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Evaluation of Biocorrosion Caused by Chemical Reactivity of Sulfate-Reducing Bacteria (SRB) in Petroleum Wells in the Algerians Hassi Messaoud Region

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KEYWORDS
Biocorrosion, Sulfate-reducing bacteria (BSR), Monitoring, Corrosion coupons, Ultrasonics, Radiography, Corrosion rate.

ABSTRACT:
This work presents a study on the issue of bacterial biocorrosion in oil production equipment within the fields of HassiMassoud. Biocorrosion is exacerbated by the presence of sulfate-reducing bacteria developed in the Albian waters, which are responsible for numerous challenges encountered in oil installations. The objective of this study is twofold: firstly, to monitor the issue of bacterial corrosion using chemical methods involving the detection of sulfate-reducing bacteria (BSR) in Albian water samples according to APIR38 standards. Secondly, to assess bacterial corrosion through ultrasonic control and the Coupon method to test the efficiency of the corrosion inhibitor NORUST 720. The detection of BSR in water samples taken from the W1C treatment station and the MDHA6 well yields positive results, indicating the presence of BSR bacteria in oil installations with a concentration of 10^5 germs/ml. The injected inhibitor NORUST 720 in the collection and desalination network proves effective in limiting the impact of sulfate-reducing bacteria (BSR). This is corroborated by the corrosion coupon test, where the corrosion rate is estimated at 0.018 mm/year.The ultrasonic and radiographic corrosion monitoring of the line between wells MD488 and MD E2C reveals a nominal thickness of 2.74 mm

Introduction

Corrosion is one of the most important challenges facing petroleum refineries. It has received wide attention in recent decades due to the continued dependence of the global economy on industries based on oil and natural gas. With annual corrosion cost estimated at billions of dollars, suitable corrosion mitigation approaches are required to prevent assets failure due to the menace of corrosion. [1] Corrosion is a widespread and expensive issue in the oil and gas sector, and presents significant dangers to infrastructure and the environment. It costs more than $1.4 billion per year, including direct spending for equipment maintenance and replacement and indirect costs such as lost productivity and environmental damage. [2] Oil and gas fields consume a tremendous amount of ironand steel pipe, tubing, pumps, valves, and sucker rods.Leaks cause loss of oil and gas and also permit infiltration ofwater and silt, thus increasing corrosion damage. Salinewater and sulphides are often present in oil and gas wells.Corrosion in wells occurs inside and outside the casing.Surface equipment is subject to atmospheric corrosion. Insecondary recovery operations, water is pumped into thewell to force up the oil.Corrosion characteristics of a well are determined byinspection of surface equipment analysis for carbondioxide, organic acid, and ironcoupon exposure tests,and tubing-caliper surveys. Determination of ironcontent and tubing-caliper surveys are used to measure theeffectiveness of inhibitor treatment.Earlier practices involved addition of neutralizers such asammonia, sodium carbonate, sodium hydroxide, and sodiumsilicate, but these were replaced in many cases by organicinhibitors, available in oil-soluble, water-dispersible, orwater-soluble forms. In some applications, alloy steels havereplaced the medium-carbon manganese steels (J-55 and N-80) previously used. Straight chromium and nickel oncorrosion of steel by condensate-well fluid. Straightchromium stainless steels, Stellite, Monel, and copper-basealloys are commonly used for valves and other wellhead parts. Galvanic corrosion is apparently not a factor becausesubstantial amounts of high-conductivity water are notpresent. [3, 4,5,6]Corrosion of metal is the deterioration and damage caused by

