Experimental Study of the Corrosion Inhibitors CHIMEC1038 Efficiency in Gas Production Installations: A Case Study in the Algerian Gassi Touil Region

Samira Chouicha* , Abdelkader Khentout , Zineb Chaich , Smail Cheboub , Hamza Bayazid
LPTPM, Université KasdiMerbah de Ouargla, 30000 Ouargla, Algeria
Corresponding author *: samira.chouicha@gmail.com
Received: 10-05-2023 **Accepted:** 28-09-2023 **Published:** 25-12-2023

Abstract
The corrosion of gas production equipment in the Algerian Gassi Touil gas production region manifests in surface installations and poses a major problem of degradation in the presence of salts (NaCl) and iron ions in this region . Monitoring and detection ofGassi Touil corrosion are carried out through ultrasonic measurements, chemical analyses, and industrial tests involving the injection of 100% CHIMEC1038 film inhibitor. The ultrasonic test shows a decrease in thickness in the pipelines with the injection of 100% CHIMEC1038 inhibitor. Chemical analyses (iron dosage and pH) indicate a decrease in [Fe^{+2}] concentration and an increase in pH for production wells and the arrival manifold in the Nezla zone in Gassi Touil region.The industrial study demonstrates the effectiveness of the CHIMEC1038 film inhibitor in reducing the corrosion risk in production wells and the arrival manifold the efficiency is $Eff = 78{,}94\%$. Electrochemical study at T=45°C show an improvement in the efficiency of the injected corrosion inhibitor CHIMEC 1038 (E_{FF}=82.87%) to reduce the corrosion rate from V=202.9μm/year (without inhibitor) to34.93 μm/year (with inhibitor).

Keywords: CHIMEC1038, Ultrasonic, Electrochemical test, Corrosion rate, Efficiency, industrial test

Tob Regul Sci. ™ 2023 ;9(2) : 2044-2059
DOI : doi.org/10.18001/TRS.9.2.131

Introduction

Corrosion is the result of the interaction of a material (metal) with its environment. the corrosion process depends on the properties of both metal (and alloy) and surrounding environment. Usually, the more important factors causing corrosion are concentration of aggressive species (e.g., chloride), acidity (pH), iron content, fluid velocity, temperature, and potential (oxidizing power) [1,5] corrosion is a continuous problem, often difficult to eliminate completely. Prevention would be more practical and achievable than complete elimination. Corrosion processes develop fast after disruption of the protective barrier and are accompanied by a number of reactions that change the composition and properties of both the metal surface and the local environment, for example, formation of oxides, diffusion of metal cations into the coating matrix, local pH changes, and electrochemical potential [6] Corrosion is a major problem that affects most industries worldwide, causing devastating issues to the global economy. Corrosion is the deterioration of a material as a result of its interaction with its surroundings, and it can occur at any point or at any time during petroleum and natural gas processing. [7]Corrosion inhibitors are substances that, when added to an environment, decrease the rate of attack of that environment on a material such as metal. The corrosion inhibitor slows down the rate at which a metal in that environment corrodes. Corrosion inhibitors help to extend the life of equipment, minimize system failures and shutdowns, eliminate product contamination, limit heat loss, and maintain the appealing appearance of a structure. Internally, inhibitors are employed as a cost-effective corrosion control option to stainless steels and alloys, coatings, and nonmetallic composites in carbon steel pipelines and vessels, and they may often be introduced without disrupting a process. Oil and gas exploration and production, petroleum refining, chemical manufacture, heavy manufacturing, water treatment, and the product additive industries are all key users of corrosion inhibitors. [8 9 10 11 12] Many researchers have been working on the performance and mechanisms of the inhibitors based on the test results in small-scale laboratory systems. The studies of Mansfield (1985) point out that interface inhibition presumes a strong interaction between the corroding substrate and the inhibitor I21. The two dimensional adsorbate layer can affect the basic corrosion reactions in various ways : that caused by the geometric blocking effect of adsorbed inhibitive species on the metal surface, and that due to the effect of blocking the active sites on the metal surface by adsorbed inhibitive species; that due to the electro catalytic effect of the inhibitor or its reaction products. For the first case, the inhibition comes from the reduction of reaction area on the surface of the corroding metal, whereas for the other two modes, the inhibition effects are due to the changes in the average activation energy barriers of the anodic and cathodic reactions of the corrosion process. [13, 14 15 16 17]

Inhibitors forming adsorption protective films are mainly organic substances. They often have the molecular structure of a surfactant, with a hydrophilic group capable to bond with the metal surface and a hydrophobic part of the molecule protruding toward the solution bulk. Adsorbed inhibitor molecules limit oxygen diffusion and the water access to the metal surface, so reducing the corrosion rate. [18 19 20 21 22 23]The production of gas and oil in the Gas to Liquids (GTL) field in Algeria is of great importance. The GTL field is one of the largest gas and oil fields in the country and contains significant reserves of these two vital sources, with an estimated production capacity of 12 million cubic meters of gas per day from the gas fields. The operating capacity of the CPF (Central Processing Facility) ranges from 30% (3.6 million cubic meters of gas per day) to 110% (13.2 million cubic meters of gas per day). [24]The corrosion of gas and oil production equipment in this region is the process of degradation of facilities. It occurs due to the interaction of metal with the surrounding environment, including humidity, toxic gases, and acids. Corrosion can lead to the deterioration and failure of equipment, necessitating expensive measures for maintenance and replacement. [25]According to National Association of Corrosion

