The Effect of Different Gas Pressures and Quorum Quenching Method on the Performance of Membrane Aerated Biofilm Reactor (MABR)

Banu Taşkan, Halil Hasar

***Abstract*—**Membrane aerated biofilm reactors (MABRs) are a future advanced treatment technology that is widely used in the future for wastewater treatment. However, the increase in the biofilm thickness on the membrane surface with the operation period and accordingly the decrease in the treatment performance is the main problem of MABR systems. Despite the use of different methods to solve this problem, no exact solution has yet been found. In recent years, the quorum quenching method has begun to be used to provide biofouling control on membrane bioreactors. In this study, the effect of different O_2 gas pressures and QQ application on the biofilm layer thickness formed over time on the membrane surface and reactor performance was investigated. It has been found that the QQ microorganism containing reactor with the increase of the gas pressure given to the reactors have higher treatment performance than vacant beads containing reactor. In addition, it has been determined that the amount of dead microorganism in the control reactor depending on the thickening of the biofilm layer is greater than that of other reactor.

***Index Terms*—**Biofilm thickness, membrane aerated biofilm reactor, quorum quenching, oxygen gas pressure.

I. Introduction

While membrane aerated biofilm reactors (MABR) provide surface area for biofilm development, membrane fibers are used as a way of conveying the gas substrate required for the process (Essila et al., 2000). MABR has attracted great interest due to its operational advantages such as providing high surface area for biofilm growth and minimizing gas waste. One of the most important problems encountered in MABR operation is excessive biofilm accumulation on the membrane fiber surface (Syron and Casey, 2008). Excessive biofilm growth not only leads to non-uniform gas distribution, it also inhibits substrate or gas diffusion and consequently degrades system performance.

Extreme biofilm growth that inhibits long-term stable operation is the most important factor limiting the widespread use of MABRs. For this reason, it is thought that this problem can be avoided by the Quorum quenching method between microorganisms which is one of the newly developed methods and enables biofilm control. This newly developed biological approach is the quorum quenching (QQ) method, which occurs through the degradation of quorum sensing (QS) between microorganisms. Researchers are trying to control biofouling in different systems using this method (Davies, 2003; Dobretsov et al., 2009; Hook et al., 2012).

In this study, the effect of different O_2 gas pressures and QQ applications on the increased biofilm thickness on the membrane surface during wastewater treatment using MABR was investigated. In addition, the effect of operating conditions on the amount of living / dead microorganisms in biofilm samples taken from the membrane surface was examined by using fluorescence microscopy.

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II. Material-Methods

2.1. Production of QQ Beads

In this study, *Rhodococcus sp.* BH4 bacteria as QQ bacteria were used. This bacterium was planted in Luria Bertani (LB) (Miller, US) liquid medium and incubated at 30 ° C for 24 h. The solution of the Rhodococcus sp BH4 bacteria, which had proliferated after 24 hours, was centrifuged (12000 g, 15 dk). After centrifugation, the suspension of BH4 was then blended into the suspension of sterile sodium alginate. The suspension of BH4-alginate was dropped into a 3% (w / v) $CaCl_2$ solution mixed on the magnetic stirrer via a nozzle with a flow rate of 1.6 mL / min and beads containing QQ microorganisms (Cell Entrapping Bead) were obtained (Kim et. al., 2012).

2.2. Determination of Activity of QQ Beads

The indicating agar plates are prepared by X-Gal addition (0.2 g / L) and mixing 9:1 with incubated A136 overnight of LB-agar. The samples taken at certain time intervals from the test tubes of the reaction are placed in the sample wells opened on the indicating agar plates. As a result of the chain reactions between C8-HSL, A136 and X-Gal, blue color formation takes place. The concentrations of C8-HSL in the samples can be calculated by using the diameters of the zones formed by standard solutions with known concentrations. In this view, the decrease in the concentration of C8-HSL over time gives information about QQ activity (Park et al., 2001; Oh et al., 2012; Kim et. al., 2012; Köse-Mutlu et al., 2015).

