Nitrate Reduction in a Dual Chamber Microbial Fuel Cell

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Abstract: In this study, the potential of a using a two chamber microbial fuel cell to treat nitrates in the cathode chamber of a dual chambered microbial fuel cell without aeration and denitrifying bacteria was studied. The experiment was successful with a nitrate removal rate of 0.263 mg/L/day.

1. Introduction: Nitrates contamination is a major problem worldwide. When nitrogen from fertilizers or animal manure are decomposed, they are converted into nitrates which are beneficial for the soil and agriculture industry in small amounts but an excess of nitrates in soil result in their leaching into the ground contaminating ground water and surface waters (WRIG). Excess of nitrates in water causes health problems in humans; especially concerning is "Methemoglobinemia" (also known as the "blue baby syndrome") in infants (Horold, 1993). Excess nitrates in the environment cause eutrophication and anoxia, which hamper the growth of aquatic plants and animals (WRIG). In the US, main known sources of nitrate contamination are untreated or partially treated wastes from large scale agricultural industries and concentrated animal feeding operations. The census of Agriculture, 2007 indicated that Texas produced 699,431,000 kg of Nitrogen (highest of all states) or 1325 kg of Nitrogen per square kilometer of farm land (ranked 37) from animal manure alone. The national average being, 123,496 thousand kg of Nitrogen per state or 2217 kg of Nitrogen per square kilometer of farm land (Nutrient Policy Data, EPA). The EPA has regulated the concentration of nitrates-nitrogen in drinking water to be no more than 10 ppm or 10 mg/L. Nitrates have been treated conventionally in packed bed bioreactors, membrane bioreactors or by ion-exchange, reverse osmosis, or electro-reduction. The common element in these operations is the extent of power required to run these operations. The Microbial Fuel Cell is an innovative waste treatment technology which produces power when the carbonaceous waste material is being degraded by microbial metabolism. This power can then be utilized to treat wastes in the other cell of the system, which makes the system beneficial twice over and sustainable. The power production in the MFC is dependent on a variety of factors like the use of catalysts like a buffer solution (Kim, 2007), the bacterial strain used and many more. The nitrate removal efficiency also depends upon the pH of the nitrate solution. More acidic the solution, the higher the (removal) activity (Horold et al., 1993).

2. Objectives: The main objective of this study was to investigate the potential of nitrate as the oxidant in the cathode chamber of a microbial fuel cell without the catalytic properties of aeration and denitrifying bacteria.

3. Materials and Methods: For the treatment, the setup included two cell H type microbial fuel cell system connected internally through a cation exchange membrane and externally through carbon fiber brush electrodes. The working volume was 500 mL for both chambers. The anodic solution consisted of 500 ML of bacterial growth medium (1.33 g/L $K_2HPO_4.3H_2O$, 0.5 g/L KH_2PO_4, 0.5 g/L $MgSO_4$, 0.1 g/L KCl, 2 g/L $NaNO_3$, 0.5 g/L yeast extract), 2% used vegetable oil as substrate and 25 mL of bacterial inoculation solution. 2% of used vegetable oil was further added to the system after 3 days. The cathodic solution consisted of 500 mL of 20 mg/L of KNO_3 solution. The power production was measured across a 1000 ohm resistor. The nitrate degradation was monitored using the absorbance data at 220.1 nm obtained from a UV Spectrometer analyzed against a nitrate calibration curve previously obtained. The pH, ORP, Resistivity and conductivity of the solution was continuously monitored. The experiment was run for 10 days. The reactions expected are as follows;

Anodic Reaction: $C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^-$

Cathodic Reaction: $2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_20$ (Feng, 2011). The setup is shown in Fig. 1.

4. Results and Discussion: The Voltage vs. Time relationship shown in Fig. 3 shows that the power production was 3X10^{-3} mW/m^3 at the 45th hour. The Concentration vs. Time relationship shown in Fig. 2 indicates a linear decrease in nitrate concentration by 13.4% over the ten days, the rate of removal being 0.263 mg/L/day.