Engineers (NACE), estimates the global cost of corrosion to be US$2.5 trillion, equivalent to roughly 3.4 percent of the global Gross Domestic Product (GDP). The two-year global study released at the CORROSION 2016 conference in Vancouver, B.C., examined the economics of corrosion and the role of corrosion management in establishing industry best practices. The study found that implementing corrosion prevention best practices could result in global savings of between 15-35 percent of the cost of damage, or between $375-875 billion (USD). [26]. Protecting production equipment against corrosion and minimizing the economic costs associated with equipment failures are crucial concerns for industries. To achieve this, it is essential to implement effective corrosion management practices and prevention strategies. Here are some key measures to achieve this goal: Our work involves studying the corrosion issues of raw gas production equipment in GASSI TOUIL, where corrosion manifests within the above-ground installations due to the chemical attack of salt (NaCl) and iron ions. The monitoring of the corrosion problem at the Algerian Gassi Touil field is carried out through the application of specific techniques, represented by the industrial and electrochemical study of the effectiveness of the filament chemical inhibitor CHIMEC 1038 (Inhibitors forming adsorption protective films) injected in this region.

1 Presentation of the Corrosion Problem in theAlgerian Gassi Touil Field

The corrosion phenomenon poses detrimental problems both inside and outside gas-to-liquids (GTL) production equipment, such as pipe perforation, bursting, and loss of effluent circulation. Generally, the origin of this corrosion is quite complex; it is triggered by the presence of salts (NaCl) and iron ions under favorable operating conditions, leading to corrosion initiation. The equipment affected by this corrosion includes figure 1:
-Surface equipment of wells: Carbon steel sleeves downstream of the nozzle face severe hydrodynamic conditions due to the geometric variation of the pipeline,
-Junctions, manifolds of gas-producing wells, and various collectors

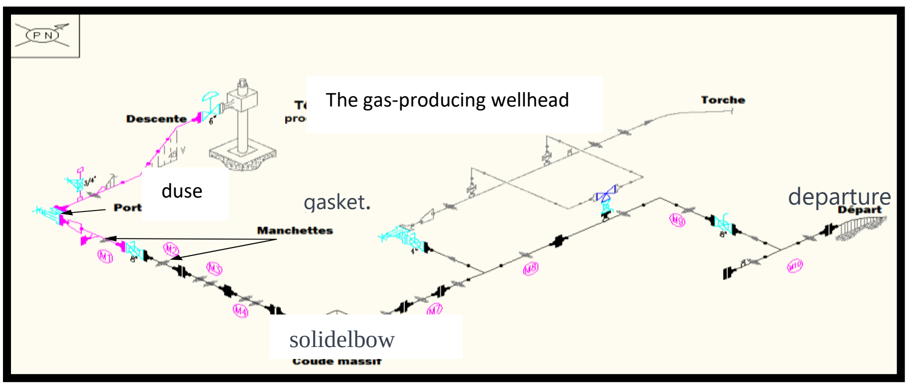

Figure1 : Surface Installation of a PPG from the Wellhead to the Departure to the Manifold

2 Inspections and Corrosion Detection

The thickness measurements are carried out by Ultrasonic testing. This technique is based on transmission and reflection of ultrasonic waves inside the pipes to be inspected are carried out by a transducer with frequencies ranging from 100 kHz to 25 MHz, which are beyond the audible range for the human ear. The thickness values of the pipelines are displayed directly on the device's screen. We measured the thickness at the point of perforation of the 4'' GT44 pipe figure2 from the SAT inlet to the CP production center.

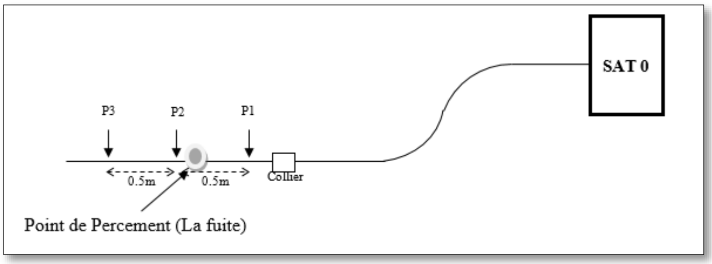

Figure 2 : Thickness Measurement at the Point of Perforation of 4'' Pipe

Table 1: Thickness Measurement Results at the Point of Perforation

Points	12 :00	03 :00	06 :00	09 :00
P01	5.74	2.95	4.24	4.99
P02	4.43	3.06	3.47	3.47
P03	3.66	3.01	2.87	3.54

Figure 3: Perforation Level of 4'' Pipe

After Visual Inspection and Thickness Measurements, a significant thickness degradation was observed in the buried section of the 4'' pipeline.