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chemical, electrochemical, Microbiologically and physical interactions between metallic materials and the surrounding environment. Rustiness of metal is the most common form of corrosion. During corrosion, a chemical or electrochemical multi-phase reaction occurs at the interface of the metal, which turns the metal into an oxidation (ion) state. This will significantly reduce the strength, plasticity, toughness, and other mechanical properties of metallic materials, destroy the geometry of metal components, increase the abrasion between rotating parts, deteriorate the electrical, optical, and other physical properties, shorten the service life of equipment, and even cause catastrophic accidents such as conflagration and explosion. In 1975, the economic loss caused by metal corrosion in the United States was 70 billion U.S. dollars, accounting for 4.2% of the gross national product that year. According to the statistics of industrially. [7 8 9]Microbiologically influenced corrosion, also known as microbial or biological corrosion, is produced by particular bacteria adhering to metal in water. It is widely acknowledged to be the direct cause of catastrophic corrosion failures, with associated damage costs accounting to many billions of US$ annually. Certain activities of microbial organisms such as their adherence capabilities are known to lead to the acceleration in corrosion rates of metals. Bacterial adherence is the beginning of the process of colonization of a surface, known as biofilm development that involves physicochemical and molecular interactions. This process of bacterial adhesion is influenced by a myriad of parameters which are broadly categorized as environment, bacterial, and material characteristics. [10, 11]Biocorrosion may be prevented by reducing biofilm formation on the surface of the metal. Biocides and few dispersive agents are applied to the metal surface to reduce the formation of biofilm as a part of chemical treatment. Nevertheless, these treatments have lost their applications due to the environmental concerns. Therefore, development of eco-friendly inhibitors is drawing attention in the recent years [12].Microbial corrosion is caused by a mixture of bacteria, medium, and metal [4]. Metal corrosion is caused by a variety of microorganisms. Out of those, the bacteria which are responsible are classified as aerobic or anaerobic. Slime-forming bacteria, sulphate-reducing bacteria (SRB), iron-oxidizing bacteria (IOB), and iron-reducing bacteria (IRB) are some of the subgroups that these bacteria may be split into [13 14 15 16].Sulfate-reducing bacteria (SRB), an anaerobic bacterial group, are found in many environments like freshwater, marine sediments, agricultural soil, and oil wells where sulfate is present. SRB derives energy from electron donors such as sulfate, elemental sulfur or metals, and fermenting nitrate. It is the major bacterial group involved in the microbiologically influenced corrosion (MIC), souring, and biofouling problems in oil-gas-producing facilities as well as transporting and storage facilities. SRB utilizes sulfate ions as an electron acceptor and produce H_2S, which is an agent of corrosion, causing severe economic damages. Various theories have been proposed on the direct involvement of H_2S and iron sulfides in corrosion; H_2S directly attacks and causes corrosion of metals and alloys. Many reviews have been presented on the aforementioned aspects. [17,18 19 20]Many studies have been conducted to investigate steel corrosion induced by SRB, and several mechanisms have been reported [21], [22], [23], [24]. For instance, metal corrosion can be accelerated through consumption of cathodic hydrogen via hydrogenase catalysis during SRB metabolism (cathodic depolarization theory) [21]. The metabolic product (H_2S) of SRB also accelerates metal corrosion [22]. EPS, which is the main component of SRB biofilm, affects corrosion processes by strongly complexing action with metal ions [23]. Some SRB promote corrosion by direct electron exchange between metal surface and microbial cells [24].HassiMessaoud, being a major hub for oil production in Algeria, requires a comprehensive understanding of factors contributing to bacterial corrosion, especially the presence of SRB. These anaerobic microorganisms are known for their ability to metabolize sulfates in production fluids, thereby generating corrosive compounds such as hydrogen sulfide (H2S), which can accelerate the metal corrosion process.The activity of sulfate-reducing bacteria SRB in oil wells can contribute to microbiologically influenced corrosion. This type of corrosion can result in the degradation of metal surfaces, leading to pitting, cracking, and general metal loss.The objective of our study is to conduct an investigation into the presence of bacterial corrosion caused by sulfate-reducing bacteria (SRB) in the production equipment in HassiMessaoud. This research is of utmost importance in the oil sector, where bacterial

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corrosion can have devastating consequences on equipment integrity, jeopardizing operational safety, facility sustainability, and incurring substantial costs in terms of maintenance and repairs.The method used in our study involves monitoring the bacterial levels in the reservoir and tracking bacterial corrosion through methods such as the coupon method, ultrasonic measurement, and radiographic testing.

