

Applicability of Iron Chelate Compounds as An Electron Acceptor for A Double-Chamber Microbial Fuel Cell

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1. Preface

I addressed a research topic of “Applicability of iron chelate compounds as an electron acceptor for a double-chamber microbial fuel cell” at the IWA conference in Brisbane, Queensland, Australia from 9th to 14th October 2016.

2. Summary and Presentation

2.1 Introduction

A microbial fuel cell (MFC) is defined as a system in which microorganisms function as catalysts to convert chemical energy into electrical energy. Thus, the MFC is expected to become an organic wastewater treatment system with an energy recovery function. Anaerobic oxidation of organic matter at the anode and reduction of electron acceptors at the cathode constitute the oxidation-reduction reactions in the MFC. Oxygen is often used as an electron acceptor because it is rich in the air and a reaction product of oxygen is harmless. When a double-chamber MFC is used, it is important how to promote the cathodic reaction. In this study, we search for safe chelating agents easily re-oxidized by oxygen and use ferric ions as electron acceptors. Ferric ions are reduced into ferrous ions at cathodes of the MFC. Then, the ferrous ions are oxidized into ferric ions in a trickling filter-type oxidation column and are reused.

2.2 Material and Methods

2.2.1 Oxidation characteristics

We explored an easily oxidizable ferrous-chelate and an optimal hydraulic loading of the catholyte on a trickling filter-type iron oxidation column. A ferrous-chelate solution used contained 5 or 10 mM of ferrous sulfate and the same concentration of a chelating agent. The solution pH was set at 7 by the addition of 1.0 M of sodium hydroxide solution. Chelating agents examined were ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid, and triethylenetetraminehexaacetic acid. We tested the validity that a ferric-chelate compound changed a ferrous-chelate compound by atmospheric oxygen. A trickling filter-type oxidation column was an acrylic pipe with 30 mm in diameter and 500 mm in height, in which cylindrical high density polyethylene carriers with 5 mm in diameter and 5 mm in height were packed. The bulk volume of the filter bed was 314 cm³. We calculated oxidation rates by measured absorbance of iron-chelate solutions.

2.2.2 MFC operation

Figure 1 illustrates the experimental set up of MFC. The cathodic flow cell had a spacer made of polyvinyl chloride, which was sandwiched between a pair of carbon cloths (Torayca CO 6151 B, Toray, Japan) as cathodes. The outside of each carbon cloth adhered to a cation-exchange membrane (Nafion N 117, DuPont, USA) and the other side of the cation-exchange membrane adhered to a carbon cloth as an anode. The effective electrode area was 200 cm² for both cathodes and anodes. The wastewater in a sanitary chamber in Ryukoku University was pumped up to a sedimentation tank. The hydraulic retention time was 8 h. The three sets of MFCs were prepared for the experimental runs. The one of them was a control and received a tap water as the catholyte. The rest of them received the catholyte containing 5 or 10 mM of ferric-EDTA chelates. The catholyte pH was regulated to pH 7 by addition of sul-

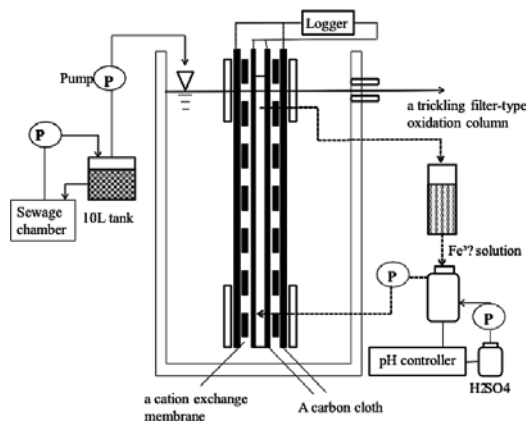


Fig. 1 The experimental setup

furic acid using a pH controller (FD-02, TKG, Japan). The hydraulic loading of a trickling filter-type oxidation column was $6.6\text{--}6.9\text{ m}^3\text{ m}^{-3}\text{ d}^{-1}$. The ferric-EDTA chelates were prepared by mixing an adequate amount of ferric nitrate and EDTA.

2.3 Results and Discussion

2.3.1 Oxidation characteristics of ferrous-chelate

The observed oxidation rate of ferrous-chelate strongly depended on the chelating agent used, namely the highest in EDTA (date not shown). The oxidation efficiency can be approximated to a constant in the range of hydraulic loadings less than $10\text{ m}^3\text{ m}^{-3}\text{ d}^{-1}$.

2.3.2 Applicability of EDTA as a ligand of iron for MFC

Figure 2 shows changes in the generated currents over time. As can be seen from this figure, the generated current was enhanced using the ferric-EDTA chelate solution as a catholyte. When tap water was used as a catholyte, dissolved oxygen played the electron acceptor. The solubility of oxygen to water is

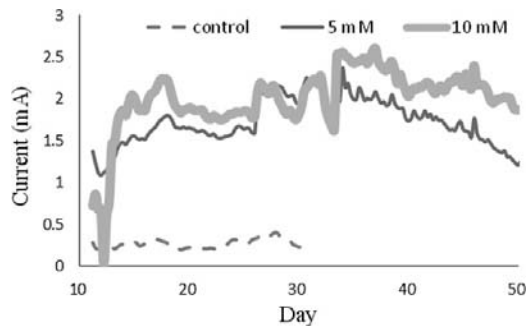


Fig. 2 Changes in generated currents during the MFC operations. Ferric-EDTA chelates (5 or 10 mM) were used as catholytes. In the control a tap water substituted for the ferric-EDTA chelate solution.

0.266 mM at 25°C . In this research 5 or 10 mM of ferric-EDTA chelate solution was used as the catholyte. Therefore, the equivalent density of electron acceptor of the ferric-EDTA chelate solution was 4.7-9.4-times higher than that of the oxygen-saturated water. Consequently, it was considered to promote the cathodic reaction and to enhance the generated current. However, dissolved COD_{cr} removal efficiencies were $71.3 \pm 11.4\%$ (average \pm sample standard deviation) for the 5 mM ferric-EDTA chelate solution, $67.0 \pm 11.3\%$ for the 10 mM ferric-EDTA chelate solution, and $67.0 \pm 11.8\%$ for the control. There was no significant difference of the three. It was indicated that anaerobic bacteria except exoelectrogenic bacteria were responsible for the organic removal in this system.

3. Acknowledgement

Advice and comments given by Prof. N. Kishimoto have been grateful in this research. I would like to show my greatest appreciation to him.