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BACTERIAL ADHERENCE ON A POLYMERIC COATING APPLIED ON CARBON STEEL

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AGENDA

- Introduction.
- Purpose.
- Experimental procedure.
- Experimental results.
- Summary and Conclusions.
- Future assessments.

INTRODUCTION

Microorganism-influenced corrosion (MIC) is the degradation of metallic and non-metallic materials due to the interaction among the material's surfaces and the biofilm.

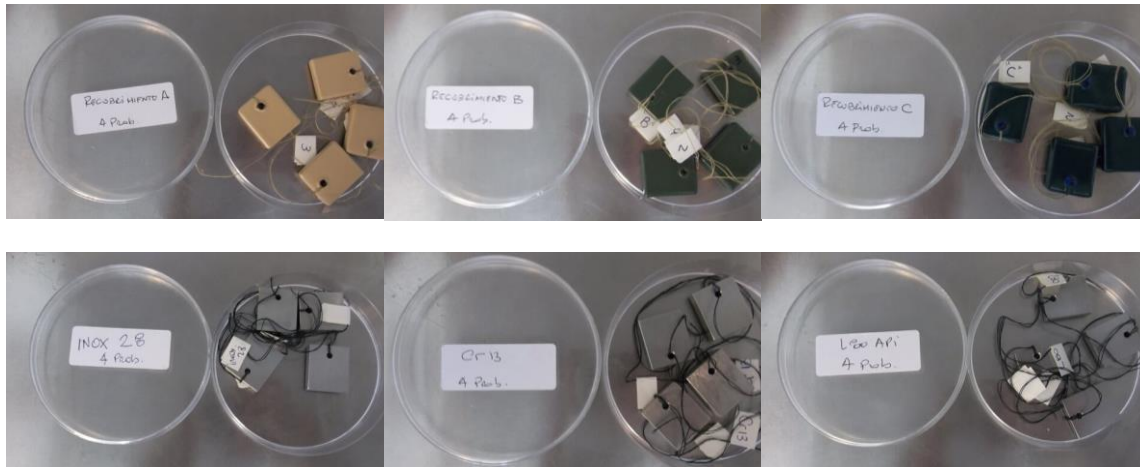
MIC does not produce a unique form or morphology of corrosion, instead, can result in accelerated general and localized corrosion, under-deposit corrosion (UDC), galvanic corrosion and dealloying among others features.

PURPOSE

The aim of this work was to test in a biotic environment different materials (metallic and non-metallic) generally used in the oil and gas industry with the aim to evaluate their performances, where chemical product (biocides) are not able to be deployed due to lack of adequate facilities or environmental problems (National parks, sub-zero regions, etc.) .

EXPERIMENTAL PROCEDURE

The assayed materials were prismatic coupons (20x23x3 mm) of: L-80 API 5CT carbon steel coated with different epoxy-phenolic coatings named A, B and C; bare L-80 carbon steel, bare martensitic stainless steel L80Cr13 (UNS S41426) and highly alloyed austenitic stainless steel (UNS 08028) (Figure 1). Coupons of 80x80x3 mm of L-80 API 5CT carbon steel coated with the epoxy-phenolic coating A were used for impedance studies and DNA extraction.



Coupons of the different tested materials.

EXPERIMENTAL PROCEDURE

Typical chemical compositions of the analyzed steels.

Carbon steel L80 API 5CT

C	Si	Mn	P	S	Cr	Ni
≤ 0.25	≤ 0.3	≤ 1.2	≤ 0.030	≤ 0.002	≤ 0.1	≤ 0.01

Martensitic stainless steel L80 Cr13 (UNS S41426)

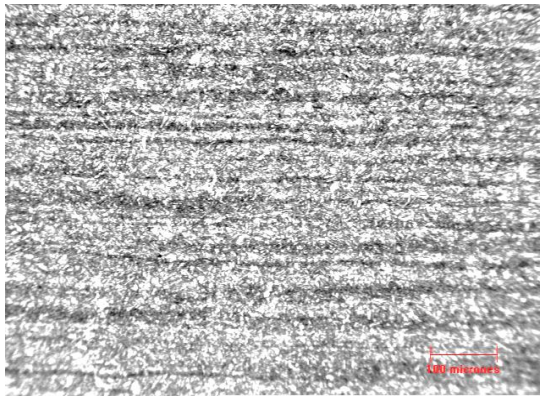
C	Si	Mn	P	S	Cr	Ni
≤ 0.22	≤ 1	≤ 1	≤ 0.020	≤ 0.005	12-14	≤ 0.5

Highly alloyed austenitic stainless steel (UNS 08028)