1-1The Biocorrosion Issue

The oil production in the HassiMassoud region involves the injection of pressurized water into geological formations to decrease salt concentration and enhance crude oil production through sweep efficiency. Reservoir water accompanies the oil in the producing reservoir, originating either from the aquifer at the base of oil reservoirs or from the rock itself. This water is typically highly saturated with salts, with sodium chloride being the predominant salt, often accompanied by varying quantities of calcium, potassium, magnesium, carbonates, and chlorides.These salts contribute to the corrosion of oil production facilities. The selection of the Albian aquifer is based on criteria such as its low cost, low hardness, sufficient volume availability, and its effectiveness in displacing oil, ranging from 20 to 80% depending on capillarity, water wetting ability, and reservoir rock heterogeneity. The Albian aquifer, located approximately 1500 meters deep, is accessed through water-producing wells to supply the injection unit.

While the Albian aquifer meets physical criteria for cost-effective use in well washing and pressure maintenance, it presents a chemical incompatibility with reservoir water (Cambrian). The challenge arises from the sulfate content in the Albian water, promoting the development of sulfate-reducing bacteria responsible for degrading oil production facilities in the HassiMessaoud region. Sulfate-Reducing Bacteria (BSR) are found in the reservoir bottom.

Sulfate-reducing bacteria pose numerous challenges in oil production installations and in lifting salt-laden wells to prevent blockage by Albian desalting water, leading to another issue – metal loss, pitting, and cracking due to bacterial corrosion. [25]

1-2 Biocorrosion of Oil Production Well Installations:

In our case, the internal corrosion of pipelines and production facilities is a highly intricate issue due to the presence of both downhole and surface installations, coupled with an extensively dense washing network and collection system. These systems ensure the conveyance of fluids from wells to industrial complexes. The root cause of this problem lies in the presence and proliferation of sulfate-reducing bacteria (BSR) in both Albian and Cambrian waters.

Table 1. Average Analyses of Albian and Cambrian Waters in Hassi Messoud[26]

Aquifer Ions	ALBIAN	CAMBRIAN
	(mg/l)	(mg/l)
HCO_3^-	170	0
Cl^-	420	210 000
SO_4^{2-}	550	0
Ca^{2+}	210	36 000
Mg^{2+}	70	6 500
Ba^{2+}	0	580
Sr^{2+}	0	970.00
Na^+	220	80 000
K^+	0	4 500
Iron total	0	5 500
pH	7.3	3.6
Density at 25°C	1.00	1.232
Depth (m)	1050-1350	Deposit

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The table 1 indicates the significant presence of sulfate ions in the Albian water, suggesting that this environment is conducive to the growth of sulfate-reducing bacteria (BSR).

1-3Sulfate-Reducing Bacteria (SRB)

Sulfate-reducing bacteria (SRB) constitute a specific type of bacteria involved in microbial corrosion within petroleum reservoirs. These bacteria are anaerobic, thriving in the absence of oxygen. They derive their energy from the reduction of sulfate present in water to hydrogen sulfide (H_2S). H_2S is a corrosive gas that can damage metallic equipment, particularly in oil production facilities.

1-4 Mechanism of Microbial Corrosion

The mechanisms of biocorrosion are diverse, reflecting the variety of microorganisms, environments, and materials involved. Biocorrosion by SRB can lead to significant issues such as equipment embrittlement, reduction in the thickness of metal walls, the formation of pits, and other forms of localized corrosion.It is commonly accepted that microbial corrosion of metals in anaerobic environments is attributed to the catalysis of proton or water reduction. [27]

$$2H^+ + 2e^- \longrightarrow H_2$$

$$2H_2O + 2\,e^- \longrightarrow H_2 + 2OH^-$$

Sulfate-reducing bacteria (BSR) metabolically produce sulfide ions:

$$SO_4^{-2} + 4H_2O + 8\,e^- \longrightarrow S^{-2} + 8OH^-$$

Anodic Corrosion of Iron: $Fe \longrightarrow Fe^{2+} + 2é$ (oxidation)

$$Fe^{2+} + S^{2-} \longrightarrow FeS$$

$$Fe^{2+} + 2OH^- \longrightarrow Fe(OH)_2$$

Global Reaction: $4Fe + 2SO_4^{2-} + 4H_2O \longrightarrow 2\,FeS + 2Fe(OH)_2 + 4OH^-$

