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SUBMERSIBLE MICROBIAL FUEL CELL-BASED BIOSENSOR FOR IN SITU BOD MONITORING

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ABSTRACT
A biological oxygen demand (BOD) biosensor based on the microbial fuel cell (MFC) technology was tested for online and in situ monitoring of biodegradable organic content of domestic wastewater. A stable current density of 282±23 mA/m^2 was obtained with domestic wastewater containing a BOD_5 of 317±15 mg O_2/L at 22±2 °C, 1.53±0.04 mS/cm and pH 6.9±0.1. The current density showed a linear relationship with BOD_5 concentration ranging from 17±0.5 mg O_2/L to 78±7.6 mg O_2/L. The current generation from the SMFC biosensor was dependent on the measurement conditions such as temperature, conductivity, and pH. These results provide useful information for the development of a biosensor for real-time in situ monitoring of wastewater quality.

INTRODUCTION

The BOD_5 may be the most used test to assess the amount of pollutant organic matter in water, however, is time and labour consuming, and is done ex-situ.
A recent online biosensor to quantify BOD was developed using the MFC concept (Kim et al. 2003). The usual configuration was a mediator-less MFC, with two chambers separated by a cation exchange membrane and continuous wastewater flow (Gil et al. 2003, Kim et al. 2003, Kang et al. 2003, Chang et al 2004, 2005, Moon et al. 2004, 2005). This configuration is complex and the setup is not suitable for in situ applications. Recently, a very compact MFC configuration, known as submersible microbial fuel cell (SMFC), was developed by Min and Angelidaki (2008). The aim of the present study was adapt and test the SMFC configuration as an in situ BOD_5 biosensor.

MATERIAL AND METHODS

Biofilm formation

A biosensor was operated at room temperature (22 ± 2 ºC) during 3 weeks to biofilm formation in the anodic surface. The biosensor was immersed into 1 L of domestic wastewater contained in a glass vessel tightly and anaerobically closed. The cathode chamber was continuously flushed with air (5 mL/min).

Effect of BOD_5 concentration and environmental parameters on current density

Five wastewater dilutions were prepared with tap water (17±0.5 mg O_2/L - 183±4.6 mg O_2/L) and tested until the maximum current density peak. The maximum voltage (U) was measured 2 times consecutively for each concentration across a fixed resistance (R) equal to 1 kΩ. Temperature, pH and conductivity (σ) were tested independently using a diluted domestic wastewater (143.5±8.7 mg O_2/L, 1.1±0.012 mS/cm and pH 6.5±0.2). T tested varied from 11±0.2 °C to 33±0.3 °C. The wastewater pH was adjusted in the range of 6.0±0.1 to 8.5±0.1. The wastewater σ varied between 1.1±0.012 mS/cm and 13.4±0.013 mS/cm.

Analytical methods and calculations

The organic content of wastewater was assessed both as chemical oxygen demand (COD), and BOD_5, as described in Standard Methods. A correlation between BOD_5 and COD was experimentally determined. Then, the polarization curve (U versus current density (j)) and the power curve (power density (P) versus j) were recorded using a series of R in the range of 22 kΩ to 100 Ω. The current intensity (i) and density (j) were calculated according to the Ohm´s law.

RESULTS AND DISCUSSION

Biofilm formation

After a period of 3 weeks, the SMFC operated with domestic wastewater (317±15 mg O_2/L of BOD_5) was stabilized at a maximum value of 0.27 mA (282±23 mA/m^2).

Performance of SMFC-type BOD_5 biosensor

The open circuit voltage measured in the stable phase of current generation (wastewater = 298.2±4.2 mg O_2/L of BOD_5) was 414±6 mV. The shape of the polarization curve (data not shown) confirmed the prevalence of ohmic losses generated by the resistence of membrane, electrolyte of the wastewater and, bacterial metabolism. The maximum P obtained in the power curve (data not shown) was 72 mW/m^2, which is equivalent to a j = 283 mA/m^2 (1 kΩ). These values are in agreement with the obtained in stable phase of the SMFC operation (1 kΩ).

Current generation at various BOD_5 concentrations

With the different diluted wastewaters (Figure 1), the current density increased linearly with BOD_5 up to a concentration of 78±8 mg O_2/L (j = 2.68 i – 18.78 with r^2 = 0.996). The range of BOD_5 concentration that we could measure by the SMFC are in agreement by those published in literature (Gil et al. 2003, Kim et al. 2003, Chang et al 2004, Moon et al. 2004, Kim et al. 2006). The response time for a BOD_5 concentration of 17±1 mg O_2/L was shorter than 30 min, however, about 10 h were needed for concentrations higher than 78±8 mg O_2/L. The response time in some studies was quite low (Chang et al. 2004, Moon et al. 2004, Moon et al. 2005), probably due to the continuously mode of operation of the biosensor.

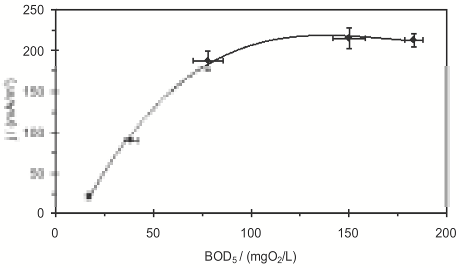

Figure 1: Current density (j) generated in the SMFC as a function of initial BOD_5 concentration of wastewater.

Effect of environmental conditions

The effect of changes in environmental parameters in the performance of the biosensor was assessed using domestic wastewater with a BOD_5 of 144±9 mg O_2/L (Figure 2).

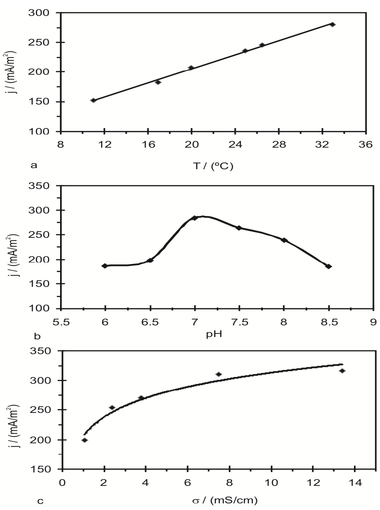

Figure 2: Effect of temperature (T) (a), pH (b) and, conductivity (σ) (c) on current density (i) generation.

The j increased linearly with T (Figure 2a), about 6 mA/(m^2 ºC). The maximum j (288.33 mA/m^2) was obtained at pH 7.0, while the minimum j correspond to pH interval 6±0.1 - 6.5±0.1 and to pH 8±0.1 with respectively 185.55 mA/m^2 and 184.44 mA/m^2 (Figure 2b). These results are consistent with literature studies regardless of MFC configuration and substrates (Gil et al. 2003). The j increased with the σ of domestic wastewater in the range of 1.1±0.012 mS/cm to 7.51±0.01 mS/cm, from 199 mA/m^2 to 316 mA/m^2, respectively, the effect being more important between 1.1±0.012 and 2.1±0.013 mS/cm (Figure 2c). These results suggested that a correction factor should be applied to measurements done under other environmental conditions.

CONCLUSIONS

BOD_5 values of up to 78±8 mg O_2/L could be measured based on a linear relation. pH and Temperature influenced the current densities. The optimum pH was 7. The advantage of the SMFC is that no special anaerobic chamber (anode chamber) is needed because the sensor might be directly submerged in a wastewater channel or anaerobic reactor.

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