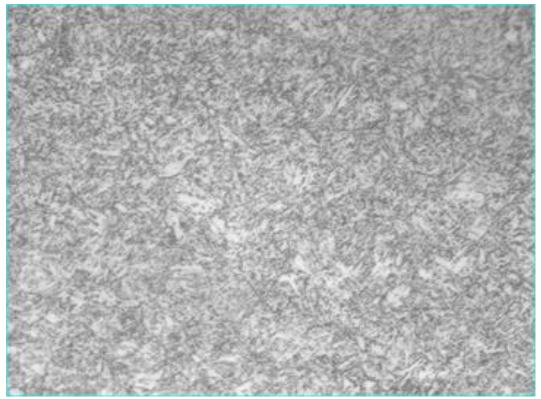
C	Si	Mn	P	S	Cr	Ni	Mo	Cu
≤ 0.020	≤ 0.6	≤ 2.0	≤ 0.025	≤ 0.010	27	31	3.5	1.0

EXPERIMENTAL PROCEDURE

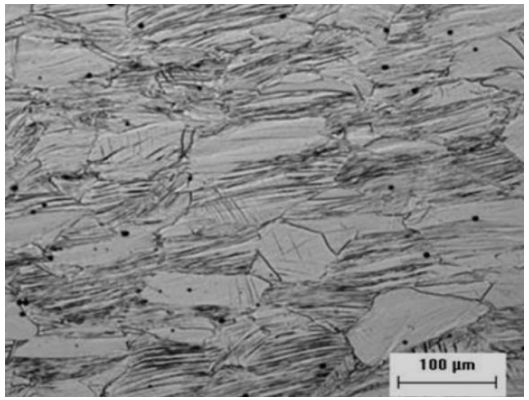
Typical microstructures of the analyzed steels



Carbon steel L80 API 5CT (200X)



Martensitic stainless steel L80 Cr13 (UNS S41426) (200X)



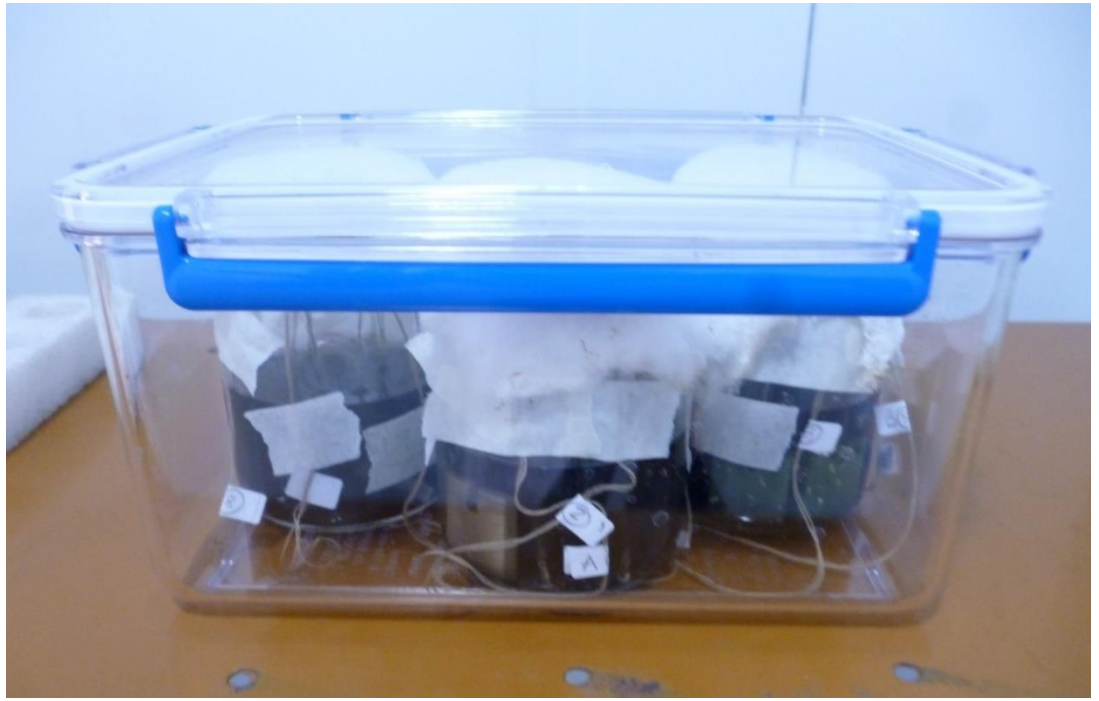
Highly alloyed austenitic stainless steel (UNS 08028) (200X)

EXPERIMENTAL PROCEDURE

Exposure of the coupons to the SRB culture

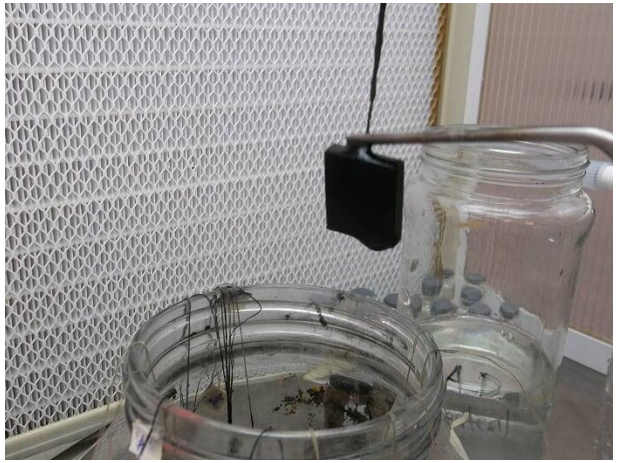
Inoculum: a 3-day-old mixed culture of SRB (obtained from an oil storage tank)