Sulfide lesions combine with ferrous ions to form deposits of iron sulfide (FeS). The formed FeS catalyzes the reduction of protons or water on the material's surface, leading to an increase in electron transfer and consequently an acceleration of metal dissolution. Bacterial corrosion depends on the uniformity of the FeS deposit, its crystalline state, the nature of the steel, surface defects of the steel, etc. In reality, the mechanisms of biocorrosion are likely more complex than this simple mechanism and remain challenging to elucidate

- **Figure 1.** Sulfate-Reducing Bacteria (SRB)[28]

2- Experimental Study of Biocorrosion

2-1 Detection of Sulfate-Reducing Bacteria (SRB)

Bacterial control for SRB is conducted in a laboratory setting with controlled salinity. The detection method is based on the preparation of a culture medium and monitoring using a kit over a period of 21 days.[29]

Preparation of the Culture Medium:

The culture medium employed in our study is the API RP 38 medium (American Petroleum Institute Recommended Practice, specifically designed for sulfate-reducing bacteria. Toprepare the medium, 1 liter of Albian system water is first sterilized in an autoclave

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for 20 minutes to eliminate bacteria. The composition of the medium includes:

- 0.01 g of Potassium Phosphate (K2HPO4)
- 1.00 g of Sodium Sulfate (Na2SO4)
- 0.20 g of Magnesium Sulfate (MgSO4.7H2O)
- 4.00 ml of 60% Sodium Lactate (C3H5NaO3)
- 1.00 g of YeastExtract
- 0.10 g of Ascorbic Acid (C6H8O6)

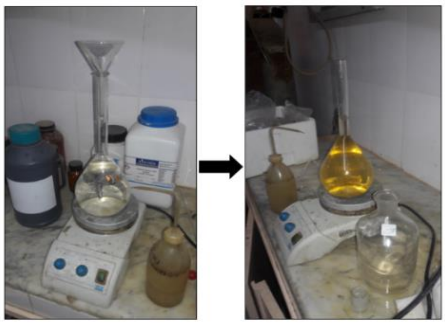

Figure 2. Dissolve the components in the Albian system water.

Dissolve the mentioned reagents in 1 liter of Albian system water, then sterilize the medium in an autoclave for a duration of 15 minutes.

Procedure:

- Place one nail in each bottle.
- Add 18 ml of the culture medium to each bottle.
- Seal the bottles using a designed rubber stopper.
- Bubble nitrogen to purge all the oxygen present in the bottles.

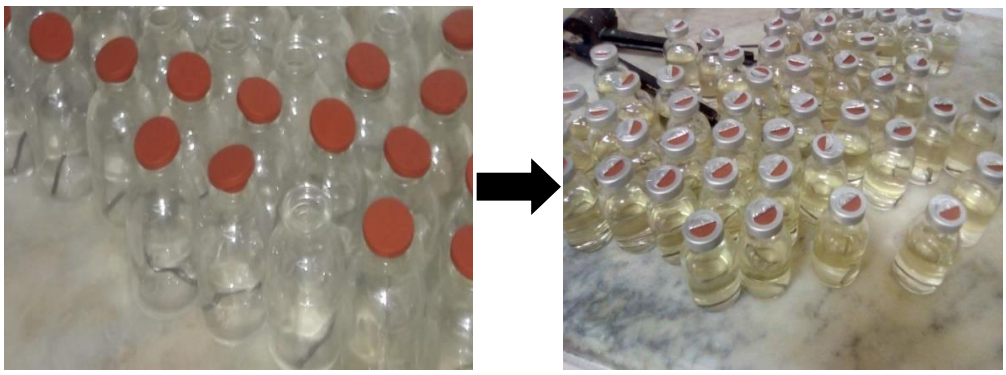

Figure 3. Nitrogen bubbling to purge oxygen from the bottles.

