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Removal and recovery of phosphorus as struvite from swine wastewater using microbial fuel cell

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ABSTRACT

Air–cathode single chamber microbial fuel cells (MFCs) were operated with swine wastewater. The maximum power density, the maximum current density, the average value of COD-removal efficiency, and the coulombic efficiency were 1–2.3 W/m^2, 6.0–7.0 A/m^2, 76–91%, and 37–47%, respectively. During operation, 70–82% of the phosphorus was removed from the influent, and some precipitations were observed on the surface of the liquid side of the cathodes. The amount of phosphorus contained in these precipitates was estimated to be equivalent 4.6–27% of the influent. The main component of these precipitates was revealed by X-ray diffraction analysis to be struvite. Furthermore, our results indicate that phosphorus in suspended solid form was first dissolved, and then precipitated on the cathode. By scanning electron microscope observation, the morphology of the precipitates was irregularly shaped, including crystals with hexagonal cross-section surfaces, and was different from the familiar needle-like ones. These results indicate that simultaneous recovery of electrical power and phosphorus from wastewater by microbial fuel cell is possible.

1. Introduction

Microbial fuel cell (MFC) has attracted attention recently as a promising technology for the simultaneous treatment of wastewater and recovery of electricity. MFC can produce electricity from organic matter in wastewater with the aid of the catalytic reaction of electrogenic microorganisms (Kim et al., 1999, 2002; Bond and Lovley, 2003). In regard to the application for wastewater treatment, advanced treatment such as phosphorus removal is important. Generally, both domestic and animal wastewaters contain high levels of phosphorus, which can lead to eutrophication of aquatic plants in the receiving water environment (Seviour et al., 2003).

Furthermore, wastewater is one of the potential recovery sources of phosphorus (Shu et al., 2006; Suzuki et al., 2007). Phosphorus is a limiting plant nutrient, and the addition of phosphate-based fertilizers to soil is necessary to increase agricultural yields. It has been suggested that the remaining accessible reserves of clean phosphate rock will be depleted within 50 years (Gilbert, 2009). There are currently no substitutes for phosphorus, and its depletion may lead to a decrease in food-production capacity. Therefore, the recovery of phosphorus from wastewater has become an important issue worldwide. Struvite crystallization is a promising method for phosphorus recovery from wastewater (Nelson et al., 2003). Struvite is a crystal of magnesium ammonium phosphate (MAP) with equal molar concentrations of Mg, ammonium (NH_4), and P combined with six water molecules ($MgNH_4PO_4{\cdot}6H_2O$). Since the solubility of struvite decreases with increasing pH (Doyle and Parsons, 2002), it can be recovered under alkaline conditions. However, struvite crystallization is costly, due mainly to the chemicals that are required for pH adjustment (Jaffer et al., 2002).

As for phosphorus removal and recovery by MFCs, only a few studies have been reported, in spite of its importance. Fischer et al. (2011) suggested that MFC technology could enable phosphate recovery from digested sewage sludge. However, in this method, MFC was used only to release orthophosphate from iron phosphate. A subsequent addition of magnesium and ammonium, as well as pH adjustment outside of the MFC, was needed for phosphorus recovery. Recently, we observed a large amount of precipitate containing highly concentrated phosphorus on the surface of the liquid side of the cathode when the air–cathode MFC was operated with swine wastewater (Hirooka et al., 2011; Ichihashi et al., 2012). Since the precipitate also contained a high concentration of magnesium (Mg), we hypothesized that phosphate is removed as struvite because the pH near the cathode was higher than at the other site in the reactor. This hypothesis is consistent with the concept that there is a local pH increase near the cathode (Zhao et al., 2006), where water is being consumed and hydroxide is generated as a byproduct (Fornero et al., 2010).

Based on these results and considerations, we indicated the possibility that phosphorus can be removed and recovered from

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