Flasks containing 1L of Postgate´s C medium



Anaerobic jar for 60 d in a culture chamber at 28 ± 2 ° C
Periodically, sulfate and bacteria counts were measured

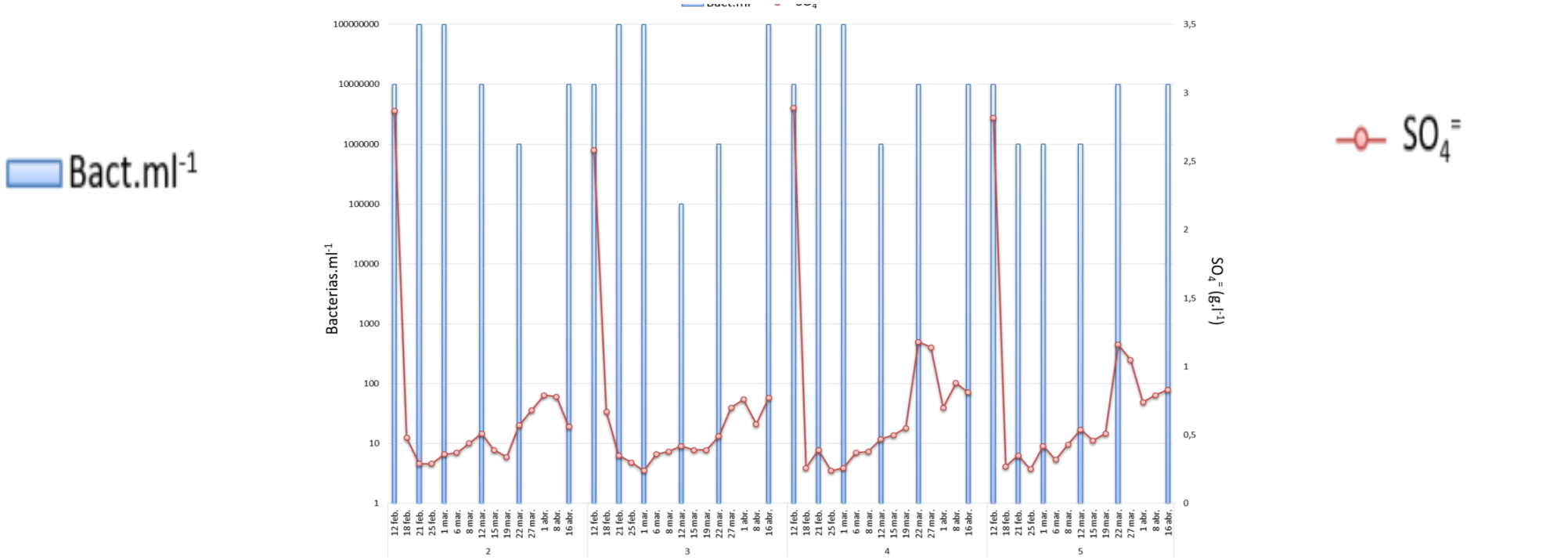
EXPERIMENTAL PROCEDURE



After 30 and 60 days, coupons were withdrawn from the flasks for:

- **Sessile Bacteria Enumeration**
- **Electrochemical Impedance Spectroscopy**
- **Scanning Electron Microscopy & EDX**
- **Epifluorescence Microscopy**
- **Biofilm DNA Analysis by Illumina Next-Generation Sequencing (NGS) technique**

