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# Application of microbial fuel cell for the monitoring and control of sulfur-related odor generation

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***Abstract*— A single-chamber microbial fuel cell (MFC) was employed to assess the feasibility as a sulfur-related odor monitoring and control system. Immediately after the system started, electricity generation increased up to a maximum level of 4.4 mV. After the first 8 days, the oxidation-reduction potential at the surface of anode was maintained around -100 mV. Sulfate level decreased during this period while no significant variation was observed. Such phenomena were attributable to the oxidation of sulfide compounds microbially reduced from sulfate on the anode surface, resulting in enhancement in the electron transfer. This also stimulated the additional increases in electricity generation. The results presented in this study should be useful for the development of an MFC-based device to monitor and control the odor generating compounds from the urban sewage system as well as of the future ubiquitous city technologies.**

***Keywords-odor monitoring; microbial fuel cell; sulfide related odor compounds***

## I. INTRODUCTION

Volatile sulfur-related compounds (VSCs) are the representative malodorous substances easily found in the urban sewage system. Sulfate commonly present in most wastewaters is reduced to sulfide, a representative odorous substance, by sulfate-reducing microorganisms under anaerobic and reduced conditions, which can create the environment in which other types of strong odor generating organic VSCs as well [1, 2].

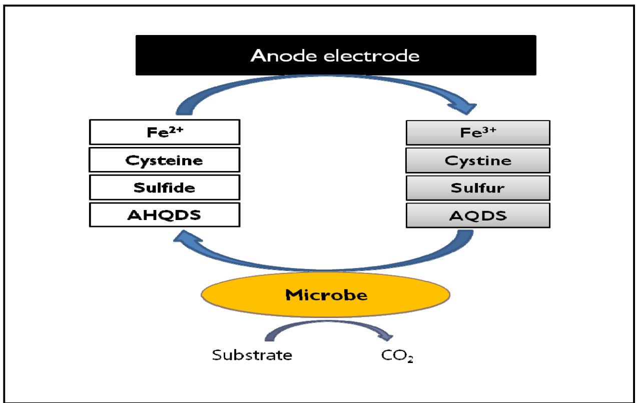


Figure 1. Electron shuttles in the MFC system [5].

Microbial fuel cell (MFC) is a device that can generate electricity from organic and inorganic substances in the anode by microbial metabolism [3-5]. Mediators including sulfide and ferrous ions play an important role in electron transport for the biologically catalyzed electricity generation [4]. They shuttle electrons between anode and bacteria transferring the electrons. Fig. 1 illustrates the overall process for various compounds used as electron shuttles in the MFC system [5]. Each of these compounds has a different potential that possesses in the oxidation-reduction reaction, and their differences result in differences in generated electricity. The difference in the chance of contact between electron shuttles and anode electrode can also cause the variation in electricity generation. In other words, the higher the concentrations of electron shuttles in the anode phase, the more the electricity generation [6]. Upon the phenomena, electricity generated in the MFC system can be used as a signal of the rate of sulfide generation as well as odor generation monitoring. In this study, lab-scale single-chamber MFC was employed to evaluate the applicability of MFC as a sulfur-related odor monitoring and control system in the urban sewage system.

## II. METHODS

### *A. Synthetic wastewater and sediment*

A composting soil that contained a high amount of humus materials (organic matter ~ 60.6% by weight) was used as a synthetic underlying sediment in this study. A synthetic wastewater of which composition was quite similar to that of typical urban household wastewaters was prepared with the amendment of $Na_2SO_4$ (100mg/L as sulfate).

### *B. MFC reactor*

A cylindrical shape and single-chamber MFC reactor (inner diameter of 100 mm and height of 240 mm) was made on a lab-scale using acryl plastic. Each volume of water phase (synthetic wastewater described above) and sediment phase (synthetic sediment soil described above) was 0.785 L, respectively. Graphite felt was used as cathode (3 mm × 70 mm × 60 mm, thickness × L × W) and anode (3 mm × 180 mm × 50 mm) electrodes, respectively. Anode was buried 2 cm below the water-sediment interface and cathode was placed 5 cm above the interface. Anode and cathode were connected with a platinum wire and electrically insulated copper wire through a resistance (10 Ω). Circuit voltage was measured using a digital multimeter (2700, Keithley Instrument Inc., Cleveland, OH, USA).