2.3. Reactor Setup and Operating Conditions

The membrane module, which was prepared to contain 40 hydrophobic hollow-fiber gas transfer membranes, was fixed by placing it vertically in the MABR. The study was conducted using two parallel reactors, the main reactor and the control reactor. For this purpose, one main reactor and one parallel control reactor have been installed. The reactors were continuously mixed using a magnetic stirrer. MABRs were

inoculated with the effluent from the aeration pond of the domestic wastewater treatment plant. *Rhodococcus sp* BH4 bacteria having QQ activity isolated from a true MBR plant were added to the main reactor by immobilization in the sodium alginate beads (CEBs). The QQ activity of CEBs was determined before addition to the reactors. After the inoculation, QQ beads to the main reactor were added, while the control reactor were included the same amount of vacant beads. All reactors were operated in exactly the same conditions (100 COD, 36 h HRT, 10 ml bead concentration) parallel to each other. Thus, it was investigated the effect of different O_2 pressures (2, 4, 6 psi) on MABR performance in the all reactors.

2.4. Analysis

COD analysis was conducted with the aim of determining the performance of MABRs. COD were determined according to Standard Methods (APHA, 2005). Live and dead bacteria in the biofilm structure on the membrane surface were determined by using fluorescence microscopy.

III. Results and Discussions

The COD results of MABRs are shown in Fig 1. When the effect of different gas pressures on MABR performance in control reactors was examined, the effluent COD concentration decreased from 100 mg/L to 60 mg/L in P1 period (2 psi O_2 gas pressure) and to 45 mg/L levels in P3 period (6 psi O_2 gas pressure). Due to the microorganisms were not able to find enough oxygen in the environment at low gas pressures, the treatment performance of the reactors and the amount of viable microorganisms in the environment were observed to decrease. Hence, it was found that the increase of O_2 gas pressure in the control and main reactors increases the COD removal in the P3 period when compared to the other periods. Although all the operating conditions are the same, it was detected that the COD removal in the main reactor containing QQ beads was higher than in the control reactor containing vacant beads. The excess biofilm thickness on the membrane fiber in the MABR can be controlled by the QQ method. Moreover, the treatment performance of the main reactor increased more than the control reactors in parallel with the increase of the gas pressure. In the P3 period, while the effluent COD concentration in the control reactor was 45 mg/L, it decreased to 30 mg/L in the main reactor.

In biofilm samples taken from the membrane surface in MABR reactors, the results obtained from live/dead microorganism analysis carried out by using fluorescence microscopy are shown in Fig 2. When the results obtained are examined, it is seen that the amount of living microorganisms in the environment is increased due to the increase of O_2 gas pressure in the reactors using QQ beads. An increase in the biofilm thickness on the membrane surface, which leads to non-uniform gas distribution, the effective usage of the gas substrate by microorganisms restricted. Therefore, it was determined that the amount of dead microorganisms in the control reactor depending on the thickening of the biofilm layer was higher. The amount of live microorganism in the environment during P3 period is more suppressed than P1. The reason is that microorganisms can use more oxygen in P3 period. It was determined that the amount of dead microorganisms in the main reactors containing QQ beads was much less than that of control reactors and that the amount of living organisms is increased due to the increase of gas pressure.