EXPERIMENTAL RESULTS

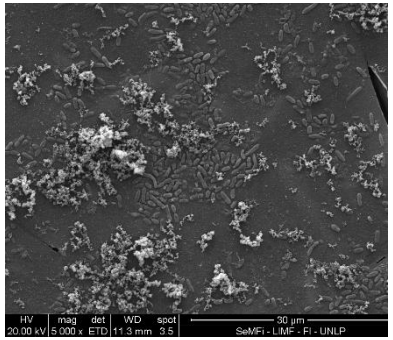
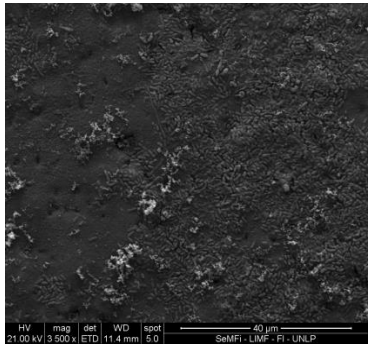
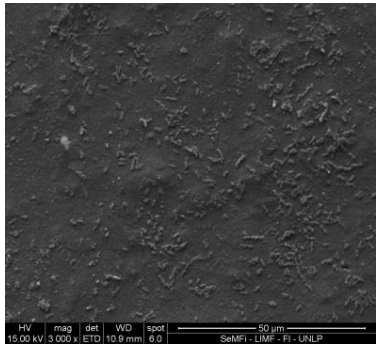
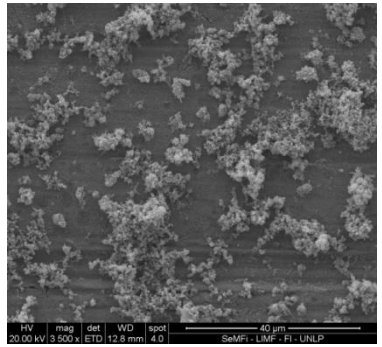
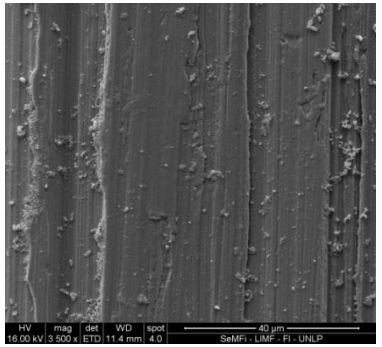
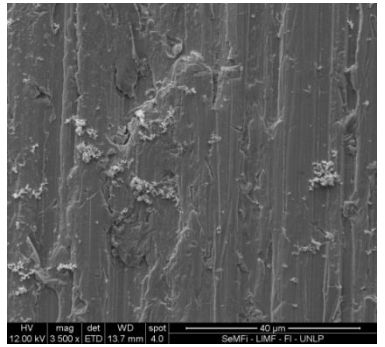
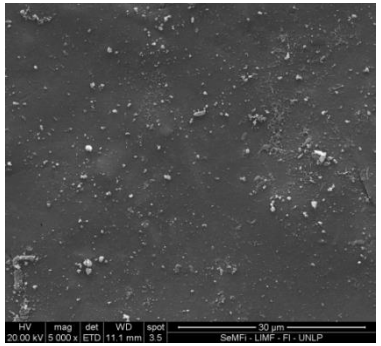
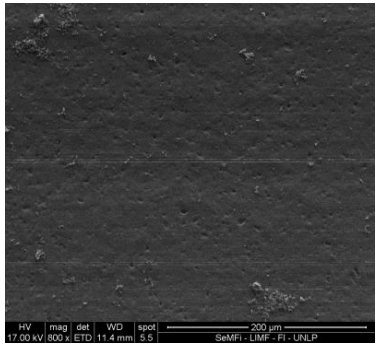
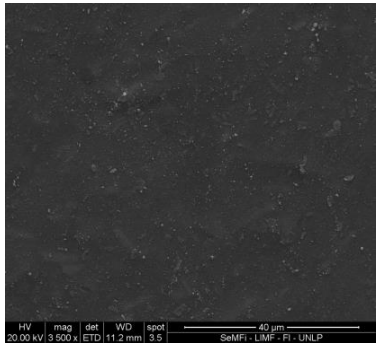
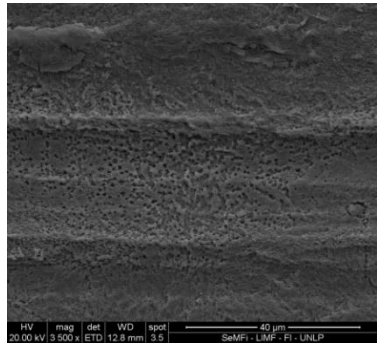
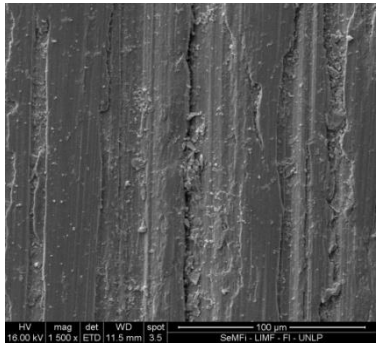
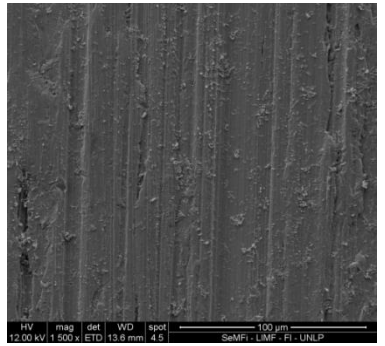


Number of attached bacteria (bact.cm^{-2}) forming biofilm on the different coupons after 60 d of exposure to the culture