## III. RESULTS AND DISCUSSION

### A. *Electricity generation*

Fig. 2 presents the electricity generation from the beginning of MFC operation. Electricity generation began immediately after the system run and the circuit voltage increased in the first 3 days and then leveled off. After 6 days, the circuit voltage dropped dramatically to the level lower than 1.5 mV. After 7 days, the circuit voltage increased sharply to a maximum level of 4.4 mV. This result demonstrated that electricity can be generated using organic compounds contained in the urban sewage sediment as a substrate without inoculation of specific electrically catalyzing microbes, and thus, MFC can be applied to the urban sewage system directly without additional devices or special handlings.

### B. *Sulfate behavior*

Variation in the sulfate concentration in the MFC reactor was monitored as depicted in Fig. 3. Sulfate concentration remained constant over the first 8 days. This indicated that sulfate-reducing microbes were inhibited to reduce sulfate to sulfide. This may have been attributed either to the oxygen that was received when water and sediment were placed in the reactor initially and remained or to the increased redox potential stimulated by iron-reducing microbes that played an important role in generating electricity as observed in the relevant previous studies [7].

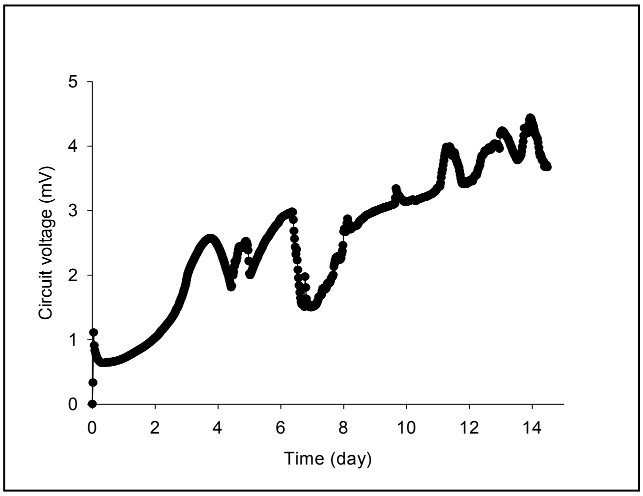


Figure 2. Electricity generation.

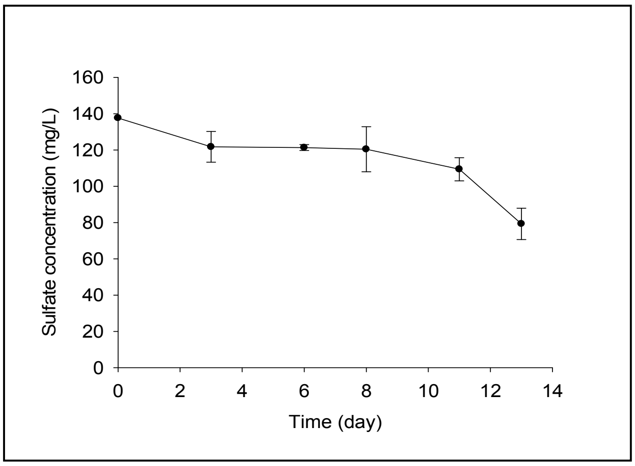


Figure 3. Sulfate behavior.

### C. *Oxidation-Rediction potential*

Fig. 4 shows the behaviors of oxidation-reduction potentials (ORP) in the water phase and at the anode surface of sediment. Over the entire period of reactor run, ORP value for the water phase was ranging between 400 and 450 mV (vs. standard hydrogen electrode, SHE). On the other hand, ORP at the surface of anode was maintained at the level higher than -30 mV (vs. SHE) over the first 8 days and then dropped to the level slightly lower than -100 mV (vs. SHE). Ryckelynck et. al. [8] reported that sulfide was oxidized to elemental sulfur and ORP value ranged from -100 to -150 mV at the anode surface. Likewise, electricity generation observed after 8 days in this study appeared to result from the electrochemical oxidation of sulfide which could have been produced by sulfate-reducing bacteria.