3 Experimental study of the inhibitor CHIMEC1038

3-1 Procedure for the Analysis of Iron Contentand PH

This procedure is applicable to various sampling points within the oil and gas facilities of the GASSI TOUIL field (Wells, Manifolds, CPF, CP). [25]

This procedure outlines the steps for preparing and analyzing a sample for iron concentration using a spectrophotometer. We Use a pipette to draw 1ml of water into a 100ml flask. Also, take 10 ml of the prepared sample into a 10ml vial. Then we place the vial with the prepared sample into the spectrophotometer and initialize it to the 'zero' value.and we perform titration with the iron-over reagent and agitate, We Insert the vial with the prepared sample into the

spectrophotometer for 3 minutes. After a 3-minute reaction in the spectrophotometer, press 'measure,' and read the result. Finally we Multiply the value displayed on the spectrophotometer screen by 100 to obtain the iron concentration value in (g/L) of iron."
The procedure of Separation Using Decantation Bulb and pH Measurement using pH meter we Transfer the sample to an ampoule ofdecantation for effective separation of water and condensate. Then we ensure a clear distinction between the two phases to obtain accurate measurements. We Use a pH meterfor pH measurement. We Immerse the pH electrode in the separated sample and record the pH value.

3-2Treatment Procedure for industrial study of inhibitor CHIMEC 1038

Corrosion inhibitor treatment by CHIMEC 1038 is carried out through continuous injection into the first sleeve downstream of the wells and manifolds of Nazzla zone using a dosing pump powered by solar panels and calibrated to achieve the optimal concentration of the inhibitor. The continuous treatment is conducted in two stages: The first stage involves administering a shock treatment necessary for the formation of the inhibitor film (the duration of this stage can extend up to 24 hours). The second stage involves maintaining the film, where the inhibitor concentration is reduced to a low dose in this treatment mode. The operator must ensure the proper functioning of the dosing pumps and the continuous availability of the corrosion inhibitor.

Table 3 : Safety Data Sheet for Inhibitor CHIMEC 1038 [27]

Physical proprieties of CHIMEC 1038	Film forming inhibitors
Appearance	liquid
Density at 20°c kg/m3	885
Viscosity at 20°c mPa s	<50
Solubility	Soluble in hydrocarbons and dispersible in water

3-3 Electrochemical Study of Inhibitor CHIMEC 1038

The purpose is to study the inhibitory effectiveness of CHIMEC 1038 on the corrosion of X65 steel in the corrosive environment of the Gassi Touil field. The study was conducted using electrochemical methods at the CRAPC laboratory in Ouargla figure 4,5 and 6, with the assistance of a Voltalab 40 (PGZ 301) controlled by a microcomputer (Voltamaster 04 Software). A three-electrode setup was employed for the study.

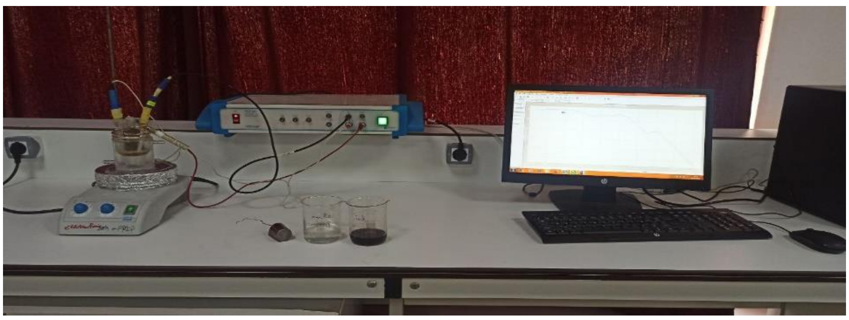

Figure 4 Experimental Setup3

3-1 Description of the Experimental Setup:

In all experiments, a three-electrode setup was employed, consisting of a reference electrode, an auxiliary electrode, and a working electrode. The Voltalab equipment was utilized to trace potential curves, impedance, and subsequently the Tafel curve.

Figure 5: Voltalab Apparatus

3-3-2 Electrochemical Cell:

The electrochemical cell used is made of PYREX glass with a capacity of 100 ml, providing a sufficient volume to maintain a constant concentration of electroactive species during manipulation. It features a double wall and a cover with 5 openings to accommodate the three electrodes and the degassing tube.

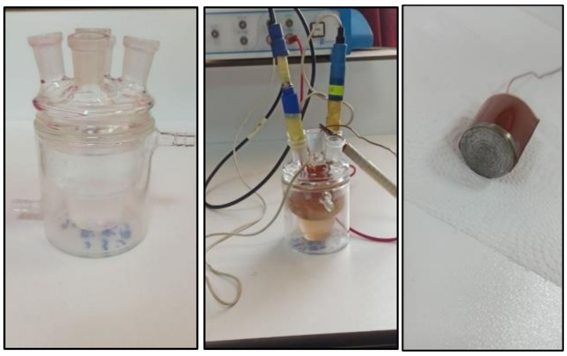

Figure 6 . Electrochemical Cell

Electrodes:

a. **Working Electrode**: Comprised of a clean 3cm surface X65 steel plate prepared with sandpaper.
b. **Auxiliary Electrode** (Counter Electrode): A platinum wire was used as the counter electrode.
c. **Reference Electrode**: All potential measurements were taken with respect to the saturated calomel electrode (SCE) in potassium chloride (KCl).

