High Concentration Perchlorate Degradation in Microbial Fuel Cell

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Abstract

In this study, microbial fuel cell was used to degrade 300 mg/L of perchlorate in the cathode chamber. Total of 77% and 47% of perchlorate were degraded with the addition of bacteria mixture and 30 mg/L of Fe/Ni nanoparticles respectively in the cathode chamber.

1 Introduction

Earlier study proved that biosurfactant production in the anode chamber of a microbial fuel cell (MFC) with used vegetable oil as substrate was feasible (Prashanth et al. 2009). Recent studies showed that oxide substrates can be reduced with MFC by using the cathode chamber of MFC with or without microorganisms (Thrash et al. 2007; Heijne et al. 2006). Perchlorate, which is highly soluble in water and is very resistant to degradation in natural environment, is considered to be a major contamination in groundwater and soil (Logan 2001). The degradation pathway for perchlorate is shown in equation (1). MFC has been reported as a device to reduce perchlorate (Thrash et al. 2007).

$$ClO_4^- + 8e^- + 8H^+ \longrightarrow 4H_2O + Cl^- \quad \text{(Cathode Chamber)} \qquad (1)$$

2 Objective

The objective was to investigate the possibility of perchlorate reduction in the cathode chamber of MFC with bacterial mixture or Fe/Ni nanoparticles in the chamber.

3 Materials and Methods

A concentric cylindrical MFC was designed, and aluminum was used as the electrodes. Disks were connected consecutively to form the cathode electrode in the inside chamber. A sheet of aluminum was used as anode electrode. Cation exchange membrane (Membranes International Inc.) was used for proton exchange. Ag/AgCl electrode was used as the reference electrode. A resistor of 100 Ω was connected with wires and the two electrodes. Two peristaltic pumps were used for liquid fill up and daily refill after sample extraction. Perchlorate concentration was measured using the UV-vis spectrophotometer, with method suggested by Pourreza and Mousavi (2005). Mixture of bacteria from activated sludge and soil samples was inoculated into the cathode chamber. 300 mg/L of perchlorate was added to the cathode chamber. Used vegetable oil was used as electron donor in the anode chamber, and biosurfactant was produced in the chamber. The following parameters were monitored daily: pH, ORP, OD, and surface tension of the anode chamber; pH, ORP, OD for cells, OD for perchlorate concentration (centrifuged); open circuit voltage, current, anode potential, and cathode potential. For nanoparticles test, 300 mg/L perchlorate buffer liquid with 30 mg/L Fe/Ni nanoparticles was prepared and injected into the cathode chamber of MFC. For the controls, 300 mg/L perchlorate with 30 mg/L Fe/Ni nanoparticle solution and bacteria solution was stirred in conical flasks.

4 Results and Discussion

With the mixture of bacteria, concentration of perchlorate decreased daily, and 77% of perchlorate was degraded after 6 days of testing in the MFC, while in the control study using bacteria only to

degrade perchlorate had almost no change (Figure 1). In the case Fe/Ni nanoparticle, 30 mg/L degraded 47% of perchlorate after 6 days operation in MFC, while the control only reached 17% degradation of perchlorate (Figure 1).

The anode potential of MFC increased with time, suggesting biosurfactant production with time. While the cathode potential decreased with time, suggesting perchlorate reduction with time. In the cathode chamber, pH was about 7.2~7.6, and ORP was about -60 mV. For the anode chamber, pH was 7.0~7.5, ORP dropped from -30 mV to -62 mV, and then raised to -53 mV, suggesting the generation and removal of electrons in the anode chamber during the process. Surface tension of the liquid in the anode chamber dropped to 27 mN/m at the end of the test.

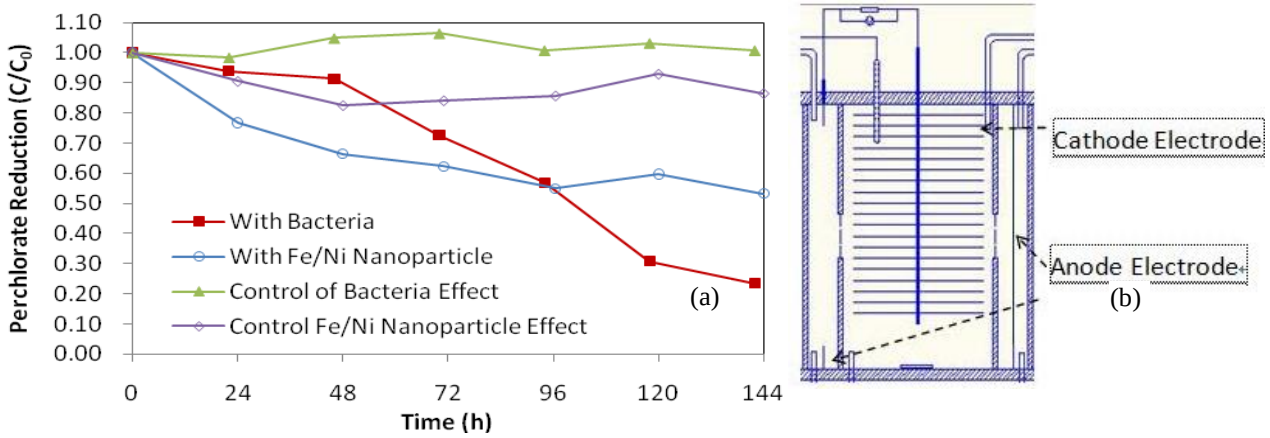

Figure 1 a) Perchlorate Concentration Change with Operation Time
b) Sketch of Concentric Cylindrical MFC

5 Conclusions

In the cathode chamber of MFC, 77% of perchlorate (300 mg/L) was degraded after 6 days operation in MFC with the help of bacteria, and Fe/Ni nanoparticle could also degrade perchlorate in MFC with maximum degradation of 47%. Without MFC, 30 mg/L nanoparticle could only degrade 17% of perchlorate during the tested period, while bacteria mixture did not degrade.

5 Acknowledgements

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6 References

Heijne A.T., Hamelers H.V.M., Wilde V.D., Rozendal R.A., Buisman C.J.N. (2006), "A bipolar membrane combined with ferric iron reduction as an efficient cathode system in microbial fuel cells", Environ. Sci. Technol., Vol.40, pp.5200-5205

Logan B.E. (2001), "Assessing the outlook for perchlorate remediation", Environ. Sci. Technol., Vol.35, pp.483-487

Pourreza N., Mousavi H.Z. (2005), "Extraction spectrophotometric determination of trace amounts of perchlorate based on ion-pair formation with thionine." J. Analy. Chem., Vol.60, pp.921-992

Prashanth P., Liu J., Vipulanandan C. (2009), "Electricity generation during biosurfactant production in a microbial fuel cell", Proceedings, CIGMAT-2009 Conference

Thrash J.C., Trump J.I.V., Weber K.A., Miller E., Achenbach L.A., Coates J.D. (2007), "Electro-chemical simulation of microbial perchlorate reduction", Environ. Sci. Technol., Vol.41, pp.1740-1746