After nitrogen bubbling to remove oxygen from the bottles, the bottles must be sterilized in an autoclave for a duration of 20 minutes at a temperature ranging from 0 to 120°C, with a pressure not exceeding 1.5 Bar.

Detection Step: To detect bacterial corrosion or the presence of sulfate-reducing bacteria (BSR) and assess the level of risk in oil installations, two water samples need to be taken—one from an oil-producing well and the other from a treatment station.

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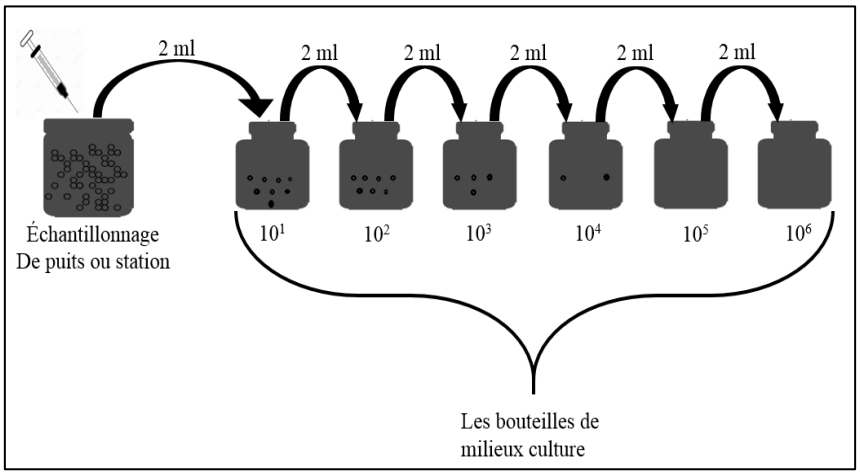

Figure 4. Preparation of the bottle kits

Afterward, incubate the kit in an oven at a temperature of 37 to 40°C for 21 days with regular monitoring each day.

2-2 Test with the injection of the corrosion inhibitor Norust 720 at 50ppm [30]

The corrosion inhibitor Norust 720 is tested in the wells and the WIC washing station using the coupon method to assess the corrosion rate (see Table 2 for the identification of the Norust 720 inhibitor).

Table 2: Safety Data Sheet for InhibitorNorust 720

Norust 720 inhibitor	**Physical properties**
	**Physical State:** Liquid at 20°C **Color:** Pale yellow **Solubility:** Soluble in water. **Solidification Point:**Lessthan 5°C **pH:**Between 5.5 – 5.9 **Viscosity:** 250 centipoise at 20°C **Flash Point:** Greater than 100°C (method: ASTM D93) **Density:** 1.10 – 1.40 g/cm³

Preparation and procedure of the coupon treatment: Prepare a 200 ml solution (30% hydrochloric acid) inhibited with a few drops of the corrosion inhibitor NORUST 720 to prevent potential corrosion by the acidic solution.For a more representative assessment of corrosion rate values, the weight loss due to the aggressiveness of the solution used for coupon treatment is eliminated. To achieve this, a fourth coupon is employed as a reference (IY 640 Blank Test, IY 730 Test with injection), with an initial weight of IY 640 = 37.0522 g and IY 730 = 36.8891 g. Place the four blank test coupons (IY 640, BC 562, BC 560, BC 561) and the four test coupons with the injection of the Norust 720 inhibitor (IY 730, CU 747, CU 753, CU 759) into the

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treatment solution. After every 30 minutes, rinse the coupons with tap water, and using a clean cloth, rub them until they are dry..

