Corrosive aggressiveness of water production due to the SRB and CO2

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Abstract In this study the corrosive aggressiveness of a production water due to the presence of carbon dioxide (CO2) and sulfate-reducing bacteria (SRB) was investigated, using a rotating cage according to ASTM G202. pH, concentrations of planktonic bacteria, content of sulfides, sulfates, iron, calcium and magnesium were measured every 24 h during the tests, at the end of the experiment sessile bacteria count, weight loss of carbon steel coupons and attack morphology of the surface by scanning electron microscopy were determined. The findings show that at concentrations between 25-100% v/v CO2 in the gas phase on the medium decreased the pH to 4.3 and inhibited the planktonic and sessile SRB growth, and for a 10% CO2, the planktonic SRB increased to ≥ 10^9 cells/mL and sessile to ≥ 10^6 cel/cm². Under this condition, a non-protective iron sulfide (mackinawite) layer formed on the coupon surface which turned out to be non-protective as small pits were detected over the entire surface of the coupon.

Keywords: synthetic produced water, sulphate-reducing bacteria, CO2, aggressiveness, mackinawite.

1. INTRODUCTION
An important factor in the degradation of pipes used in water management of production, it is pitting corrosion; which is influenced by multiple construction parameters, physical, chemical, operational and particular by the presence of dissolved gases as CO2, H2S and O2, plus bacteria Sulfate-Reducing (SRB) (Kermani,1997). Studies in the United States show that annual corrosion costs industrial level range between 1-5% of GDP each nation, and those costs are associated 15-30% microbiologically induced corrosion (CIM) (Karl Fink,2003., Roberge,2007). Microbiological corrosion of steel it manifested as a form of localized attack pitting, due to the development of a biofilm superficial. The anaerobic condition of oil pipelines, often Biofilm production facing the which almost invariably contain BSR are the leading cause of MIC by the effect of H2S, forming sulfides which precipitates iron biofilm. These iron sulfides are cathode for steel and can therefore increase anodic corrosion in (Pots,2003) sites. The CO2 and H2S corrosion of steel He is known for many years and still continues still a major problem in the industry oil, due to its high incidence under different mechanisms of action; which, together with CIM by BSR, affect the oil industry. In Tables 1 and 2 show chemical reactions that occur in aqueous solutions in the presence CO2 and H2S.

Salts of calcium and magnesium in the water production by the presence of CO2 generated fouling, and a loss heat transfer systems exchange or plugging systems pumping and distribution, increasing losses energy (Rzeczycka,2005., Revie,2011., Kermani,2003., Kemmer,1989).

<table>
<thead>
<tr>
<th>Nombre</th>
<th>Reacción</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disolución del CO₂</td>
<td>CO₂(g) ⇌ CO₂(L)</td>
</tr>
<tr>
<td>Hidratación del CO₂</td>
<td>CO₂ + H₂O ⇌ H₂CO₃</td>
</tr>
<tr>
<td>Disociación del ácido carbónico</td>
<td>H₂CO₃ ⇌ H⁺ + HCO₃⁻</td>
</tr>
<tr>
<td>Disociación del ánion bicarbonato</td>
<td>HCO₃⁻ ⇌ H⁺ + CO₂⁻</td>
</tr>
<tr>
<td>Disociación del agua</td>
<td>H₂O ⇌ H⁺ + OH⁻</td>
</tr>
<tr>
<td>Oxidación del hierro</td>
<td>Fe ⇌ Fe²⁺ + 2e⁻</td>
</tr>
<tr>
<td>Evolución de hidrógeno</td>
<td>2H⁺ + 2e⁻ ⇌ H₂</td>
</tr>
<tr>
<td>Reacción global</td>
<td>Fe + CO₂ + H₂O ⇌ Fe²⁺ + CO₂⁺ + H₂</td>
</tr>
</tbody>
</table>

Table 1 Chemical reactions that occur in aqueous solutions of CO2
Table 2: Chemical reactions that occur in aqueous solutions of H2S