.An X65 steel sample with the chemical composition as specified in Table 4 was used to prepare the working electrode.

Table 4: Chemical Composition in % of X65 Steel [28]

	C	Si	Mn	P	S	Mo	Ni	Al	Cu	V	Nb
Min	0,05	0,15	1,00	-	-	-	-	0,01	-	-	-
Max	0,14	0,35	1,50	0,020	0,005	0,25	0,25	0,04	0,080	0,080	0,040

3.3.3Experimental Products and Procedures

Products Used:

a. **Corrosive Medium**: A sample of Gassi Touil groundwater was used, taken from connection J6, with a salinity of 1.57g/l and a pH range of 5-7.

b. **Corrosion Inhibitor:** CHIMEC 1038 inhibitor, with properties mentioned earlier, was used.

c. **Distilled Water**: Used for diluting the inhibitor and cleaning the experimental equipment.

3-3-4 Experimental Procedures

The electrochemical cell, made of PYREX glass, was utilized for the experiments.The working electrode, composed of X65 steel, was prepared using a specific chemical composition mentioned in Table 4. The three-electrode setup included a reference electrode (saturated calomel electrode in potassium chloride), an auxiliary electrode (platinum wire), and the working electrode. The experimental procedures involved the use of the Voltalab apparatus for tracing Tafel curves. The corrosive medium, inhibitor, and distilled water were applied in different stages of the experiments to evaluate the inhibitory effectiveness of CHIMEC 1038 on the corrosion of X65 steel in the GTL field's corrosive environment.Without inhibitor,we prepare 100ml of the corrosive medium reacts with the

steel sample at temperaturesof 25°C and55°C. we prepare asolution with a 100 ml beaker; we added 2 ml of the inhibitor to 98 ml of the corrosive medium at temperatures of 25°C and 45°C.

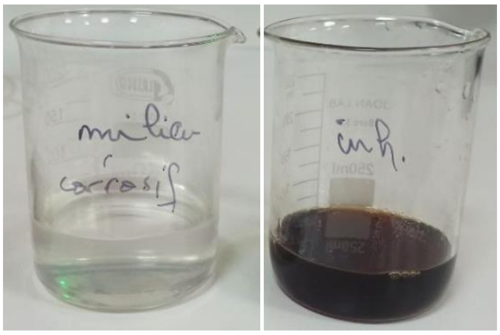

Figure 7 Preparation of solution and inhibitors Chimec 1038

4 Results and discussion

a. **Study of the Effectiveness of Inhibitor CHIMEC 1038**

This study aims to assess the effectiveness of this inhibitor on our surface production equipment after injecting it between the wellhead and the nozzle. The study involves measuring corrosion rates and conducting laboratory analyses on collected water samples. PH and Iron Content

b. **Evolution Before and After CHIMEC 1038 Injection**

The analysis of iron content and pH in figure 4 before and after the injection of CHIMEC 1038 at well TP NZ25 reveals the following trends: The PH increased from 6 and 7 (before) to 6.76 (after) during the blank test [Fe^{+2}] = 34 mg/l. After CHIMEC 1038 injection, [Fe^{+2}] varied between 22 mg/l and 16 mg/l, and during the difilming phase, [Fe^{+2}] was at 44 mg/l.