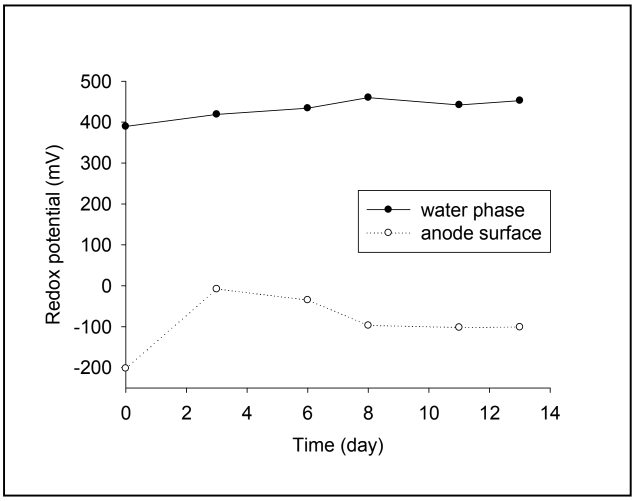


Figure 4. Oxidation and reduction potentials.

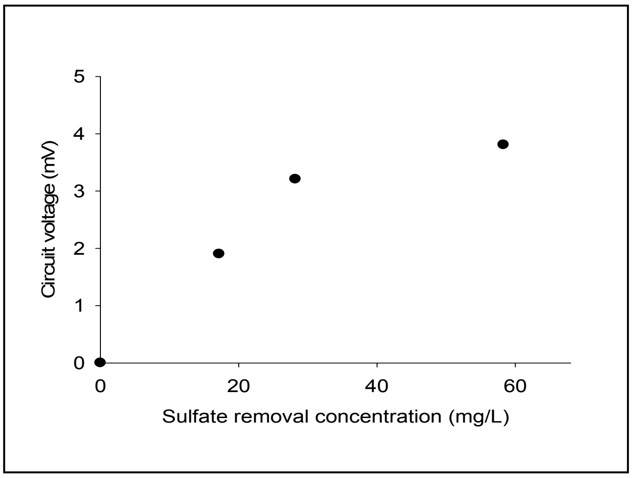


Figure 5. Relationship between sulfate removal and electricity generation.

### *D. Correlation between sulfate removal and electricity generation*

Fig. 5 demonstrates the correlation between sulfate removal and electricity generation under the assumption that after 8 days the electricity was generated electrochemically by the oxidation of sulfide. It was, in fact, very difficult to measure sulfide produced from the sediment because it can rapidly change to hydrogen sulfide gas or other sulfur compounds [9]. Therefore, it was assumed that all sulfate removed was reduced to sulfide and the concentration of sulfate removed was used instead of sulfide concentration. It was observed, then, that the concentration of sulfate removed was proportionate to the increase in circuit voltage in the concentration range of 0 - 30 mg/L. When the concentration was 58 mg/L, the increasing rate of circuit voltage decreased. This was because the electricity generation reached a point where no more significant electricity generation was enhanced. These correlations indicated that the electricity generation in the MFC system can be used as a signal of sulfur-related odor generation potential or control in the urban sewage system.

## IV. CONCLUSIONS

This research aimed at evaluating the feasibility of electricity generation as a signal of sulfur-related odor potential or control using a single-chamber MFC system. The ORP value for the anode phase (sediment phase) was maintained at a level of -100 mV. Sulfide concentration was proportional to the increase in circuit voltage. Such phenomena are useful for developing an MFC-based odor-monitoring device for the urban sewage system including manholes, rainwater collectors, wastewater channels, etc. In addition, the results of this study are expected to shed a light on the attempt to develop future city technologies and design strategies for the ubiquitous cities in Korea.

## ACKNOWLEDGMENTS

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