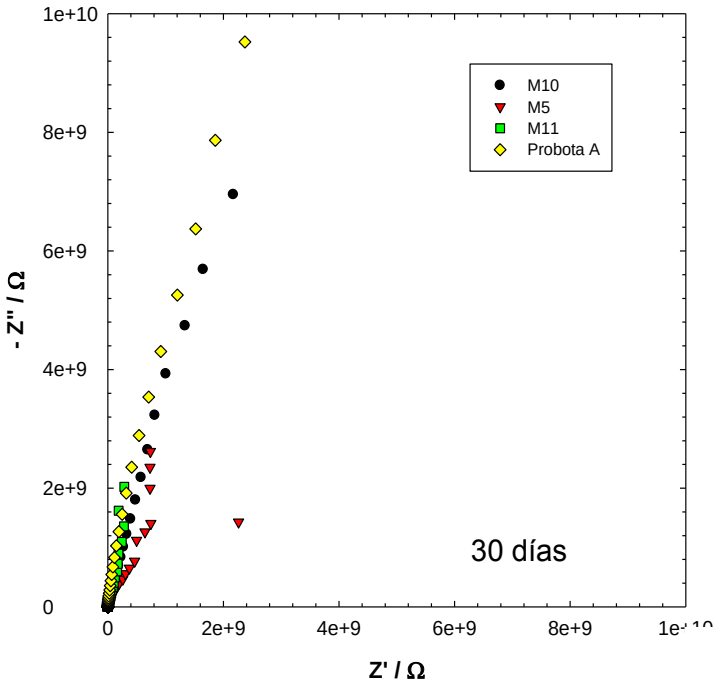
A	B	C	Cr13	L80	AI28
100-1000	10-100	10-100	100-1000	100-1000	10-100