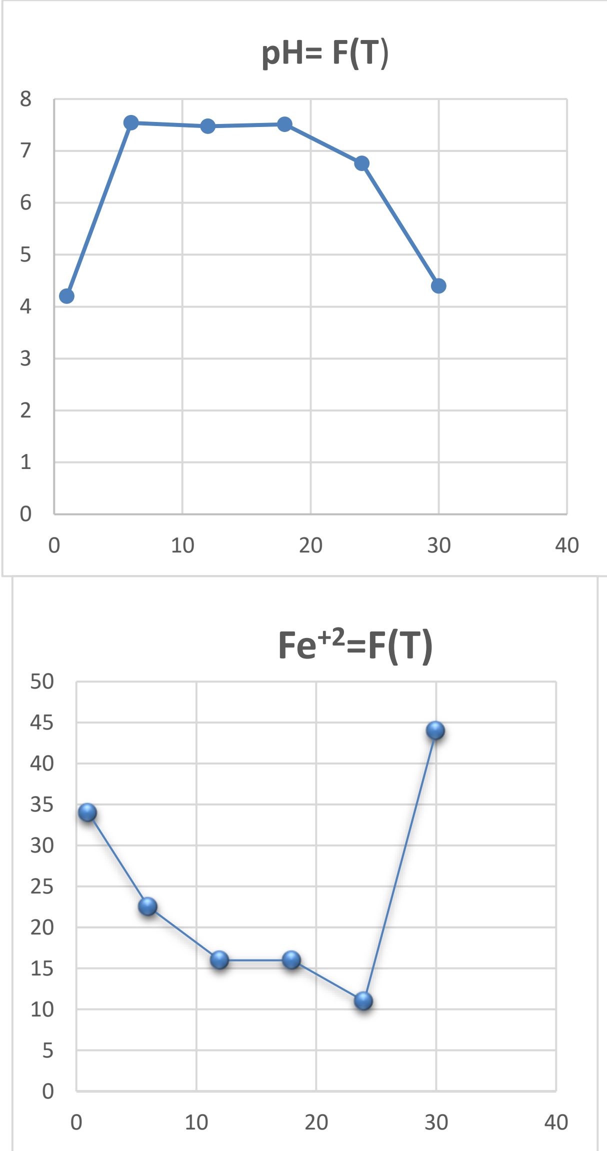

Figure 8 : The Evolution of Iron Content and pH Before and After CHIMEC 1038 Injection at Well TP NZ25

c. **The Evolution of pH and Iron Content at the MFD NZ25 Inlet**

Figure 8 illustrates that the pH increased from 5.8 to 6.24 after the injection of CHIMEC 1038, accompanied by a decrease in iron content from 190 to 43. This change confirms the neutralizing action of this inhibitor.

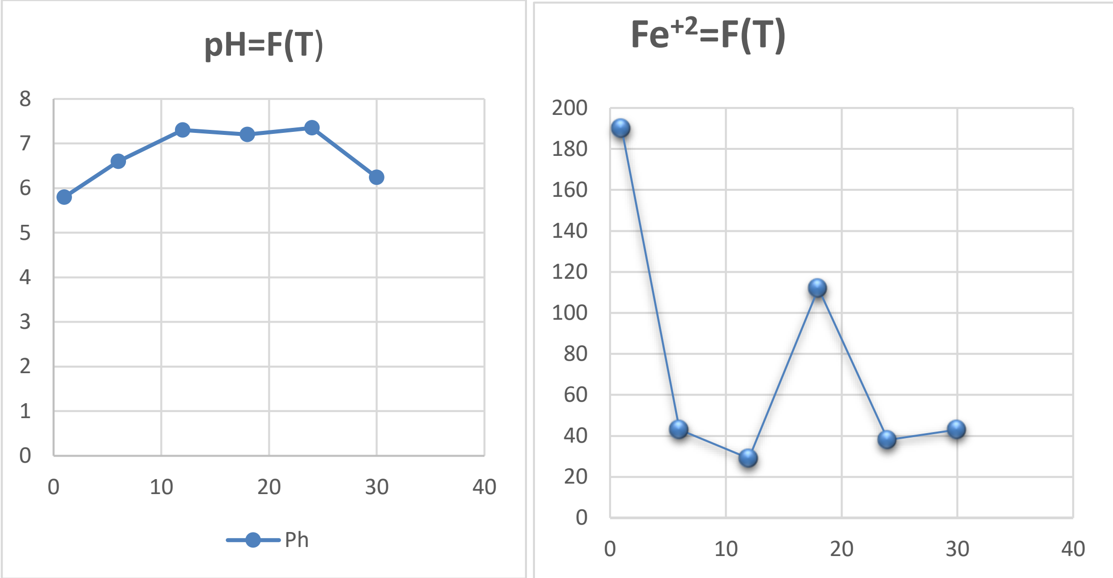

Figure 9 The Evolution of Iron Content and pH before and After CHIMEC 1038 Injection at the MFD NZ25 Inlet

d. **The Evolution of pH and Iron Content at Well TP NZ26**

Similarly, the analysis results of PH at the collector's departure point (Figure 10) reveal an increase in PH from 4.2 to 5.72. Additionally, the iron content decreased from 34 mg/l to 13.5 mg/l.