<table>
<thead>
<tr>
<th>Nombre</th>
<th>Reacción</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reacción Anóxica</td>
<td>4FeO → 4Fe^2+ + 8e^-</td>
</tr>
<tr>
<td>Disociación del agua</td>
<td>8H^+ + 8e^- → 4H₂</td>
</tr>
<tr>
<td>Reacción catódica</td>
<td>8H⁺ → 8e⁻ → 8H (adsorbido)</td>
</tr>
<tr>
<td>Consumo bacteriano</td>
<td>SO₄^2⁻ + 4H⁺ → SO₂⁻ + 4H₂O</td>
</tr>
<tr>
<td>Producto de corrosión</td>
<td>Fe^2+ + SO₄^2⁻ → FeS↓</td>
</tr>
<tr>
<td>Reacción global</td>
<td>4Fe + SO₄^2⁻ + 4H₂O → 3Fe(OH)↓ + FeS↓</td>
</tr>
</tbody>
</table>

2. METHODOLOGY

Activating the mixed culture of BSR (BSR) and preparation of inocula a mixed culture of BSR (CMBSR) was used Isolated water production station flow of western Venezuela, with which various concentrates prepared mixed cultures grown in Postgate B, with chlorides (PGBCl) (Table 3), according to NACE Standard TM0194, (NACE,2004) refrigerated at 4 ° C for preservation and then Test inocula were prepared by centrifugation at 6000 rpm for one hour to ensure remove all bacterial consortium the spent culture medium, centrifuging diluting solid it is containing the bacterial consortium Synthetic water production (APS) Fresh serving as a medium to prepare the inoculum liquid phase and incubate at 37°C for 48 h before the start of each test.

Preparation of production water Synthetic (APS) The APS was prepared based on the quality of water natural (APN) (Table 1) of flow station in western Venezuela aggressive considered to present problems corrosion, sulfate-reducing bacteria, CO₂ and trend antifouling, following the general guidelines specified in ASTM D 1141 (ASTM,2008). Since only available characterization inorganic water; to ensure growth BSR, sodium lactate is added as filler organic equivalent to that recommended by the standard NACE TM0194 for the preparation of the medium Postgate culture sulfate B and to ensure energy load required by the BSR bacteria.

3. SYSTEM PREPARATION FOR TESTING ROTARY CASE

All tests were done in duplicate with a low flow rate (0.3048 m / s) to simulate the condition more critical level field for growth of BSR, at atmospheric pressure and 37 ° C. The tests were performed using a rotary housing according to ASTM G 170 (ASTM,2006), ASTM G 184 (ASTM,2006) and ASTM G 202 (ASTM,2009) with 8 coupons per test of 34.14 cm² area; carbon steel according to the composition indicated in Table 4, which were prepared as indicated in ASTM G 01 (ASTM,2003) and ASTM G31 (ASTM,2004) with sandpaper from 240 to 600 grain size and ensuring the cleanliness of the exposing them to ultraviolet light at least for 2 hours before each test. Figure 1 shows a schematic diagram the rotating system at atmospheric pressure box. a volume of 3.6L was used APS with 10% (0.4L) of inoculum and exposure times 96 h. The deaeration of APS and cylinder rotary case before and during the tests He performed with argon at 1 h / L solution and / or volume of the container as indicated in ASTM G 202 (ASTM,2009). At the end of each test pickled coupons and determined the mass loss as indicated in the standards ASTM G16 (ASTM,2010) and ASTM G46 (ASTM,2005).

Table 3: Water conditions natural production and reagents to prepare APS and PGBCl