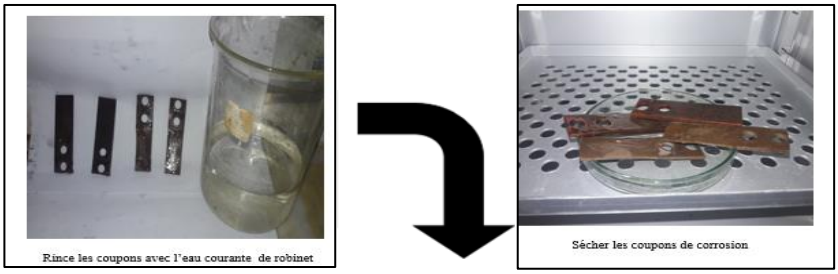

Figure 5. Preparation of Coupons

Repeat these stepsuntil the complete disappearance of corrosion products on the surfaces. Subsequently, place them in the oven at 90°C to eliminate any remaining traces of water that could distort weight values. After 24 hours, weigh the coupons and calculate the corrosion rate.The results of corrosion tests on coupons immersed in the pipes of the desalination network and the collection network, in the presence and absence of the inhibitor and biocide, were obtained using the weight loss method. These results are presented in tabular form, specifically Table 4,5 showcasing the corrosion rate. [31]

$$\mathbf{V_{corrosion}} = \frac{\mathbf{3650X\Delta P\prime\ (g)}}{\mathbf{density}\left(\frac{\mathbf{g}}{\mathbf{cm^3}}\right)\mathbf{xsurface}\left(\mathbf{cm^2}\right)\mathbf{xtimes\ (day)}} \qquad \mathbf{(1)}$$

2-3 Ultrasonic Testing (UT) Inspection

Ultrasonic Testing (UT) inspection of the well line from MD 488 to MD E2C:

Description of the line:

- Grade: API Gr B
- Diameter: 3" and 6" with nominal thickness: 7.62 mm and 7.11 mm

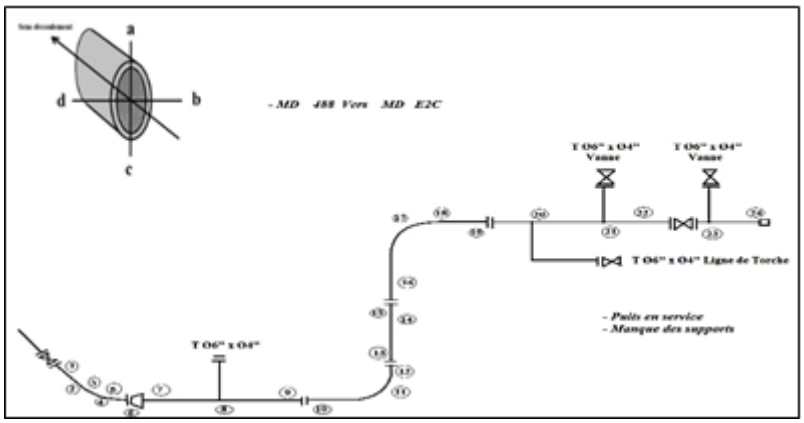

Figure 6. Ultrasonic Inspection of Well MD 488 to MD E2C

Execution of the inspection: Install the UT device module, make contact at points A, B, C, D with the pipeline using a coupling agent film after selection.

2-4 Radiographic Inspection:

This method uses X-rays to inspect welds, coatings, and other critical areas, radiographic inspection will be conducted at critical point No. 5 to confirm the thickness reduction.

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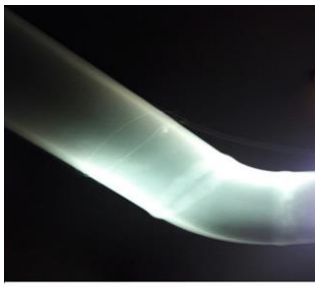

Figure 7. Radiographicinspectionof Well Descent MD 488

3. Results and Discussions

3-1 Bacteria Detection

In Figure 8, a change in the color of the medium to black is observed, indicating the presence of sulfate-reducing bacteria. Counts are conducted to determine the degree of microbial population on the different networks, leading to rigorous field treatment.

