The effect of sodium chloride and sodium bicarbonate derived anolytes, and anolyte-catholyte combination on biofilms

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Abstract

Microbial biofilms are problematic in industrial environments where large areas of submerged surfaces are exposed to relatively high nutrient fluxes, providing niches for the formation of copious surface-associated growth. Biofilms growing in drinking water distribution pipes cause deterioration in the microbiological quality of water contributing to the occurrence of water-borne diseases. Many bacteria are resistant to moderate levels of biocides, with bacteria in biofilms being the most difficult to control. Electrochemical activation (ECA) technology provides an alternative way of controlling these micro-organisms. The main objective of this study was to evaluate an electrochemically activated solution, anolyte, as an environmentally safe disinfectant for the control of biofilms. Biofilms were grown using the Pederson device and then exposed to different concentrations of the biocide. Light microscopy and scanning electron microscopy were used to view the effect of treatment on the biofilm structure. Re-growth of the biofilm after treatment with anolyte was detected through epifluorescence microscopy after DAPI staining of the coupons. Neat (undiluted) and mildly dilute anolyte removed the biofilm while the more dilute anolyte did not have any effect on the biofilm. Re-growth of the biofilm occurred after 24 h of biofilm treatment with anolyte and anolyte-catholyte combination, showed by the increase in colony forming units. Re-growth of planktonic bacteria however, occurred only after 72 h of treatment.

Keywords: Biofilms, electrochemical activation, anolyte, catholyte

Introduction

Microbial biofilms are problematic in a range of industrial environments where large areas of submerged surfaces are exposed to relatively high nutrient fluxes, providing niches for the formation of copious surface-associated growth (Cloete et al., 1992; Costerton et al., 1994; Videla, 2002). Bacterial colonisation of surfaces in an aqueous environment is a basic strategy for survival in nature as nutrients are more available at the solid-liquid interface (Hoppe, 1984; Lawrence et al., 1987). The resulting aggregates form micro-colonies which develop into biofilms (McCoy et al., 1981). These biofilms promote corrosion of ferrous and other metals by the concerted metabolic activity of a number of biofilm-associated bacterial types (McLeod et al., 1998), a process collectively termed microbially influenced corrosion (MIC). MIC comprises a number of specific mechanisms relating either directly or indirectly to the metabolic activity of a variety of micro-organisms, notably the action of sulphidogenic bacteria (Lee et al., 1995; Dawood and Brözel, 1998). Bacteria colonising the processing equipment in the food industry may be an important source of bacterial contamination, and studies have shown that both spoilage bacteria like *Pseudomonas* spp. (Hall-Stoodley and Stoodley, 2002) and pathogenic bacteria such as *Listeria monocytogens* may contaminate products directly from the processing environment (Bagge et al., 2001). As the costs attributable to MIC and biofouling are high, effective control of bacterial numbers in an industrial aqueous environment is essential.

A range of bactericidal substances, commonly termed biocides or micro-biocides are available, all of which are claimed by their producers to kill bacteria occurring in aqueous systems quantitatively (Russel and Chopra, 1990; Chen and Steward, 2000; Videla, 2002). Research has indicated that bacteria growing as biofilms are significantly more resistant to most antimicrobial agents known currently, so that methods for their control pose an ongoing challenge (Cloete et al., 1992; Costerton et al., 1994; Cochran et al., 2000; Russell, 2001; Gilbert et al., 2003; Ludensky, 2003; Vickery and Cossart, 2004). According to Gilbert et al. (2003), biocides are spectacular in their failure to control adherent biofilm communities, and developments to remedy the situation have been limited.

Large doses of biocide or antibiotics which are either detrimental to the environment or above toxic threshold, respectively, are required to eliminate biofilms (Gilbert et al., 2003). Very little information is available on the biodegradability of biocides in natural water systems. This makes biocides hazardous from an environmental point of view. Chlorine is the most widely used oxidising biocide (Norwood and Gilmour, 2000; Meyer, 2003); however, it has its limitations. An environmentally sensible alternative to chlorine and other commonly used biocides is needed.

Electrochemically activated water may provide such an alternative. Water of varying mineralisation is passed through an electrochemical cell, the specific design of which permits harnessing of two distinct and electrically opposite streams of activated water. Aside from its distinctive attributes, the negatively charged antioxidant solution (catholyte) can also be channelled back into the anode chamber, thereby modulating the quality of the positively charged oxidant solution (anolyte) that is produced. Without maintenance of the activated stage these diverse products degrade to the relaxed state of benign water and the anomalous attributes of the activated solutions such as altered conductivity and surface tension similarly revert to pre-activation status. However, the heightened electrical

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