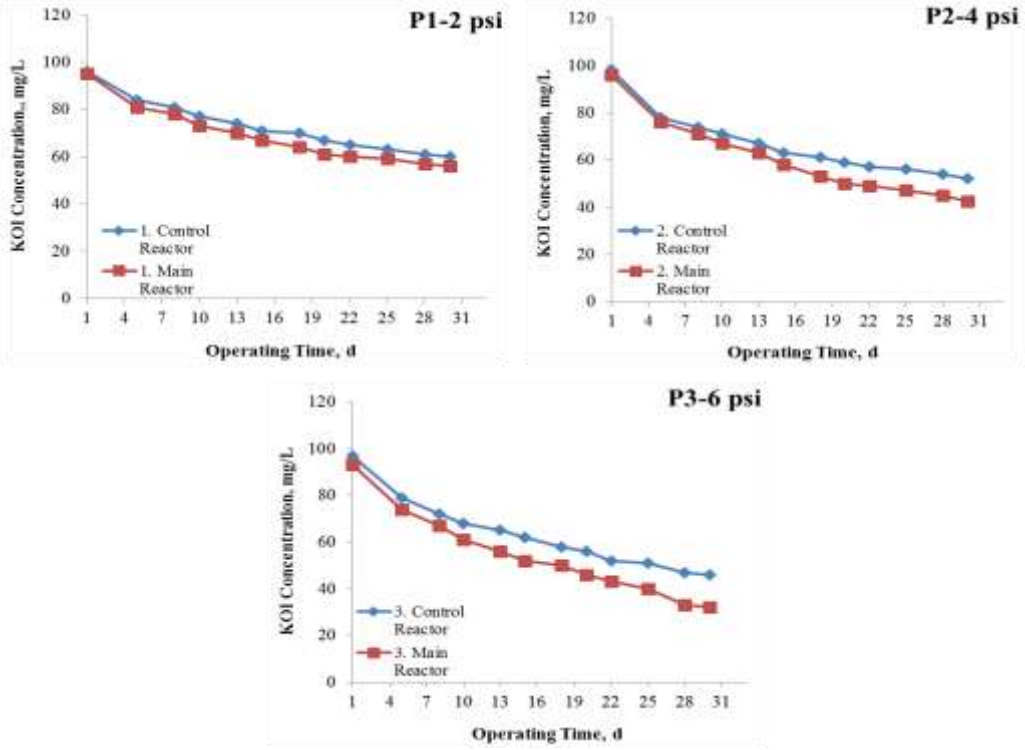

Fig.1. COD results of reactors at different gas pressures.

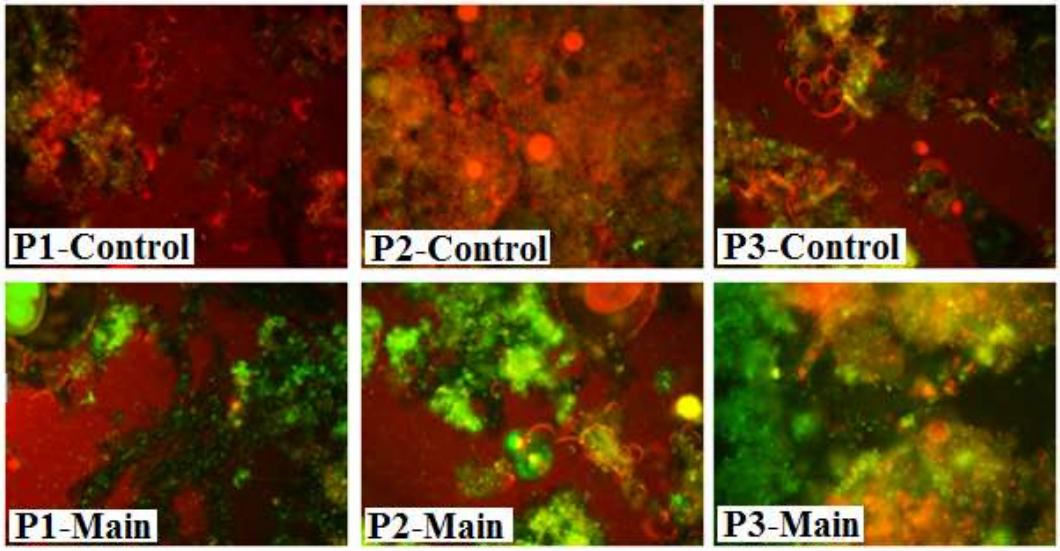

Fig. 2. Fluorescence microscopy images of living and dead bacteria in the biofilm structure formed on the membrane surface.

IV. Conclusions

One of the most important problems encountered in MABR operation is excessive biofilm accumulation on the membrane fiber surface. Excessive biofilm growth not only leads to non-uniform gas distribution, it also inhibits substrate or gas diffusion and consequently degrades system performance. Extreme biofilm growth that inhibits long-term stable operation is the most important factor limiting the widespread use of MABRs. The data obtained from the study showed that the excess biofilm thickness of MABR was keep under controlled by the QQ method. Moreover, the treatment performance of the main reactors increased more than the control reactors in parallel with the increase of the gas pressure. In the P3 period (6 psi O_2 gas pressure), the results of the treatment performance of the main reactor were found to be higher than the others. Due to the microorganisms were not able to find enough oxygen in the environment at low gas pressures, the treatment performance of the reactors and the amount of viable microorganisms in the environment were observed to decrease. It was determined that the amount of dead microorganisms in the control reactor due to the thickening of the biofilm layer especially in the low gas pressure was higher than the QQ beads containing main reactor. The amount of living organisms in the reactors increased due to the increase of gas pressure.

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