

Study and treatment of installations against bacterial corrosion

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Abstract

In this work, we study the effects of bacterial growth on pipelines in the south of Algeria (bacterial corrosion of distribution and transport pipes). In addition, we study efficacy of inhibitor (NORUST 720) and biocide (biocide 2 CHIMEC 7660) used to treatment this problem. This problem of bacterial corrosion is frequently encountered in the production and injection circuits during the extraction of the oil. Hence, it leads to the formation of deposits on the inner surface of the pipes which causing a risk of clogging. First, we analyse the water separated from petroleum to detect the presence of Sulphate-Reducing Bacteria (SRB). Second, we study the behaviour of steel in an environment contaminated by SRB. For this purpose, we use, the pH, SEM, and EDX machines a analysing the surface of the samples which allow us to observe and knowledge the deposition chemical composition formed on the surface of the samples.

Keywords: Corrosion; Bacterial Corrosion; Sulphate-Reducing Bacteria; treatment; Steel N 80.

1. Introduction

The oil industry is an important driving force of the Algerian economy. However, this industry is faced with numerous challenges. One of these challenges is bacterial corrosion. Corrosion, in general, can be defined as a phenomenon of materials degradation under the effect of the physical, chemical or electrochemical actions of the surrounding environment. Corrosion is responsible for an annual cost up to 5% of the Gross National Product (GNP) of an industrial country [1][2].

The process where bacterial metabolic acts help creating favorable conditions for corrosion to occur is called bacterial corrosion [3][4]. The main bacterial type associated with this deterioration is the anaerobic Sulfate-Reducing Bacteria (SRB). In low oxygen environments and in the presence of sulfate, SRBs contribute to the mineralization of organic material by the process of sulfate reduction [4-7]. Furthermore, these bacteria are known for their exceptional enzymatic capability that allows them to grow in rather complex conditions and to adhere to various surfaces, including metallic based materials [8][9][10]. This bacterial corrosion is widely observed in petroleum pipelines which might result in pipes clogging and other severe losses in the oil and gas industries [11].

In order to avoid the harmful effects of BSR on metallic materials and installations, a chemical treatment with biocides is applied. The term biocide or bactericide includes all the chemicals which destroy or prevent the development of microorganisms [12]. Quaternary ammonium compounds (QUATS), formaldehyde, glutaraldehyde, acrolein, amines and diamines in addition to methyl chloromethyl-isothiazolone (MCMi) and 4,5-dichloro-2-n-octyl-4-isothiazolin-3-one (DCOI) are some of the widely used compounds in industrial biocides [13][14].

The purpose of this work was to study the deposit resulting from bacterial corrosion on the surface of N80 steel samples and determine the elements contributing to the formation of this deposit. Furthermore, this study evaluated the effectiveness of the industrial inhibitor (NORUST 720) and biocide (biocide 2 CHIMEC 7660) in the removal of these deposits.

We organize the rest of paper as follows: Section 2 represents our approach followed, Section 3 explains some obtained results with discussion, and Section 4 concludes the paper.

2. Our approach

We conducted this study on samples of oil pipe that carry crude oil during the extraction (steel N 80) that having a high resistance to the pressure. In addition, it can be used during drilling of oil wells and can withstand the wall of a well after the completion of the latter, to ensure a normal operation in all the wells. Note that, the surface of the samples is rectified, degreasers and dried, whose chemical composition (%) represent in the Table 1.

Table 1.The chemical composition of the base metal (weight %)

Components	Weight (%)
C (Carbon)	0.24
Si (Silicon)	0.22
Mn (Manganese)	1.19
P (Phosphorus)	0.013
S (Sulfur)	0.004
Cr (Chromium)	0.036
Mo (Molybdenum)	0.021
Ni (Nickel)	0.028
Nb (Niobium)	0.006
V (Vanadium)	0.017
Ti (Titanium)	0.011
Cu (Copper)	0.019

Table 2 represents a description about the situation of each sample of our experimentations.

Table 2.Description of the samples

Sample number	Description of situation
Sample 1	N80 steel was placed in SRB contaminated environment for 90 days at 37°C.
Sample 2	N80 steel was placed in SRB contaminated environment for 60 days at 37°C then treated by NORUST 720 and left for another 30 days at 37 °C.
Sample 3	N80 steel was placed in SRB contaminated environment for 60 days at 37°C then treated by biocide 2 CHIMEC 7660 and left for another 30 days at 37 °C.