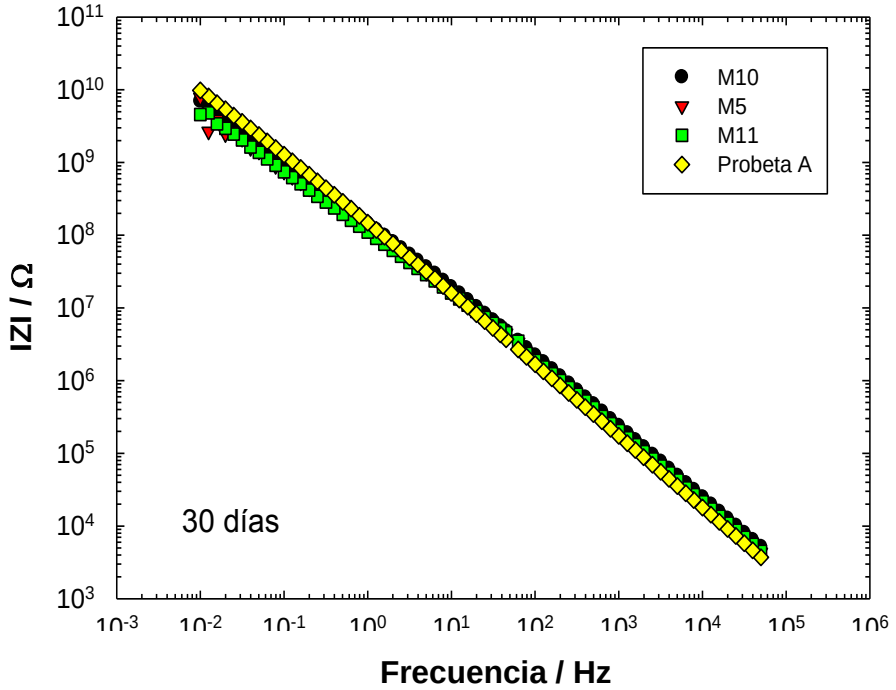
EXPERIMENTAL RESULTS

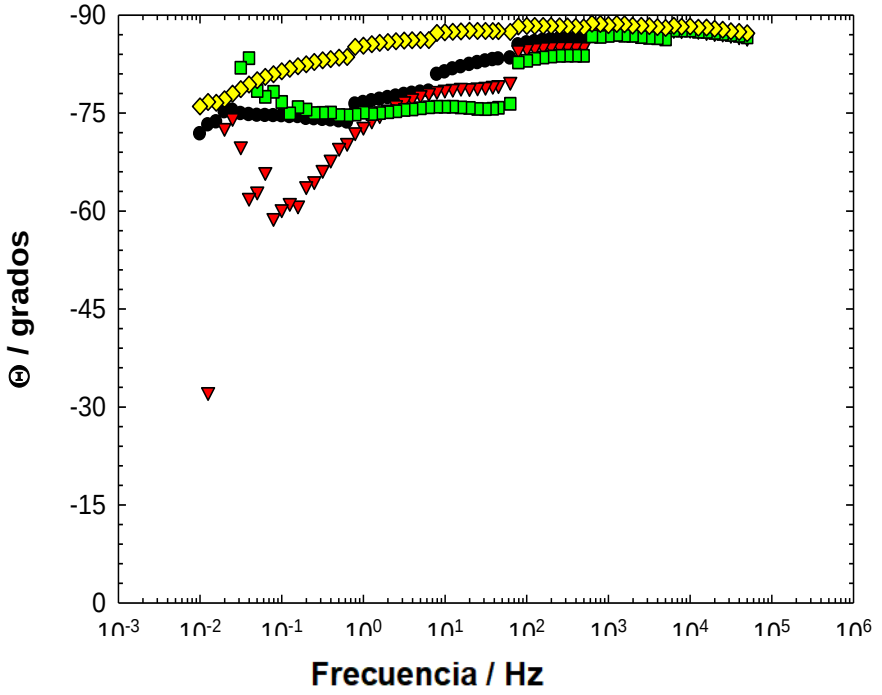
Biofilm and Surface Observations

Material →	A	B	C	L80	Cr13	AI28
Biofilm						
Under biofilm						

EXPERIMENTAL RESULTS