Figure 8: Detection of Sulfate-Reducing Bacteria (BSR) through Color Changes in Samples in Well MDHA6

Table 3. Daily Monitoring of Samples from Well MDHA6

	Incubation in days																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Interpretation:

Observing the results from Table 3, it is noteworthy that the presence of sulfate-reducing bacteria (BSR) is evident in all tested samples from the 5th to the 21st day. The bacterial concentration in the wells is consistently high, reaching 10^5 germs/ml. This indicates a significant microbial population or the presence of microorganisms per millimeter across the different networks, signifying a very high corrosion rate in the oil production wells.

3-2 Corrosion Rate in the Blank Test of Norust 720 Inhibitor

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Table 4: Blank Test Results

Well	CIS Upstream	CIS down stream	MD HA6	References coupon
Ref	**BC 562**	**BC 560**	**BC 561**	**IY 640**
P_{int}	37,253	37,0327	37,325	37,0522
P_{fin}	32,8475	35,0123	36,9179	36,9913
ΔP	4,4055	2,0204	0,4071	0,0609
ΔP'	4,4664	2,0813	0,468	-----
T(day)	80	80	80	-----
Vmm/an	1,616386798	0,753220903	0,169368848	-----
V mpy	63,63727551	29,65436627	6,668064871	-----

3-3 Corrosion Rate in the Norust 720 Inhibitor Injection Test

Table 5. Results of the Test with Norust 720 Inhibitor Injection

Wells	CIS Upstream	CIS down stream	MD HA6	Coupon de reference
Ref	**CU 747**	**CU 753**	**CU 759**	**IY 730**
P_{int}	37,2754	37,5564	37,2903	36,8891
P_{fin}	28,2412	37,4682	37,2701	36,8524
ΔP	9,0342	0,0882	0,0202	0,0367
ΔP'	9,0709	0,1249	0,0569	-------
T(jour)	90	90	90	-------
Vmm/an	2,918001673	0,040178859	0,01830406	-------
V mpy	114,8819556	1,581844829	0,720632272	-------

- **P. :**Initial weight of the coupons.
- **$P._{fi}$:**Final weight of the coupons.
- **ΔP :** Weight loss,is the difference between initial and final weights (ΔP = P. in - P.fi).
- **T (j) :**Time in days.
- **Densité (d**): Density, specified as 7.85 for steel.
- **Surface:** Surface area of the coupons, given in square centimeters (cm^2).
- **Vmpy:** Corrosion rate in mils per year. 1 mil = 0.001 inches.
- **Vmm/year:** Corrosion rate in millimeters per year. Note: 1 mpy (mil per year) is equivalent to 25.4 microns per year or 0.0254 mm per year.

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Figure 9. Coupons from Blank and Injection Tests

It is evident that the impact of the corrosion inhibitor combined with a biocide is highly significant, both in the desalination network and the collection network of oil production wells. The corrosion rate is notably reduced, even compared to the corrosion rate tolerated in the oil industry, which is typically on the order of 2 mils per year (mpy).This observation leads to the conclusion that the corrosion inhibitor based on amines, specifically NORUST 720, forms an impermeable organic film, thereby eliminating the contact between metal and water.

3-4 Ultrasonic Test Results

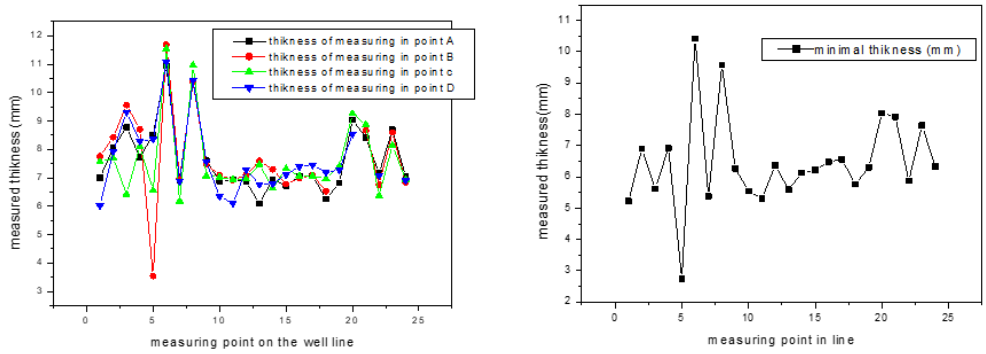

Figure 10. Measurement of Line Thickness (A) and Nominal Thickness (B)

In Curve 10A, thickness measurements are conducted using ultrasonics to assess the integrity of the walls of the MD488 well line at different points A, B, C, D. Variations in pipe thickness are observed, indicating the detection of thinning zones and corrosion of various types, especially biocorrosion caused by the formation of FeS and other potential defects.