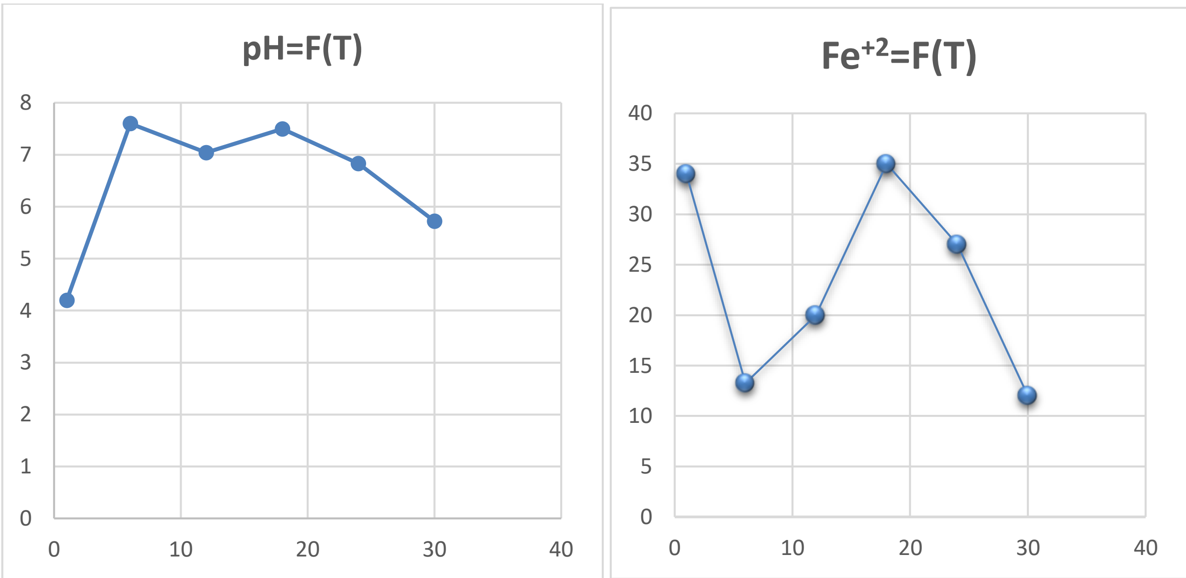

Figure 10 :The Evolution of Iron Content and pH Before and After CHIMEC 1038 Injection at Well TP NZ26

e. . The Evolution of pH and Iron Content at the MFD NZ26 Inlet

At the entrance of the module, there is also an observed increase in pH from 5.9 to 6.26 and a decrease in iron content from 140 to 42 (Figure 11). The effect of the inhibitor is clearly evident on the PH of the environment and the iron content.

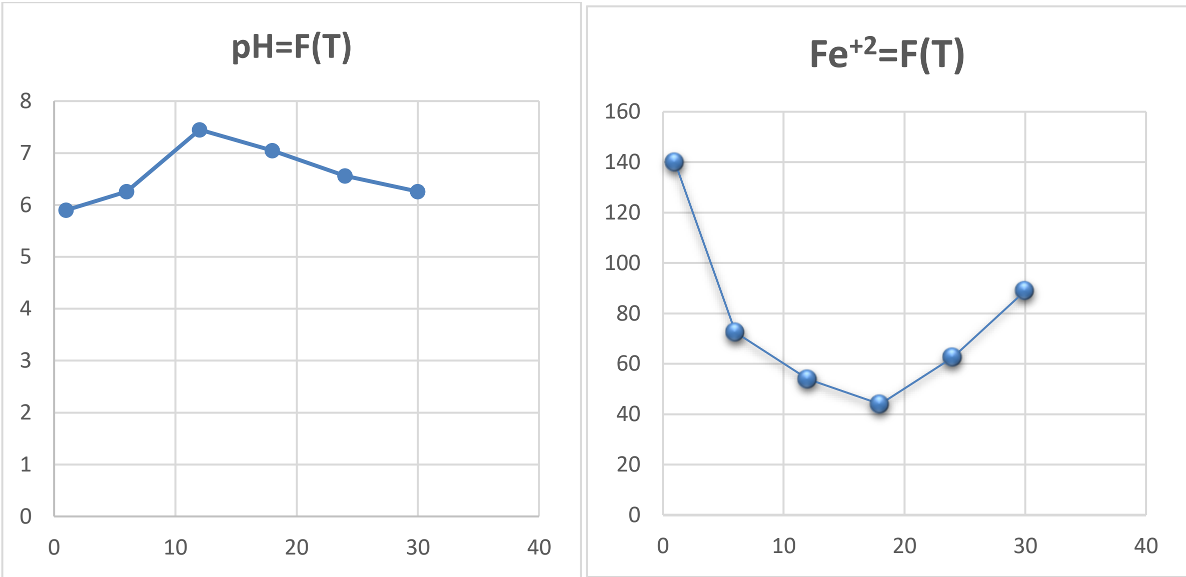

Figure 11 :The Evolution of Iron Content and PH Before and After CHIMEC 1038 Injection at the MFD NZ26 Inlet

The industrial test of the corrosion inhibitor gas CHIMEC 1038 from the CHIMEC company has been underway under normal conditions since its initiation on 12/01/2023. The evaluation of treatment effectiveness for each injection stage is currently being conducted by the DTD/SH team and the Corrosion Inspection Service of GTL, in the presence of the representative from CHIMEC 1038, with the aim of drawing conclusive results. The test results figure 8 ,9, 10 and 11 indicate a positive impact of the inhibitor. There is a noticeable decrease in iron content, suggesting effective corrosion inhibition. Additionally, there is an increase in PH values, further supporting the inhibitory action of the treatment. From the corrosion rate measurements withowt and with inhibitors chimec1038 it was possible to determinate the efficiency related to the industrial study

$$E_{FF}=\frac{Vcb-Vab}{Vab}\times 100 \quad (1)$$

Vcb ,Vab are the corrosion rate measured before and after the injection of the inhibitors CHIMEC 1038.

$$E_{FF}=\frac{380-80}{Vab380}\times 100 = 78{,}94\% \quad (2)$$

These findings suggest that the inhibitor, likely CHIMEC 1038, is demonstrating effectiveness in reducing corrosion (as evidenced by lower iron content) and influencing the PH of the system positively.