<table>
<thead>
<tr>
<th>Parámetro</th>
<th>Concentración (mg/L)</th>
<th>Reactivos para preparar 1 L de APS</th>
<th>Reactivos para preparar 10 L de PGBCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.9</td>
<td>HCl, H₃PO₄</td>
<td>HCl, H₃PO₄</td>
</tr>
<tr>
<td>Dureza Total</td>
<td>560.0</td>
<td>MgCl₂</td>
<td>MgCl₂</td>
</tr>
<tr>
<td>Dureza Calcita</td>
<td>206.0</td>
<td>Fe₂O₃H₂O (lunar)</td>
<td>Fe₂O₃H₂O (lunar)</td>
</tr>
<tr>
<td>Dureza Magnesita</td>
<td>478.0</td>
<td>NaCl</td>
<td>NaCl</td>
</tr>
<tr>
<td>Sódico</td>
<td>139.0</td>
<td>MgSO₄-TiO₂</td>
<td>MgSO₄-TiO₂</td>
</tr>
<tr>
<td>Carbono</td>
<td>1632.0</td>
<td>Na₃PO₄</td>
<td>Na₃PO₄</td>
</tr>
<tr>
<td>Magnesio</td>
<td>592.0</td>
<td>CaCl₂</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>Bronciones</td>
<td>90.0</td>
<td>Ca₃(PO₄)₂(XLS)</td>
<td>Ca₃(PO₄)₂(XLS)</td>
</tr>
<tr>
<td>Abatimiento de CO₂</td>
<td>430.0</td>
<td>Fe₂O₃H₂O</td>
<td>Fe₂O₃H₂O</td>
</tr>
<tr>
<td>Hierro</td>
<td>12.0</td>
<td>CaCl₂</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>Sodio</td>
<td>745.0</td>
<td>Ca₃(PO₄)₂(XLS)</td>
<td>Ca₃(PO₄)₂(XLS)</td>
</tr>
<tr>
<td>Cloruro</td>
<td>3687.3</td>
<td>Agua destilada</td>
<td>Agua destilada</td>
</tr>
<tr>
<td>K2O</td>
<td>785.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentración (mg/L)</td>
<td>85.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSB plantation</td>
<td>10^10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSB sedimentos (volumen)</td>
<td>10^7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BAR population count For the development of each test were available previously that: inocula of CMBSR 48 h of incubation, APS, tubes Postgate medium B with 16,000 mg / L chloride (PGBCl) for serial dilutions and Anaerobic buffer saline phosphate (BFSa) for sonicated coupons. Adherent biofilms to the substrate surface (sessile bacteria) are usually the most important biological component Bacterial ecology of a system in study. Sessile bacteria, emerge coupon with the use of an ultrasonic sonicator to dislodge biofilm, which together with the products associated with it must be completely dispersed in a sterile solution BFSa, since it provides a means for maintaining live bacteria without providing nutrients for its growth. In this study we standardized the previously sonicated with the following parameters: 100% amplitude, 360 s total time, 18 cycles of 20 s each 10 s the sonicator 10 s on and off per cycle for total energy supplied 2880 J. Post sonicated homogenized with the BFSa and dispersed biofilm removed in order taking a representative sample (1 mL) for subsequent bacterial quantification with serial dilution technique as recommended by NACE TM0194. This same technique serial dilution used for quantification growth of planktonic reactor.

Figure 1. Rotating box.

4. TEST FOR CHOOSING% CO2
4 tests were performed in duplicate each one to evaluate the effect of CO2 on growth BSR planktonic and sessile. They were used CO2 gas mixtures / Argon in proportion 100/0, 50/50, 25/75 and 10/90%; to determine the maximum amount of CO2 which guarantees BSR growth of planktonic similar level and sessile the field. With this maximum amount of CO2 vidence of aggressiveness is done later corrosive, behavior was monitored at the time of planktonic growth; so as pH, sulfur content by the method methylene blue, sulfate, calcium, magnesium and iron by atomic emission spectroscopy, and the coupon mass loss was determined. To the end of the test was determined content sessile BSR, the growth curve was performed BSR planktonic at APS with 10% CMBSR with 10% CO2 without the presence of CO2 using the rotary case. Water samples were taken reactor every 24 hours during the 96 hours of the test, for counting planktonic BSR and end Count of sessile BSR test.

