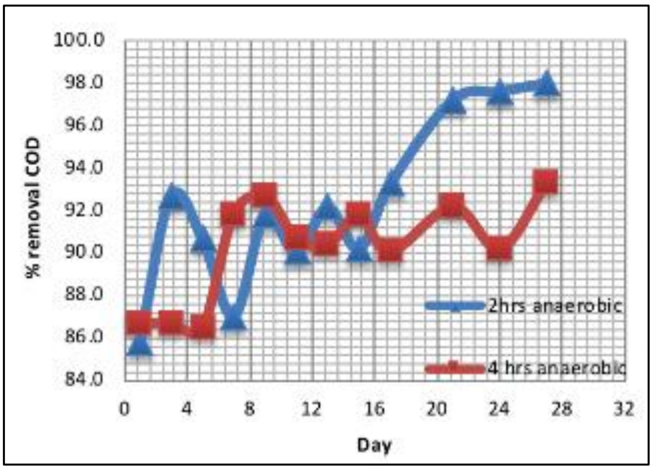
Two carriers were taken out from the reactor at the end of the experiment for SEM analysis. Carriers were dipped into 100ml of reactor effluent and the removed biomass from the carrier was used for SEM analysis according to the method reported by [11].

3. Results and Discussion

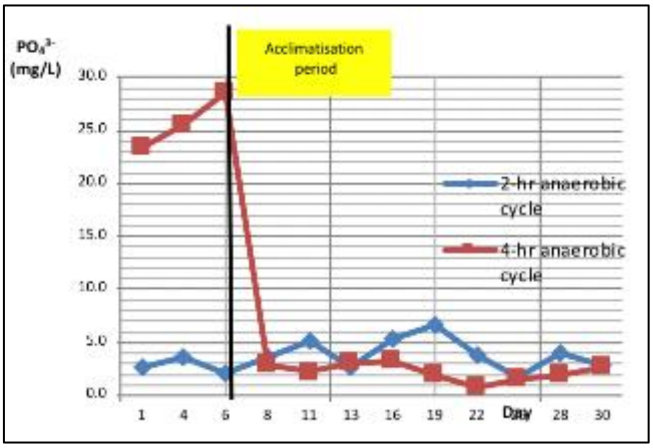
3.1 Reactor Performance

The time course profiles of COD and phosphates removal efficiencies are shown in Fig.3. Inoculated activated sludge was in the stage of adaptation on the 1st day, since the removal rate of COD was poor, and the COD concentration in effluent was 28 mg/L (Fig.2(i)). However, COD removal rate was kept under 92%, and the effluent COD maintain under 50 mg/L in the following time, indicated that sludge had high biological activity.

Effluent ortho-phosphate (PO_4^{3-}) concentration was less than 2.5 mg/L after the 9th day, as shown in Fig.3(ii). Average removal efficiencies for COD and phosphate were 92.2% and 68.3% for SBR1, 90.2% and 80.9% for SBR2, respectively. Increasing anaerobic period enhanced the substrate conversion and favoured the granulation process. Fluctuation on the first stage might due to acclimatisation of biomass within the SBR system. Th pH needs to be monitored continuously in the SBR to prevent inhibition of PAO bacteria.



(i)



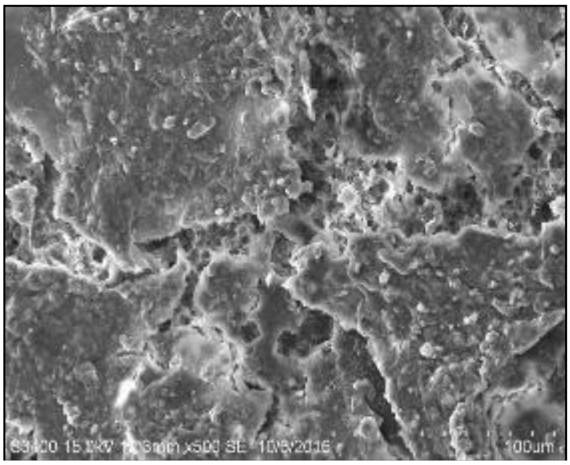
(ii)

Figure 3: Variation of (a) COD and (b) Phosphate during SBR Operation.