4-2 Evaluation of corrosion rate

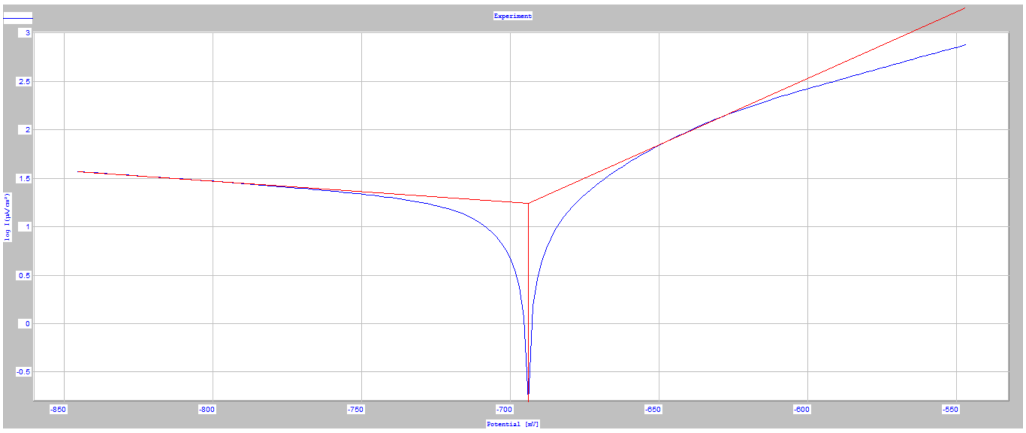

Figure 12 Tafel curve without inhibitor at 45°C.

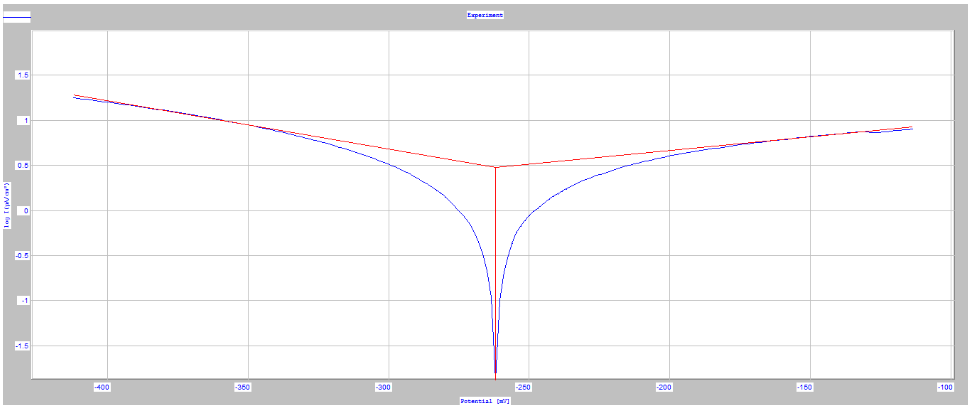

Figure 13 Tafel curve with inhibitor at 45°C

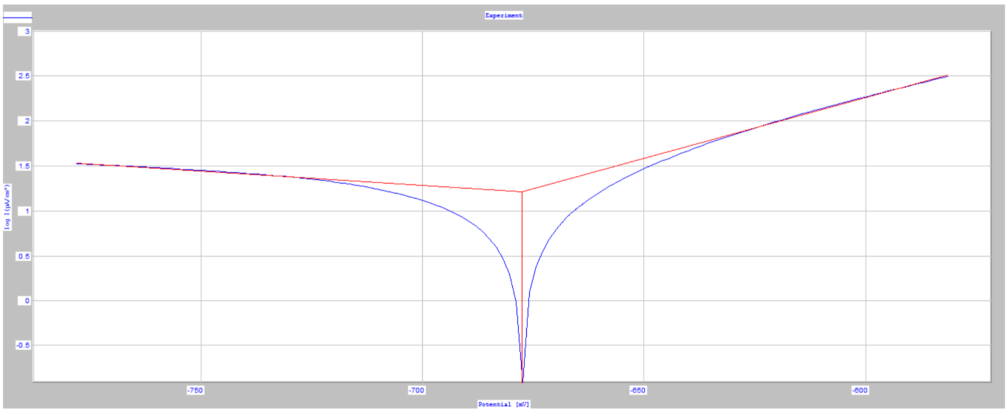

Figure 14: Tafel curve without inhibitor at 25°C.

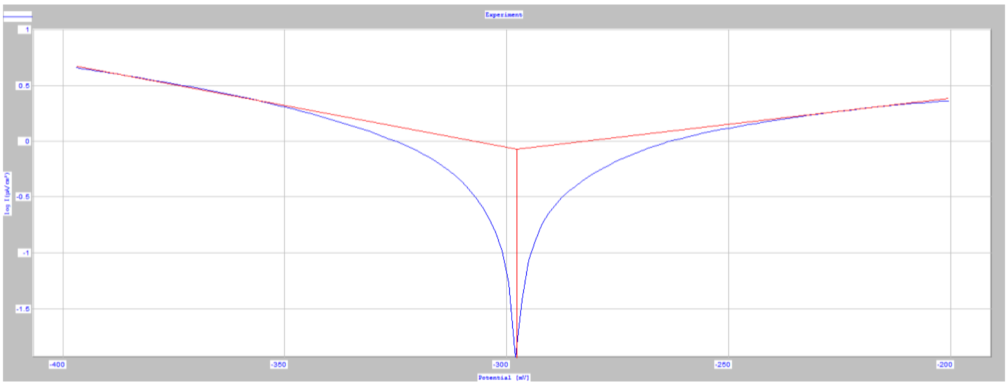

Figure 15: Tafel curve with inhibitor at 25°C.

