Electrochemically Activated water as a non-polluting anti-fouling technology
Cloete, Eugene. (2002) Corrosion 2002, NACE International
Paper 02463.

Research has indicated the problem of microbial resistance to non-oxidising biocides. Very little information is available on the biodegradability of these compounds in natural water systems. This makes these compounds hazardous from an environmental point of view. Chlorine is the most widely used oxidizing biocide, with its own limitations.
An environmentally sensible alternative to Chlorine and other oxidising biocides is needed.
ECA – water of varying mineralisation in passed through an electrochemical cell, the specific design of which permits the 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 channeled back into the anode chamber, thereby modulating the quality of the positively charged oxidant solution (anolyte) that is produced.

Without maintenance of the activated state, 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 the pre-activation status. However the heightened electrical activity and altered physicochemical attributes of the solutions differ significantly from the benign state, but remain non-toxic to mammalian tissue and the environment. The antimicrobial activity of the current ECA technology has been confirmed in this study. Electrochemically Activated water (ECA) is less toxic, less volatile, easier to handle, compatible with other water treatment chemicals, effective against biofilms and generates no by-products compared to currently used biocides.

ELECTROCHEMICALLY ACTIVATED WATER AS A NON POLLUTING

BIOFILM CONTROL TECHNOLOGY

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1. INTRODUCTION

Bacterial colonization of surfaces in an aqueous environments is a basic strategy for survival in nature as nutrients are more available at the solid - liquid interface. The resulting aggregates form micro-colonies, which develop into biofilms. Bacterial biofilms have negative consequences in the food industry. A number of mitigation approaches are currently followed to prevent and/or to remove biofilms: (i) bacteria are chemically killed by application of bactericidal compounds, (ii) biofilms are dispersed by dispersants, (iii) biofilms are removed physically by a variety of processes and (iv) the biofilm structure is weakened by enzymes or chelants.

A range of bactericidal substances, are available, all of which are claimed by their agents to kill bacteria in aqueous systems quantitatively. However, different bacteria react differently to bactericides, either due to differing cell wall properties, or to other mechanisms of resistance, either inherent or inducible. A novel alternative biofilm control method was introduced recently in the form of electro chemical activation of water. The biocidal properties of anolyte and the ability of anolyte to remove biofilms will be discussed.

2. BIOCIDAL PROPERTIES OF ANOLYTE

During Electro Chemical Activation (ECA) of water, a dilute saline solution is "activated" by passing through a cylindrical electrolytic cell in which the anodic and cathodic chambers are separated by a permeable membrane. Two separate streams of activated water are produced: Anolyte with a pH range of 2-9 and an oxidation- reduction potential (ORP) of +400 mV to +1200 mV. Anolyte is an oxidizing agent due to a mixture of Free Radicals and has an antimicrobial effect.

As a result of anode electrochemical treatment surface tension somewhat decreases, electric conductivity rises, as does the content of dissolved chlorine and oxygen, concentration of hydrogen and nitrogen decreases, and water structure changes.

The bacterial cell membrane provides the osmotic barrier for the cell and catalyses the active transport of substances into that cell. Alternations in transmembrane potential caused by the action of electron donor or electron acceptor factors are associated with powerful electro-osmotic processes accompanied by water diffusion against ORP gradients, with resultant rupture of the membranes and outflow of the bacterial cell contents. The bacterial membrane itself has an electrical charge. The anions present in Anolyte act on this membrane. Anolyte can also disrupt other functions of the cell. Unlike "higher" organisms, single celled organisms such as bacteria obtain their energy sources form the environment immediately outside the cell. Small molecules are transported across the cell membrane via an electro-chemical gradient. Thus, any significant change in the ORP of the immediate environment has drastic consequences for the cell. Even if instantaneous death of the cell does not occur, all enzymatic functions in the membrane are affected and this will also result in loss of cell viability.

The biocidal activity of hypochlorous acid generated by the current ECA technology is 300 times more active than the sodium hypochlorite generated by earlier systems. Activated solutions have been conclusively shown to exceed chemically derived equivalents both in low dosage effectiveness as well as physico-chemical purity. This heightened biocidal capacity relative to traditional chemical solutions, permits the use of ECA solutions at lower dose rates, therein obviating the risk of intoxication and adverse environmental impact.

Anolyte gave a 100 % kill of all the test isolates at a concentration of 100 % and 10 % (Table 1). At a 1:20 dilution, variable kill percentages were obtained, ranging from 100 % - 31 % (Table 1). This indicated variable susceptibility of different bacteria to anolyte. This is not an uncommon phenomenon[11]. Many organisms are intrinsically more tolerant of antimicrobial substances, than others. Anolyte was more effective against the Gram positive bacterial strains at a 1:20 dilution giving a 100 % kill against all Gram positive strains excepting *S. faecalis*. *A calcoaceticus* (Gram negative) was also killed at a 1:20 dilution (Table 1).