Table 3 gives the different amounts of chemical composition of the culture environment of bacteria.

Table 3.The chemical composition of the culture environment of bacteria

Components	Quantity
Magnesium Sulfate $MgSO_4 \cdot 7H_2O$	1 g
Ammonium sulphate $(NH_4)_2SO_4$	1 g
Sodium citrate trisodium $Na_3C_6H_5O_7 \cdot 2H_2O$	1 g
DI-potassium Hydrogenophosphate K_2HPO_4	1 g
Ascorbic acid	0.2 g
Yeast extract	0.2 g
Agar	0.1 g
Sodium Lactate	4 ml
Distilled water	1 l

We have filled 9 ml of environment prepared in vials penicillin's; to add metal nail defatted by acetone in these vials. We have plugged the vials to using capsules of rubber, capsuling then were blocked by the aluminum. After that, we have purged the vials with nitrogen to create the anaerobic environment and sterilize by autoclaving under wet pressure at 120°C for 50 minutes. Then, using a syringe, we collected 1 ml of water and we eliminated the trapped air bubbles possibly in the syringe. Subsequently, we injected the contents of the latter through the capsule in the rubber stopper of the vial containing 9 ml of culture environment. Finally, we have labeled the vials. They have incubated in the incubator at 37°C for 28 days. We found blackening deposit in the vials with increased pH of environment showing the presence SRB in the analyzed water 1.

After confirming bacteria in the water, we repeat the same operation of Kit test, but we add our samples instead of nail metal. Also, we collected 1 ml of water contains bacteria. They have incubated in the incubator at 37°C for 60 days. Then, we added the biocide or inhibitor used against the problems caused by the SRB and left it another 30 days in the incubator at 37°C.

3. Results and Discussion

First, we measured pH of the environment samples before and after incubation (See Table 4).

Table 4. pH in the environment of the samples

Environment	pH (before incubation)	pH (after incubation)
Environment of sample 1	7.10	9.01
Environment of sample 2	7.10	8.94
Environment of sample 3	7.10	4.89

Results showed that the pH of the control environment was increased from 7.1 before incubation to (9.01) and (8.94) after incubation, forming a more preferable environment for bacteria and thereafter, formation of biofilm clusters which can develop even under extreme conditions of temperature and hydrostatic pressure [15]. On the other hand, a decrease in pH (4.89) was observed in biocide treated sample. This low pH medium can trigger an inhibitory effect on bacterial growth with second, the presence of H₂S [16].

Second, we analysed the surface of the samples using the electronic microscope (SEM). The determination of the morphology of deposit that formed on the surface of the steel N80 has been carried out by scanning electron microscopy (See Figure 1). We have achieved for each sample an image with expansions of (X65, X500, and X1000).

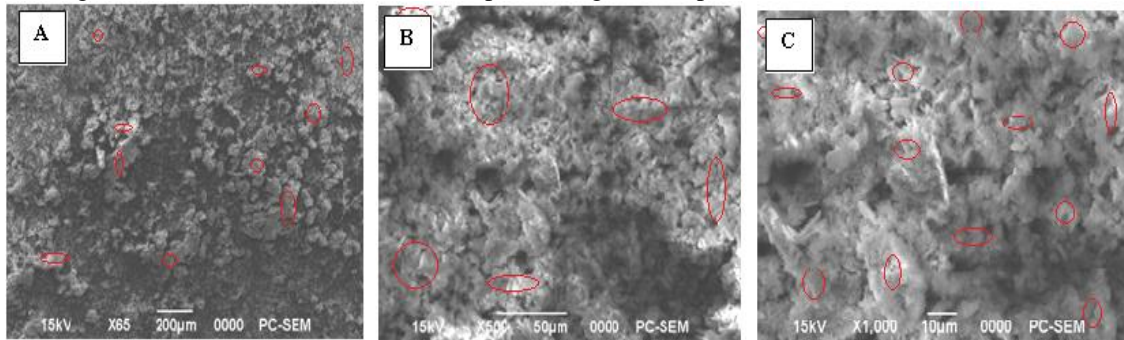


Fig.1. SEM micrographs of N80 steel samples incubated in SRB contaminated anaerobic environment for 90 days at 37 °C, (A) represent an X65 magnification with a scale bar of 200 μm, (B) represent an X500 magnification with a scale bar of 50 μm, (C) represent an X1000 magnification with a scale bar of 10 μm. Red circles refer to bacterial biofilms and the blue rectangles are cleared areas.

