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Forming microbial anodes under delayed polarisation modifies the electron transfer network and decreases the polarisation time required

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ABSTRACT

Microbial anodes were formed from compost leachate on carbon cloth electrodes. The biofilms formed at the surface of electrodes kept at open circuit contained microorganisms that switched their metabolism towards electrode respiration in response to a few minutes of polarisation. When polarisation at −0.2 V/SCE (+0.04 V/SHE) was applied to a pre-established biofilm formed at open circuit (delayed polarisation), the bacteria developed an extracellular electron transport network that showed multiple redox systems, reaching 9.4 A/m^2 after only 3–9 days of polarisation. In contrast, when polarisation was applied from the beginning, bacteria developed a well-tuned extracellular electron transfer network concomitantly with their growth, but 36 days of polarisation were required to get current of the same order (6–8 A/m^2). The difference in performance was attributed to the thinner, more heterogeneous structure of the biofilms obtained by delayed polarisation compared to the thick uniform structure obtained by full polarisation.

1. Introduction

Electro-active (EA) biofilms have been widely exploited to design microbial fuel cells (MFCs) (Lefebvre et al., 2011; Logan, 2010) microbial electrolysis cells (Geelhoed et al., 2010; Logan et al., 2008) and other related technologies. Numerous studies have identified EA bacteria (Logan, 2009) and deciphered the different electron transfer pathways that can be used inside microbial biofilms (Rabaey et al., 2007; Reguera et al., 2005; Schaetzle et al., 2008). In contrast, the mechanisms of formation, structuring and ageing of the EA biofilms have rarely been investigated. Wang et al. (2009) have observed that the start-up time of an MFC was significantly decreased when a constant potential was applied to the anode, in comparison with the same MFC implemented without applied potential. They postulated that the applied potential increased the positive charge on the anode surface and thus favoured the primary adhesion of negatively charged bacteria. The adhesion of EA species on anodes might consequently depend on the surface charge of the electrode as it has sometimes been suggested (Busalmen et al., 2008; Cheng and Logan, 2007). In contrast, Aelterman et al. (2008) did not observe significant difference in start-up time with applied potentials in the range from −0.4 to 0 V vs. Ag/AgCl. Actually Wang et al. (2009) have inoculated their MFCs with domestic wastewater, while Aelterman et al. (2008) have taken their inoculum from an operating MFC, which means that the microbial community was already adapted to generating electricity. Comparing the two studies suggests that the time necessary for wild microbial communities to adapt to electrochemical conditions depends on the applied potential, while the time necessary for already-adapted bacteria to form EA biofilms does not. When using wild communities as inoculum, the adaptation phase necessary for the cells to develop their EA capacity may consequently be an essential parameter in controlling the formation of EA biofilms, rather than electrostatic interactions between bacteria and electrode surface. The occurrence of an initial phase during which the cells must optimize attachment or the electron transfer chain to the surface has also been observed with pure cultures of *Geobacter sulfurreducens* (Marsili et al., 2010). Nevertheless, little is known so far about the way a clean electrode surface catches microbial species from a natural environment and how they shift from the conventional respiration mechanism to an anode respiring mechanism.

The purpose of this work was to give some insights into EA biofilm construction with the practical target of improving the performance of microbial anodes. Garden compost was used as the source of the inoculum. Soils are a very rich source of microorganisms (Liu et al., 2006; Torsvik et al., 1996) and garden compost has proved its excellent capacity to form EA biofilms. Microbial anodes can be formed by simply embedding polarised electrodes in a soil (Parot et al., 2008), but it is then difficult to use the resulting anodes out of their initial medium. A new procedure has been proposed recently, which consists of producing a leachate by percolating the garden compost with an ionic solution and then using the

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