The Curve 10B presents subsequent measurements of the nominal thickness on the line to monitor wear, corrosion, or other factors that may affect the actual wall thickness of the pipe over time. A thickness decrease is identified at 2.74 mm compared to the nominal thickness of 7.62 mm at point No. 5 on the line. We use the radiographic inspection to confirm this reduction in thickness

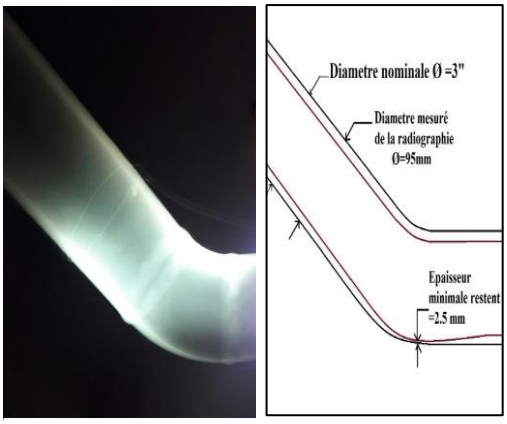

Figure 11. Radiography of Well Descent MD 488 (3)

3-5 Radiographic Inspectio

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An x-ray inspection for critical point No. 5 to confirm the reduction in thickness

3-5-1 Calculation projection factor:

The projection factor calculation is for calculating the true thickness value.

$$\eta = \frac{\text{Nominal diameter}}{\text{Diameter measured in the X-ray}} \quad (2)$$

η : Projection factor (0,8 <**η**<0,95);

Nominal diameter 3''

Diameter measure from X-ray95 mm

Projection factor: $\eta = \frac{76.2}{95} = 0,8$

The margin is 0.8 acceptable, there are no errors in the x-ray

Calculates the actual minimum value:

$V_{\text{min real}} = \text{Minimum measurement of X-rayfilm} \times \eta$

$V_{\text{min real}} = 2$ mm

Conclusion

Bio-corrosion by sulfate-reducing bacteria (SRB) poses a major challenge in various industries, especially in the petroleum sector, as exemplified in our case study of the HassiMessaoud oil field.

These anaerobic microorganisms have the ability to reduce sulfates present in the environment into hydrogen sulfide (H_2S), a corrosive gas, thereby causing significant corrosion problems in petroleum equipment. This leads to the accumulation of acids and gases, resulting in the perforation, pitting, and cracking of oil installations. Furthermore, bio-corrosion by SRB can lead to accelerated deterioration of equipment, loss of structural integrity, leaks, and high maintenance costs. It also poses potential safety risks.

Corrosion monitoring (corrosion assessment) is carried out using Non-Destructive Testing (NDT) and the weight loss method (using coupons). NDT is performed to protect the interior and exterior of the oil installation, employing Ultrasonic and Radiographic tests. Test results indicate a decrease in nominal thickness from 7.62 to 2.74 mm. The weight loss method using coupons shows a corrosion rate reduction of 0.018 mm/year in the MDHA6 well after the injection of NORUST 720 inhibitors.

Effective management of bio-corrosion involves the implementation of preventive strategies such as the use of corrosion inhibitors, biocides, environmental condition control, and regular monitoring of installations.

In summary, understanding the mechanisms of bio-corrosion by SRB and implementing preventive measures are essential to ensure the sustainability of industrial facilities and minimize the risks associated with this phenomenon. Continuous monitoring and the search for new management strategies are also crucial in the evolving context of industries facing these challenges.

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