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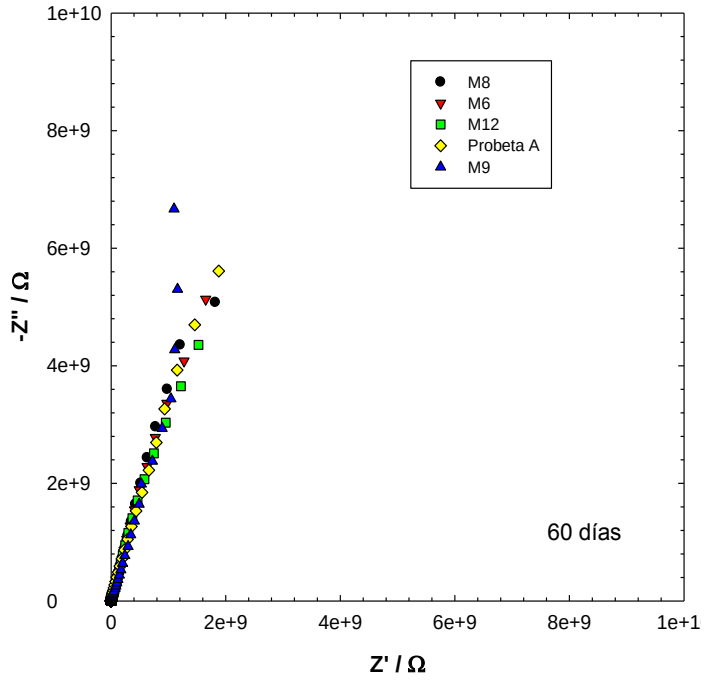
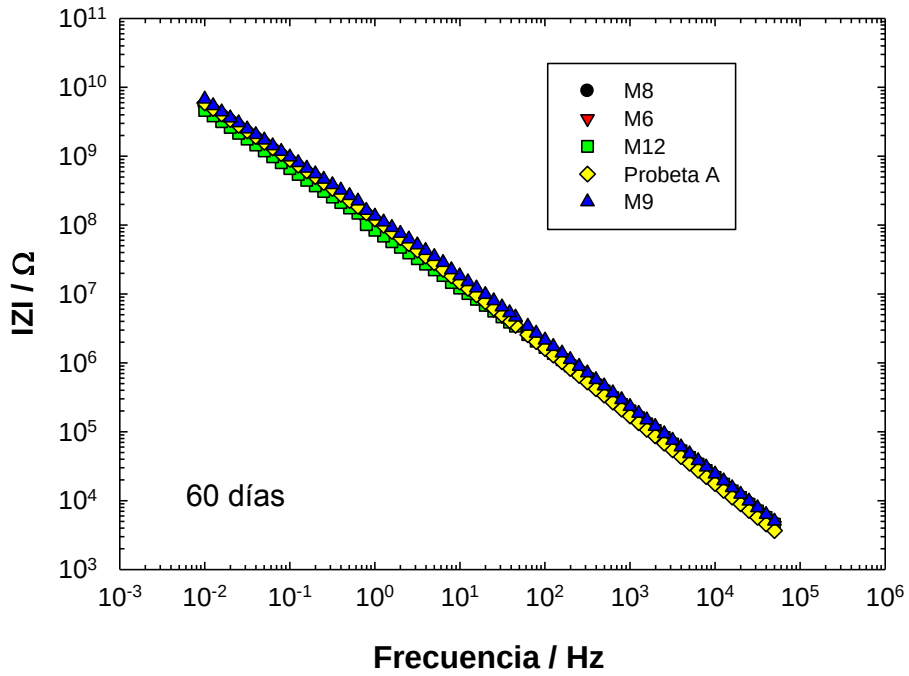
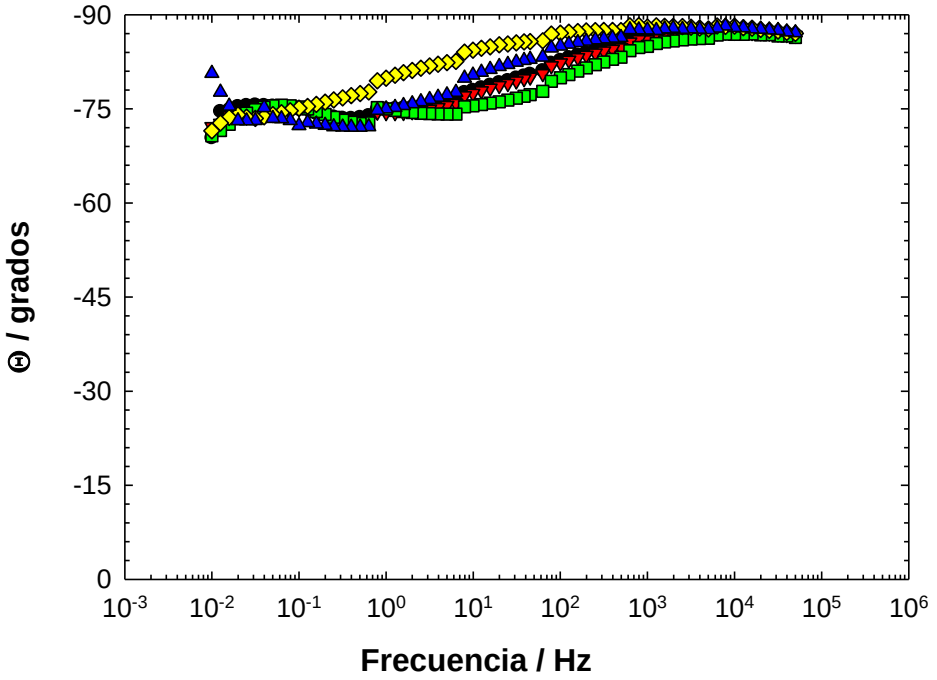
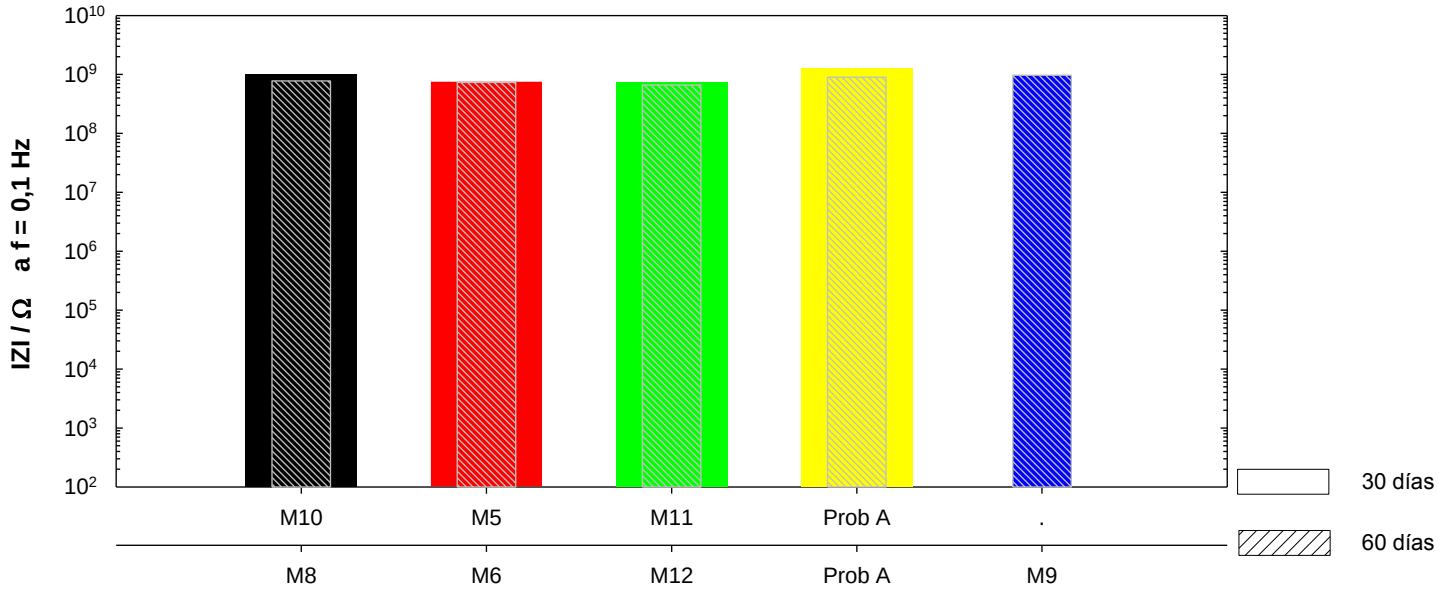