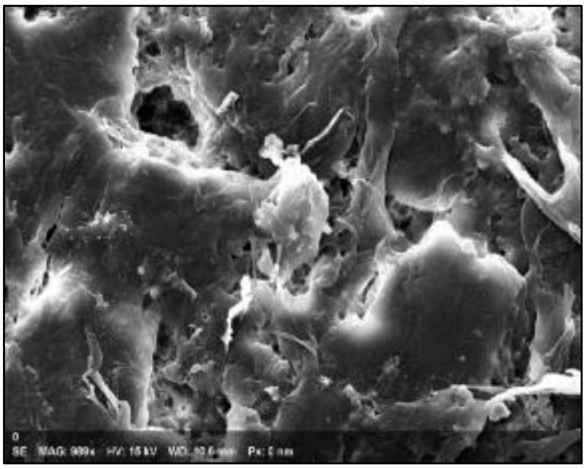
3.2 SEM-EDX analysis

The biofilm image was obtain using SEM at magnification of 500x, grown on the surface of plastic media as shown in Fig. 4(i). It revealed that the biofilm thickness formed was $1.35 x 10^{-5}$ mm after 39 days of experiment. Through SEM analysis, it was observed that spherical and rod-shaped bacteria were the dominant species on the biofilm formed on the plastic media's surface as showed in Fig 4(ii) at magnification of 989 times.

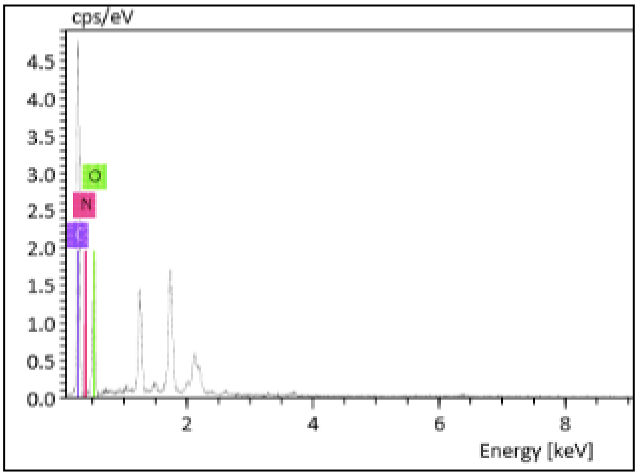
The elemental analysis performed by EDX analyzer (Fig. 4(iii)) shows that chemical components of carbon, oxygen and nitrogen were 53.06%, 43.57% and 3.37%, respectively. There are no inorganic minerals detected in the biofilm.



(i)



(ii)



(iii)

Figure 4: SEM-EDX taken from the SBR reactor.

Apart of the images from SEM analysis, the existance of filamentous bacteria has also been visualized physically in the SBR during the experiment. Fig 5 shows the physical evidence of filamentous bacteria.

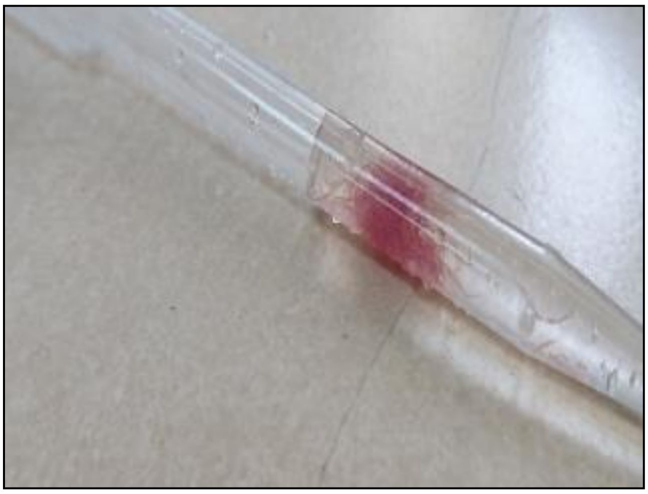


Figure 5: Filamentous bacteria found in SBR.

4. Conclusion

The viability of lab scale SBR in treating phosphorus in wastewater biologically has been studied. Average removal efficiencies for COD and phosphate were recorded at 92.2% and 68.3% respectively for SBR1, 90.2% and 80.9% respectively for SBR2. An extension period of anaerobic phase in SBR2 led to the formation of more compact sludge granules and better settleability. An extension period of anaerobic phase in SBR2 led to the formation of more compact sludge granules and better settleability. SEM analysis revealed that spherical and rod shaped were the dominant species of bacteria in the biofilm grown on the surface of the plastic media. It concluded that the activities of PAOs species were probably inhibited in the reactor.

Acknowledgement

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