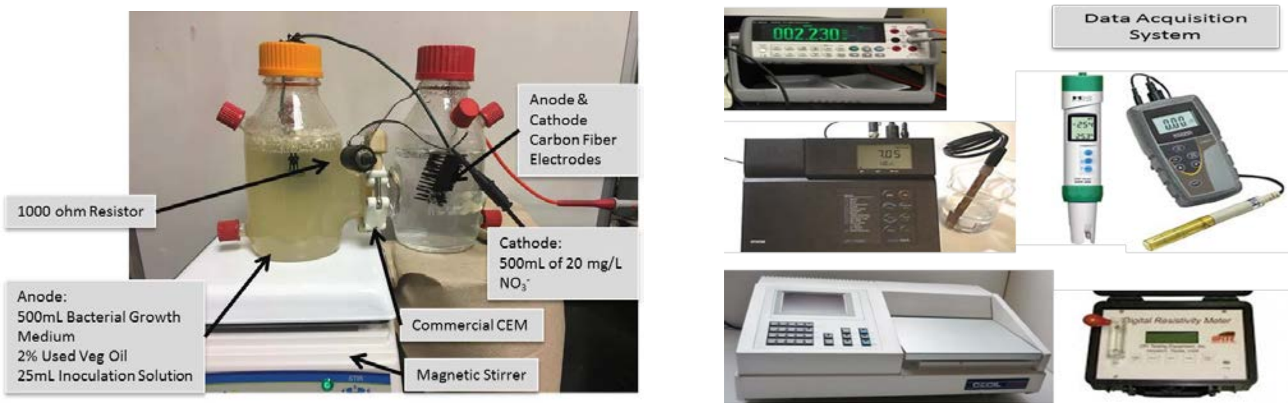

Figure 1. Experimental Setup

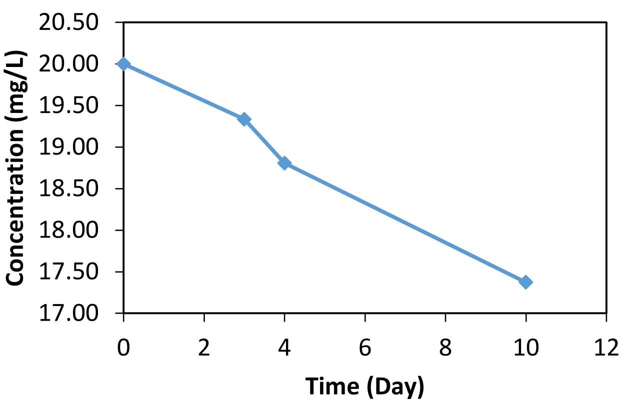

Figure 2. Nitrate concentration in cathode over time

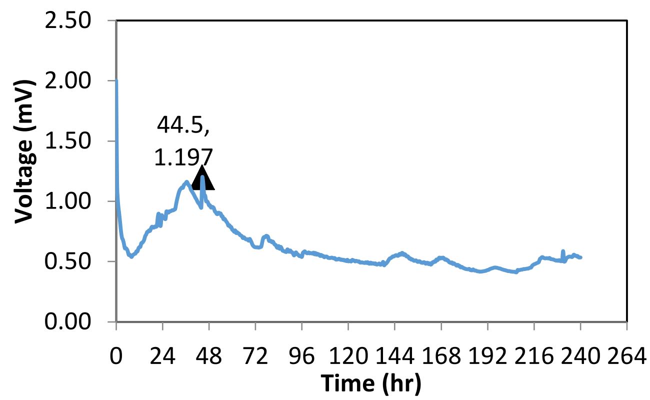

Figure 3. Voltage generated during microbial decomposition

5. Conclusions: The study showed that nitrate in the cathode chamber was removed at a rate of 0.263 mg/L/day using a microbial fuel cell without aeration or denitrifying bacteria.

6. Acknowledgements: This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) and Texas Hurricane Center for Innovative Technology (THC-IT), University of Houston, Houston with funding from Texas Hazardous Waste Research Center.

7. References

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