USE OF BIOCIDES TO PREVENT THE MICROBIOLOGICALLY INDUCED CORROSION OF CARBON STEEL PIPES

- Short communication -

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Abstract

Microbiologically induced corrosion (MIC) is the corrosion resulting from the presence and activity of microorganisms, including bacteria and fungi. Many of the secondary circuit pipes of a CANDU nuclear power plant are made of carbon steel SA106gr.B. This material is susceptible to microbiological corrosion, which has major implications in the degradation of the carbon steel components. Water used in the cooling systems may contain microbial species which can promote corrosion because the water is often untreated or minimally treated against microbial load. The most common chemical method for controlling bio-corrosion in systems is the use of biocides. In this context, the paper presents the results obtained regarding the testing of the efficiency of ADIROL-ETA 75 biocide in the annihilation or the reduction of the corrosive action of the iron-oxidizing bacteria on some samples of carbon steel SA106gr.B. The tests were performed both in an inoculated medium with a culture of iron-oxidizing bacteria and in the same kind of cultures treated with biocide. The efficiency of the biocide was studied by electrochemical, metallographic and microbiological techniques. The corrosion products due to microbial activity were analysed by X-ray diffraction.

Keywords: *ADIROL-ETA 75 biocide, iron–oxidizing bacteria, microbiologically induced corrosion*

Introduction

Water used in the cooling systems may contain microbial species which can promote corrosion because the water is often untreated or minimally treated against the microbial load.

Counteracting MIC is difficult. System cleanliness is quoted as a desired remedy but it should be noted that deionised water systems are susceptible. Biocides are therefore a preferred recourse in many situations [1].

Experimental aspects

Materials: The tests were performed on a series of carbon steel samples (SA106gr.B), which were cutted as plates. Then the samples were polished using a wet emery paper and degreased in acetone.

The chemical composition of SA106gr.B is the following: C: 0.30 wt%; Mn: 0.29-1.06 wt%; P: max. 0.048 wt%; S: max 0.058 wt%; S: min 0.10 wt%.

Media: The samples were exposed 100 days at room temperature (25±5) ^{0}C in the following media:
- inoculated medium with iron–oxidizing bacteria (Gallionella) - $3.5x10^{10}$ bacterial cells/ml liquid - Vinogradski medium: NH_4NO_3-0.5g/l, $NaNO_3$-0.5 g/l, K_2HPO_4- 0.5g/l, $MgSO_4$-0.5g/l, $CaCl_2$-0.2g/;
- treated medium with ADIROL ETA 75 biocide.

The efficiency of the biocide in annihilation or reduction of the microbial corrosion of the carbon steel was emphasized using microbiological, electrochemical and metallographic techniques.

Results and discussions

Testing of antimicrobial effect at different concentrations of the biocide

Daily observations indicated an extremely high sensibility in the presence of the tested biocide of this bacteria group. The ADIROL ETA 75 biocide totally inhibited the growth of microorganisms, even at reduced concentration of 10ppm. The results are presented in Table 1.

Table 1. Testing of ADIROL ETA 75 biocide efficiency

Biocide concent. (ppm)	**The grown of the microorganisms after :**							
	48 h		96 h		144 h		192 h	
	S*	A**	S	A	S	A	S	A
50	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-
20		-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-
BLANK***	+	++	+++	++++	++++	++++	++++	++++

* incubation in stationary conditions;
** incubation in continuous stirring conditions (150rpm);
*** the blank contained iron oxidizing culture, untreated;
- indicates the absence of growth of bacteria;
+ to ++++ indicates the intensity of bacteria growth

Corrosion Potential

Due to its simplicity, open circuit corrosion potential measurements have been used in MIC studies. Corrosion potential measurements as a function of time have been used to obtain information on MIC in inoculated medium with bacteria and in treated medium with biocide, as presented in Fig. 1).

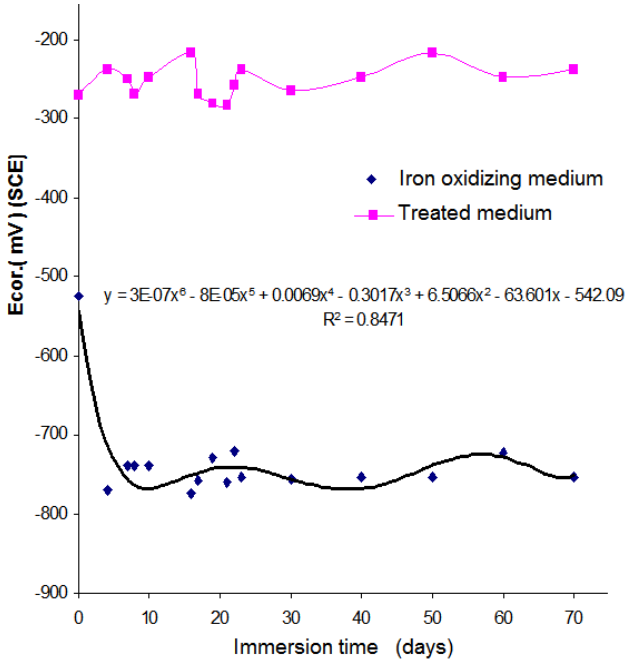


Fig.1. Variation in time of the corrosion potential

It was observed that in the culture treated with biocide the corrosion potential is maintained at about -270 mV, while in the medium with iron-oxidizing bacteria a displacement towards cathode is taking place (from - 525 mV to - 770 mV), after 4 days of immersion of the samples.