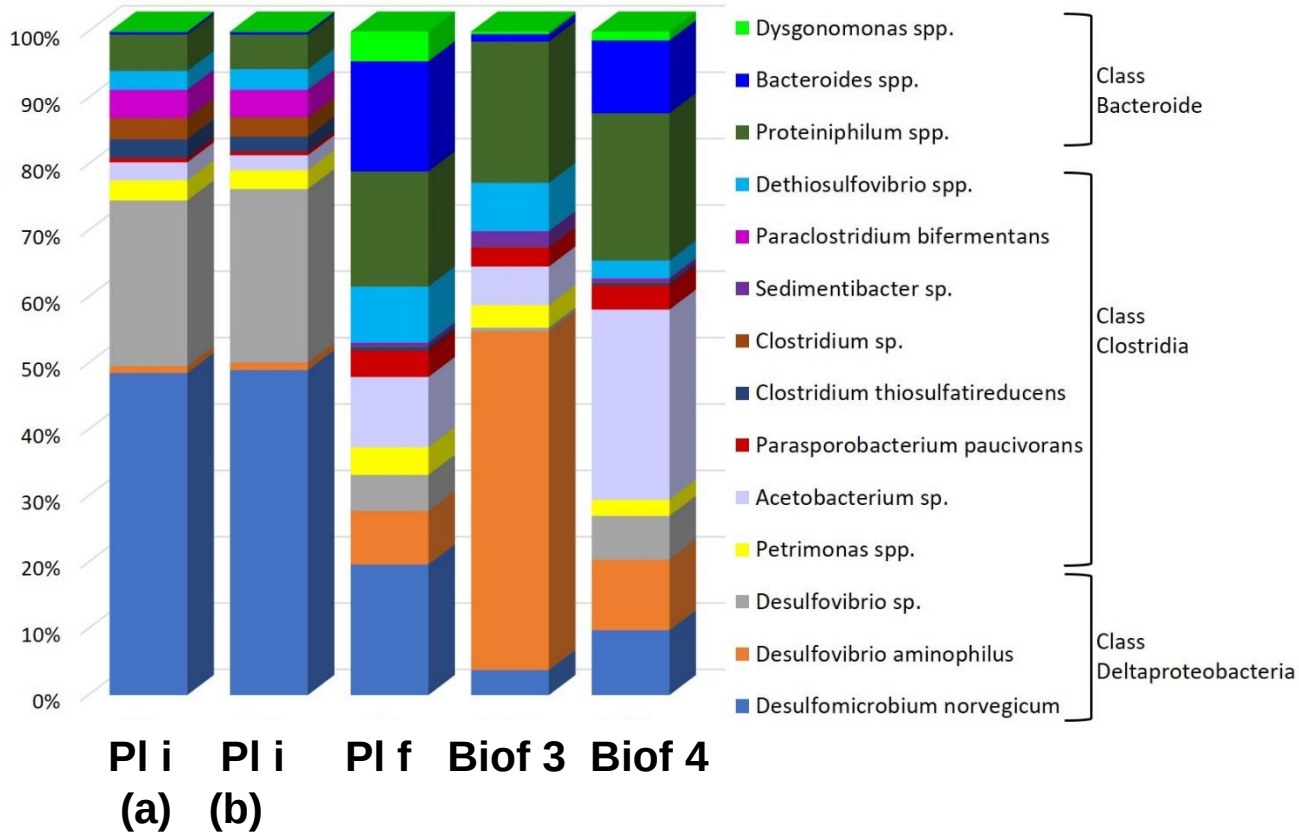


EXPERIMENTAL RESULTS

|Z| values at f = 0.1 Hz at 30 and 60 days.



Phylogenetic analysis



SUMMARY AND CONCLUSIONS

- SRB were able to establish MIC-associated biofilm on the coated and uncoated coupons. Neither the tested coatings nor the steel surfaces were able to inhibit the biofilm's growth on their surfaces.

- The EIS technique used to assess the coated samples, exposed to the mixed culture of SRB for 60 days, did not reveal any deterioration in the coating nor evidence of corrosion of the underlying steel..

- Bare carbon steel samples showed biofilm mixed with corrosion products. Localized corrosion with pitting morphology appeared after 60 days of immersion in the SRB culture.

- Martensitic steel (UNS S41426) and highly alloyed austenitic stainless steel (UNS 08028) bare samples showed the development of biofilms on their surface. However, no localized corrosion (pitting) or other type of corrosion-related morphology were detected after the test time.

- The structure of the bacterial community changes along the experiment. While SRB of the species Desulfovibrio sp. Desulfovibrio aminophilus and Desulfomicrobium norvegicum predominated at the beginning of the experiment, they diminished to 30% at the end.

- The composition of the biofilm communities were different from the planktonic ones, indicating that the species presented in the system had different tendency to attach and grow on the surface. All the species in the biofilms are anaerobic microorganisms which can generate deteriorating chemical species (organic acids and/or inorganic acids).

FUTURE ASSESSMENTS

In order to evaluate the performance of the polymeric coating in long term exposure to a SRB environment, a continuous bioreactor is currently under operation. The SRB consortium is cultivated in a 2L bioreactor, where several coupons where placed. Postgate´s C medium is continuously fed in the reactor. Sulfate concentration, pH and redox potential in the culture are monitored. The OCP of coated and uncoated steel is periodically measured.