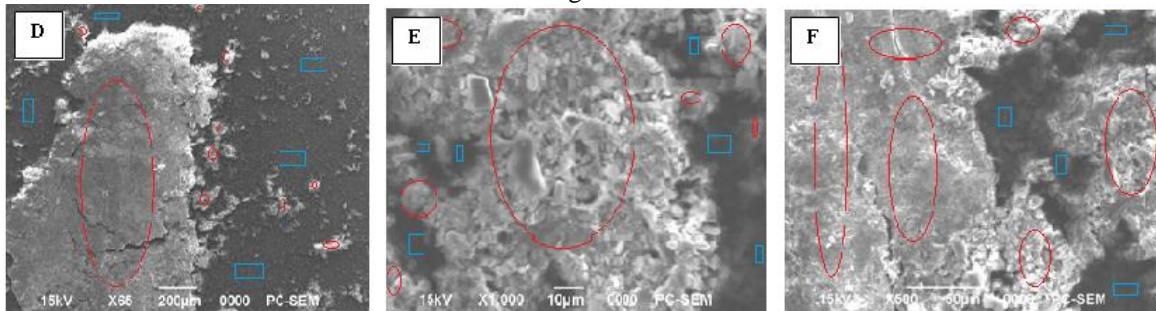


Fig.2. SEM micrographs of N80 steel samples incubated in SRB contaminated anaerobic environment for 60 days at 37 °C then treated by NORUST 720 and left for another 30 days at 37 °C. (D) represent an X65 magnification with a scale bar of 200 μm, (E) represent an X500 magnification with a scale bar of 50 μm, (F) represent an X1000 magnification with a scale bar of 10 μm. Red circles refer to bacterial biofilms and the blue rectangles are cleared areas.

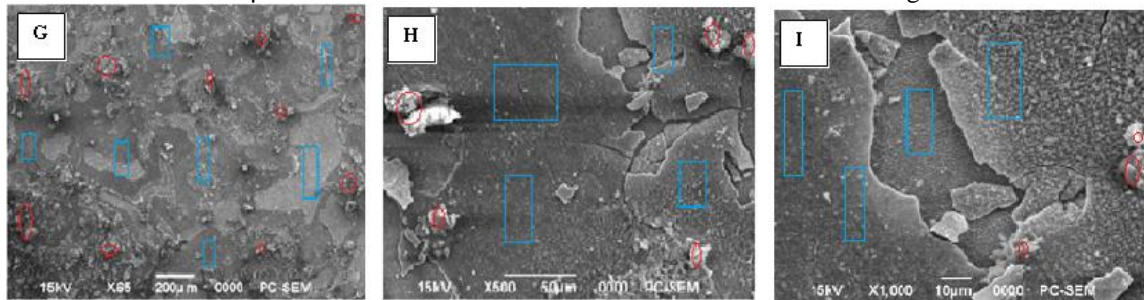


Fig.3. SEM micrographs of N80 steel samples incubated in SRB contaminated anaerobic environment for 60 days at 37 °C then treated by biocide2 CHIMEC 7660 and left for another 30 days at 37 °C. (G) represent an X65 magnification with a scale bar of 200 μm, (H) represent an X500 magnification with a scale bar of 50 μm, (I) represent an X1000 magnification with a scale bar of 10 μm. Red circles refer to bacterial biofilms and the blue rectangles are cleared areas.

The images of the surface of the sample 1 (Figure 1) show the existence of a stable adherent deposit in the form of colonies. Where, the amount of deposits on the sample surface is greatingen. As for the images of the surface of the sample 2 and 3 (Figure 2 and 3) clearly show the removal of a large part of the deposit in the form of colonies on the surface of the sample.

4. Conclusion

Biocide treatment lowered pH levels for the environment rendering it unfavorable for SRB growth and biofilm forming in comparison to the control sample. Corrosion signs were observed in both biocides treated and untreated samples; therefore, 60 days of exposure to SRB are enough to develop bacterial corrosion in untreated N80 steel. Although Biocide application was efficient enough to control bacterial growth and eliminate the forming residues after 60 days of exposure to (SRB), the bacterial corrosion occurred before the treatment was enough to cause damage to the studied surface which refers to the effectiveness of using Biocide 2 CHIMEC 7660 and NORUST 720 emphasizes on its early application.

Waiting for EDX results to know the most important components that make up the deposits formed by Sulphate-Reducing Bacteria.

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