Potentiodynamic sweep techniques

The main parameters of the potentiodynamic (PD) measurements were, as follows:

- potential range: - 800 mV ÷ + 1200 mV
- potential sweep rate: 0.5 mV/sec
- temperature of the testing solutions: room temperature.

Tafel data, presented in Table 2, indicate a corrosion rate (v_{cor}) of approximately 15 times higher in untreated medium (13.74 mpy) comparatively with 0.85 mpy corresponding to the treated medium, after 100 days of immersion.

The different behaviour of the samples in the two media is also emphasized by the very low value of the polarization resistance (R_p) in the untreated inoculated medium (0.61 $K\Omega cm^2$) comparatively with the polarization resistance in the treated medium, 13.88 $K\Omega cm^2$).

This is determined by the fact that in untreated inoculated medium the samples were covered by a biofilm with a low polarization resistance, while the surfaces of the samples from the medium treated with biocide remained unchanged.

Table 2. The results of the potentiodynamic measurements in untreated iron-oxidizing medium and in treated medium

Media	Tafel slopes data				R_p data		
	E (I=0) [mV]	i_{cor} [$\mu A/cm^2$]	v_{cor} [mpy]	E (I=0) [mV]	R_p [$K\Omega\,cm^2$]	i_{cor} [$\mu A/cm^2$]	v_{cor} [mpy[
Untreated medium, t=0	-421	1.98	0.93	-424	16.74	3.48	1.63
Treated medium, t=0	-269	0.47	0.22	-272	16.18	0.34	0.42
Untreated medium, t=100 days	-563	29.4	13.74	-566	0.61	53.24	24.84
Treated medium, t=100 days	-325.5	0.314	0.39	-325.2	15.6	0.316	0.39

The aspect of the tested samples surfaces

The exposed samples in treated medium didn't presented any modification (see Fig.2), but on the surfaces of the exposed samples in untreated inoculated medium appeared the characteristics of a bacterial attack and some thick, brown and friable deposits developed (see Fig.3).

The thickness of the biofilms varied point by point along the surfaces achieving a variable covering of them.



Fig.2. The aspect of the exposed samples in treated medium with biocide



Fig. 3. The aspect of the exposed
samples in medium with iron- oxidizing bacteria

The metallographic technique highlights a pitting corrosion on the surface of the samples tested in inoculated medium, emphasizing the appearance of some wide enough pits (14µm - 95µm in depth) and which are distributed on all surfaces of the samples, as can be seen in Fig.4.

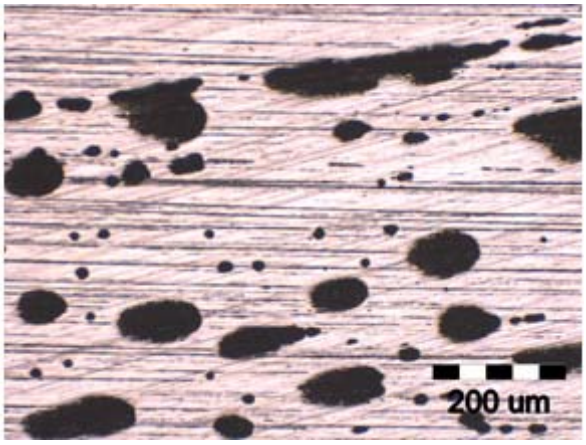


Fig. 4. The microscopic aspect of the surface exposed
sample in inoculated medium (x100)

X-ray diffraction analysis of the biofilm

In some points of the biofilm they were identified by X-ray diffraction, both corrosion products due microbial activity (Fe_2O_3), and compounds of the growth medium of the bacteria, such as $NaNO_3$.

Ref. Code	Compound Name	Chemical Formula
04-013-4761	Iron	Fe
04-015-9577	á-Fe2 O3	Fe2 O3
04-013-5433	â-Fe2 O3	Fe2 O3
01-076-9683	á-Fe1.766 O3, Hematite, syn	Fe1.766 O3
00-039-0238	â-Fe2 O3	Fe2 O3
00-034-0150	Rockbridgeite	Fe5 (P O4)3 (O H)5
04-003-5611	á-Fe	Fe
04-011-6874	Hydrogen Sodium Phosphate	H2 Na(P O4)
04-014-0701	Sodium Phosphate Hydrate	Na P O3 (H2 O)2
01-079-2056	Sodium Nitrate	Na N O3
04-010-7232	Potassium Phosphorus Oxide Hydrate	K3 P3 O6 (H2 O)4

Conclusions

The experimental results obtained demonstrate on one hand the role of iron-oxidizing bacteria in initiation of the corrosion of carbon steel and on the other hand the antimicrobial effect of the ADIROL ETA 75 against this group of microorganisms.

The tested product proved to be useful in the annihilation of iron-oxidizing bacteria even in low concentrations of 10-30 ppm, in testing conditions from the laboratory.

References

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