5. ANALYSIS OF THE CORROSIVE AGGRESSIVENESS
APS with and without the presence of BSR and CO2 tests with and without CO2 were performed in the middle APS CMBSR 10% of the total volume reactor (4L). The aggressiveness of the medium 24 h evalúocada integrating microbiological analyzes by population count sessile CMBSR planktonic, chemicals for pH determination, sulfides, sulfate, metals (Fe, Ca, Mg), gravimetric (Mass loss of vouchers), microscopic (Morphology of deposits and surface damage), a microscope was used for microscopy scanning electron Hitachi S-3200N brand. Then applying ASTM G1 is They etched coupons to observe the morphology attack. It is important to note that the speed Corrosion was not measured but calculated.

6. RESULTS AND DISCUSSION
Selecting the% CO2 in the middle APS for analysis aggressiveness. Effect of CO2 on growth BSR planktonic and sessile Of the four tests (Table 5), evidenced CO2% has significant influence the pH of the medium and thus in the development cell phone. 10% CO2 be considered for analysis aggressive ruled every 24 hours up to 96 h monitoring.

Table 5 shows that decreasing the percentage of CO2 in the rotating box from 100% 25%; It occurs a decrease in the loss of mass by being exposed to a medium coupons less corrosive with higher pHs; which increases progressively decreasing the% CO2. For CO2 concentrations between 25-100% no planktonic bacterial growth.
or sessile; on the contrary, planktonic bacteria gradually decreased from ≥10^8 cells / mL (inoculum) to 0 cells / mL in the case 100% CO2 by the low pH of the medium (4.3). This bacterial death is confirmed by the sharp reduction in the sulfur content of medium and the fact that remains approximately constant sulfate content as he seen in Figure 2. Additionally not observed biofilm formation on coupons It confirmed that there was no growth sessile BSR.

For a 10% CO2, it was obtained on average pH 5.8 which prevented bacterial death and growth allowed them both planktonic and sessile level; as well as biofilm formation and growth of sessile 10^6 cel / cm2 similar to field (Vílchez,2010); implying greater mass loss in the coupons, since that they were exposed not only to CO2 corrosiveness, but also the action sessile BSR and H2S generated by them. This significant growth of BSR level planktonic and sessile is confirmed by a reduction the content of the sulfate half and an increase Initial sulfur content up to maximum, subsequently decreasing the exhaustion sulphate content. Based on these results Clearly a pH of 5.8 is the minimum ensures a significant bacterial growth since no damages are generated to the structure cells.

**Table 5** Average values of microbiological, chemical and corrosive steel indicators Carbon exposed to different% CO2 for 96 h

<table>
<thead>
<tr>
<th>Prueba</th>
<th>% CO2</th>
<th>pH Final</th>
<th>Contaje Poblacional de BSR</th>
<th>Pérdida de masa (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incióculo Inicial (cel/mL)</td>
<td>Planctonico Final (cel/mL)</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>4.3</td>
<td>10⁶</td>
<td>10⁷/0</td>
</tr>
<tr>
<td>B</td>
<td>50</td>
<td>5.2</td>
<td>10⁷</td>
<td>10⁶/10⁶</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>5.4</td>
<td>10⁸</td>
<td>10⁷/10⁸</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>5.8</td>
<td>10⁹</td>
<td>10⁸/10⁹</td>
</tr>
</tbody>
</table>

**Figure 2.** Performance of sulfur and sulfates function of time by varying the CO2%.

7. **POPULATION GROWTH IN MEDIA WITH 10% CO2**

Table 6 shows the values of the count bacterial, sulfur content and pH obtained growth during tests performed. The Figure 3 shows the growth curve planktonic the CMBSR by the behavior of sulfides, iron sulfate and time. For BSR testing with and without CO2, using an inoculum concentrated in bacteria of 109 cells / mL, one planktonic growth observed from 108 cells / mL at 0 h to 109 cells / mL at 48 h. He planktonic growth decreased from 109 cells / mL 108 cells / mL after 48 h and remained in this concentration up to 96 h of the test.