Table 1: Percentage kill of bacterial strains at different anolyte (produced using 3 % NaCl) concentrations

		Anolyte concentration		
Bacterial strain	**Gram stain**	**100%**	**1:10**	**1:20**
Bacillus subtilis	+	100	100	78
Pseudomonas aeruginosa	-	100	100	87
Acinetobacter calcoaceticus	-	100	100	100
Lactobacillus brevis	+	100	100	100
Micrococcus luteus	+	100	100	100
Streptococcus feacalis	+	100	100	31
Pseudomonas fluorescens	-	100	100	66
Staphylococcus aureus	+	100	100	100
Pseudomonas alcaligenes	-	100	100	52
Pseudomonas medocina	-	100	100	88
Pseudomonas putida	-	100	100	90
Bacillus cereus	+	100	100	92
Micrococcus roseus	+	100	100	100
Pseudomonas stutzeri	–	100	100	57
Pseudomonas syringae	–	100	100	87

Biofilm removal study

A mature biofilm formed after 2 weeks (Fig 1a). Exposure of the biofilm to a 1:00 dilution of anolyte did not yield, any noticeable removal of the biofilm (Fig 1b). A 1:10

dilution and a neat solution of the anolyte resulted in the dispersion and removal of the biofilm after a 20 min exposure (Fig's 1c, and 1d).

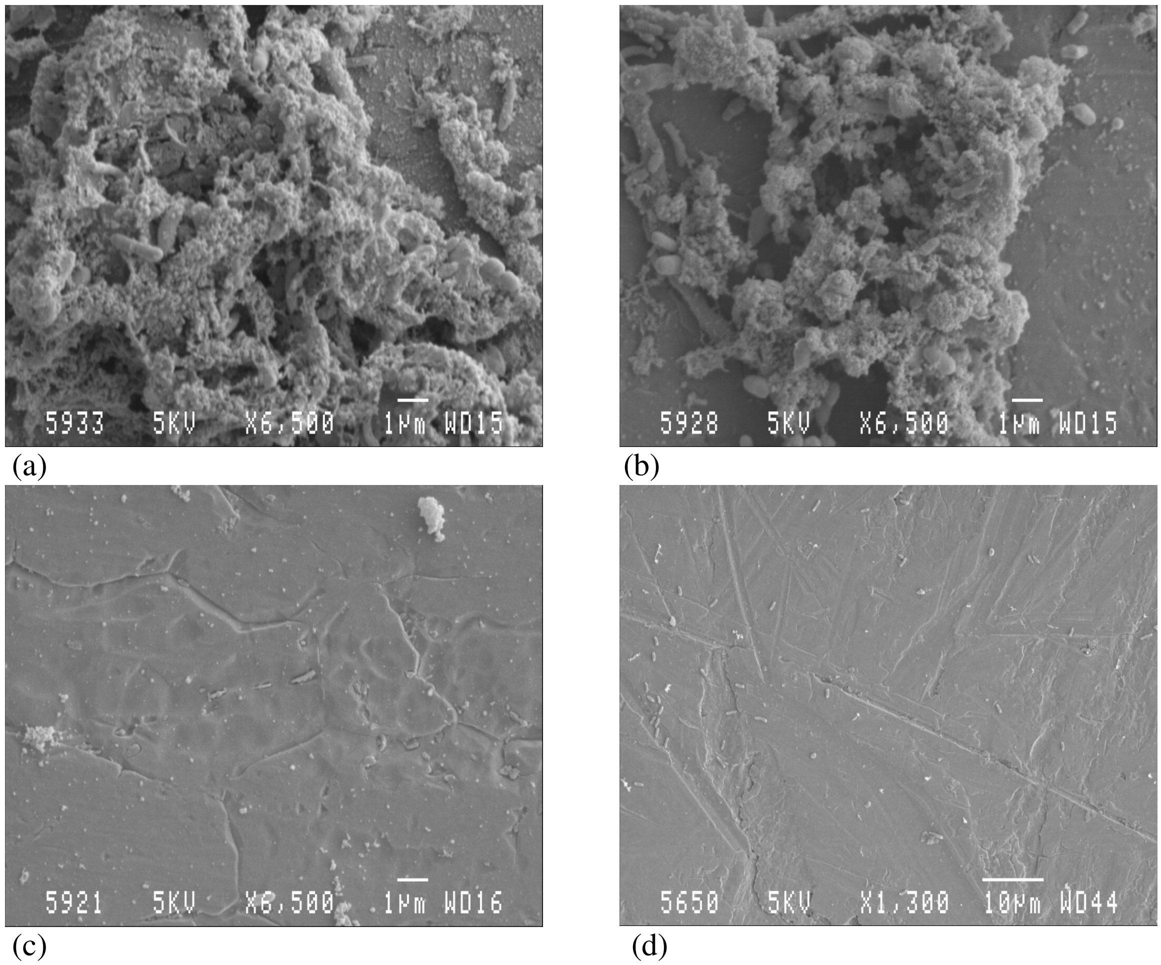

Figure 1. Biofilm control (a) and after treatment with 1:100 anolyte (b), 1:10 anolyte (c) and 100% anolyte (d).

3.CONCLUSIONS

The benefits of using ECA are in reducing environmental toxicity, reducing accident risk and in reducing chemical pollution. Since the product is produced on site, there are none of the risks normally associated with transport and storage of hazardous chemicals.

The anti-microbial activity of the current ECA technology has been confirmed in many studies. Electrochemically activated water (ECA) is effective against biofilms and generates no by-products.