Sessile bacterial growth end of the test (96 h) was between 106-107 cells / cm2 in both tests with and without CO2, similar to the level obtained plant (Zambrano,2008). The sulphide concentration in the tests without CO2 showed an average increase from 6.6 to 16.7 mg / L at 48 h, then decreased progressively to a value of 8.2 mg / L at the end of the trial, because the rotary case It was circulated a continuous flow of argon and / or CO2 to simulate the conditions at the plant level and maintaining anaerobic conditions in the system; which drugs part of the H2S generated by bacteria. The sulfur content also It was reduced due to precipitation of the same as iron sulfide associated corrosion s coupons. The behavior of sulfur in the tests with CO2 was similar to that described above.

The slowdown in growth of SRB obtained is due to exhaustion of sulphates in the middle which is reduced from 163mg / L to 1.5 mg / L at 96 h for testing without CO2 and 192.5 mg / L to 1.3 mg / L for testing CO2 due that is consumed by the SRB present in the means for growth as shown in Figure 3. 

---

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<table>
<thead>
<tr>
<th>Prueba</th>
<th>% CO2</th>
<th>pH Final</th>
<th>Contaje Poblacional de BSR</th>
<th>Pérdida de masa (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incióculo Inicial (cel/mL)</td>
<td>Planctonico Final (cel/mL)</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>4.3</td>
<td>10⁶</td>
<td>10⁷/0</td>
</tr>
<tr>
<td>B</td>
<td>50</td>
<td>5.2</td>
<td>10⁷</td>
<td>10⁶/10⁶</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>5.4</td>
<td>10⁸</td>
<td>10⁷/10⁸</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>5.8</td>
<td>10⁹</td>
<td>10⁸/10⁹</td>
</tr>
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The bacteria were kept constant in 108 cells/mL after 48 h, possibly for use another compound as electron acceptor no net production of sulfides or because at this stage the amount of sulfate requiring for dissimilation process is minimal which It has been reflected by other investigators (Pots, 2003., Videla, 2010).

The content of iron (Fe + 2) increased soluble rapidly after 48 h due to the process Corrosion coupons by the action of the different media studied (De Romero, 2005 & 2010), as It is shown in Figure 3, being higher for CO2 testing, associated with increased corrosion coupons obtained in these tests.

8. APS AGGRESSIVE CORROSIVE BSR AND CO2

Table 7 shows the mass loss occurs average of 7 per test coupons rotary case with the standard deviation. It is noted that mass loss lower than 5.4 mg was obtained in tests with single APS, where it remained neutral pH throughout the test. By injecting 10% CO2 APS loss triples mass being more aggressive medium having a pH 5.3 by the presence of CO2. To inoculate the APS 10% BSR, the medium pH was maintained slightly acid and 6.6 on average loss mass reached a value of 10.7 mg action aggressive bacteria.

The higher mass loss of 23.9 mg He obtained for testing inoculated with APS CMBSR 10% CO2 and 10%, reaching a slightly acidic pH of 5.8 due to the synergistic effect both aggressive factors (BSR and CO2). The loss of mass in tests with APS and no CO2 is mainly associated with corrosion uniform, in tests with APS more BSR It is associated primarily localized corrosion and testing with more APS BSR and CO2, it is associated with a mixed attack consisting of uniform corrosion and localized corrosion pitting.

Table 8 shows that in tests APS and CO2 with and without the addition of BSR, a significant reduction is observed in the content calcium and magnesium due to its precipitation primarily as calcium carbonate and magnesium. In all tests observed one increased iron content dissolved in the medium due to corrosive process suffered by coupons by the action of different medium studied and greater precipitation of iron testing for the presence of BSR formation of iron sulfides precipitate.

### Table 6 Bacterial growth and content of sulphides, iron and sulfate in APS with 10% CO2 and 10% SRB

<table>
<thead>
<tr>
<th>Preueba</th>
<th>Sulfato (mg/L)</th>
<th>BSR (células/cm²)</th>
<th>pH</th>
<th>Sulfato (mg/L)</th>
<th>BSR (células/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sin CO2</td>
<td>10³, 10³, 10³, 10³</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
</tr>
<tr>
<td>Con CO2</td>
<td>10³, 10³, 10³, 10³</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
<td>0 h, 24 h, 48 h, 72 h</td>
</tr>
</tbody>
</table>

Morphology attack coupons with MEB Figure 4 presents micrographs with MEB with amplifications 200X coupons exposed to different conditions. It is noted in the presence of APS (Figure 4A); not observed pitting coupons so loss mass obtained due to uniform corrosion associated with the very aggressive environment. In presence of APS + CO2 (Figure 4B); it is noted a mixed nature mainly corrosion uniform over the entire surface with formation small bites (≤20 microns in diameter average) in certain areas associated coupon the CO2 localized attack. In the presence of APS + BSR (Figure 4C); a significant increase is obtained in the number and diameter bites due to corrosion mainly mixed localized nature on the entire surface with formation of large bites (≥50 um diameter on average) due to microáanos forming iron sulphides.

**Figure 3.** Cell concentration, sulfur, iron sulfate vs time recorded media without and with 10% CO2.
Table 7 APPS without corrosive aggressiveness and BR and / or CO2

<table>
<thead>
<tr>
<th>Prueba</th>
<th>Condición</th>
<th>Pérdida de masa (mg)</th>
<th>Desviación Estándar</th>
<th>Velocidad de Corrosión (mmpy)</th>
<th>pH Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>APS</td>
<td>5.4</td>
<td>0.7</td>
<td>0.71</td>
<td>7.0</td>
</tr>
<tr>
<td>B</td>
<td>APS + CO₂</td>
<td>15.2</td>
<td>1.2</td>
<td>2.10</td>
<td>5.3</td>
</tr>
<tr>
<td>C</td>
<td>APS + BSR</td>
<td>10.7</td>
<td>1.4</td>
<td>1.46</td>
<td>0.6</td>
</tr>
<tr>
<td>D</td>
<td>APS + BSR + CO₂</td>
<td>23.0</td>
<td>0.9</td>
<td>3.23</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Table 8 pH and calcium content variation, magnesium and iron in APS with and without BSR and CO2

<table>
<thead>
<tr>
<th>Prueba</th>
<th>Condición</th>
<th>pH Final</th>
<th>Precipitación Calcio Promedio (mg/L)</th>
<th>Precipitación Magnesio Promedio (mg/L)</th>
<th>Hierro Sólido Promedio (mg/L)</th>
<th>Hierro Precipitado Promedio (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>APS</td>
<td>7.0</td>
<td>190</td>
<td>23</td>
<td>7.5</td>
<td>1.8</td>
</tr>
<tr>
<td>B</td>
<td>APS + CO₂</td>
<td>5.3</td>
<td>666</td>
<td>41</td>
<td>24.3</td>
<td>6.1</td>
</tr>
<tr>
<td>C</td>
<td>APS + BSR</td>
<td>6.6</td>
<td>215</td>
<td>33</td>
<td>13.1</td>
<td>8.6</td>
</tr>
<tr>
<td>D</td>
<td>APS + BSR + CO₂</td>
<td>5.8</td>
<td>856</td>
<td>113</td>
<td>25.3</td>
<td>21.9</td>
</tr>
</tbody>
</table>

Figure 4. SEM micrographs with 200 X for coupon exposed in tests with APS, APS + CO₂, APS and APS + + BSR BSR + CO₂.

BSR for APS + + CO₂ mixture (Figure 4D) a significant increase was also obtained in the amount of pitting corrosion due to mixed with a proportional trend both uniform by the action of CO₂ as a corrosion Pitting (≥50 mm in diameter).

9. CONCLUSIONS
A CO₂ concentration higher than 10% v / v generates an acid pH adverse growth BSR planktonic and sessile inhibiting their growth.

The APS generates CO₂ in the presence of corrosion Mixed mainly uniform nature with micropitting (≤20 microns), while in the presence of BSR and CO₂ corrosion it is generated Mixed mainly localized nature with ≥50 um bites on average. In the presence of BSR, a film is formed no protective surface iron sulfide (Mackinawite) and form a significant amount bites across the metal surface. The simulated APS is fouling the high Ca, Mg and Cl, which influences behavior corrosive thereof.

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