The Tafel curves 12 and 13 present the variation of electrical current as a function of potential. The intersection of the Tafel lines provides the corrosion current and potential of X65 steel (material used in the installationsof gas production in Gassi Touil field) for two experimental temperatures, T=25°C and T=45°C.The Tafel curves 14 and 15 with the addition of CHIMEC1038 show that the electrical current density decreases, and the corrosion rate decreases:This is explained by the formation of the CHIMEC1038 inhibitor film on the metal surface across a wide potential range.The results of the variation in corrosion rate for experiments with and without inhibitors are shown in the following table 5

Table 5: Results of the Tafel curve with and without CHIMEC1038 inhibitor.

Expériments	Rp Kohm .cm²	Vcorr µm/an	Ecorr Mv	Icorr µA/cm²	Beta a mV	Beta c mV
25°C withoutinhibitor	1.41	191.1	-677.6	16.3469	74.0	-316.4
25°C withinhibitor	31.29	9.897	-297.7	0.8462	202.0	-133.3
45°C withoutinhibitor	1.26	202.9	-694.0	17.3520	72.9	-458.6
45°C withinhibitor	13.55	34.93	-262.1	2.9872	325.3	-184.9

Rp: Polarization resistance of the metal/solution interface expressed in Kohm.cm².

Vcorr: Corrosion rate of API 5LX65 steel expressed in µm/year.

Ecorr: Corrosion potential expressed in mV.

Icorr: Corrosion current expressed in mA/cm².

Beta a: Anodic beta coefficient in mV.

Beta c: Cathodic beta coefficient in mV

4-5 Determination of Corrosion Inhibitor Efficiency

The relationship to determine the efficiency of the corrosion inhibitor has been established based on the ratio of polarization resistance to the resistance of the blank (lacking inhibitor)..

$$\text{Eff (\%)} = \frac{(\text{Icorr} - \text{I'corr})}{\text{Icorr}} \text{ X } 100 \quad (3)$$

Eff: Corrosion inhibitor efficiency expressed in %

Icorr: Value of corrosion current density in the absence of the studied inhibitor

I'corr: Value of corrosion current density in the presence of the studied inhibitor

Table 6: Corrosion inhibitor efficiency

Expériments	I'corr	Eff(%)
25°C withoutinhibitor	16.3469	0%
45°C withoutinhibitor	17.352	0%
45°C withinhibitor	2.9872	82.87%

According to the electrochemical test table 6 of the corrosion inhibitor CHIMEC1038 at 100%, an efficiency of Eff=82.87% and a corrosion rate of V_corr=34.93 µm/year were obtained. The results are significant for ensuring the protection of surface equipment with the formation of the film along the installations.

Conclusion

Our work involves the study of corrosion in the production equipment of raw gas at Algerian GASSI TOUIL region, where corrosion manifests within the aerial installations through the chemical attack of salts (NaCl) and iron ions. This leads to perforations in the installations, resulting in the leakage of effluents and subsequently causing disruptions in the production of raw gas at the GASSI TOUIL field

The detection of corrosion issues at the Gassi Touil field is accomplished through the application of specific inspection techniques, primarily represented by chemical analyses in the laboratory (iron dosing and pH measurement). Additionally, non-destructive control is performed by measuring the thickness of piping using ultrasound. The monitoring of corrosion speed is carried out through the use of an ER probe, allowing us to evaluate the effectiveness of corrosion protection methods, specifically through the injection of corrosion inhibitor CHIMEC1038 for surface installations.

The industrial tests conducted in several production wells (wells NZ25, NZ26, NZ28) show that the efficiency of CHIMEC 1038 is equal to 78.94% with an optimized injection rate: injection rate = (NZ25 = 201.63 Liters), (NZ26 = 305.37 Liters), (NZ28 = 196.95 Liters). The impact of corrosion inhibitors was analyzed through the chemical examination of pH and iron content in the water associated with the effluent

The results obtained indicate a decrease in [Fe^{+2}] and an increase in the pH value:

Well NZ25 (iron rate 34 to 15, pH 4.2 to 7.54)

Well NZ26 (iron rate 34 to 12, pH 4.2 to 7.6)

Well NZ28 (iron rate 20 to 5, pH 4.2 to 7.8)

The control of the thickness of aerial installations (pipes, elbows, etc.) provides positive results after the formation of the inhibitor film on the surfaces of the installations. Corrosion velocity measurements justify the effectiveness of the corrosion inhibitor CHIMEC1038.

Electrochemical tests conducted using the voltalab apparatus PGZ301 at T=45°C indicate the interpretation of corrosion in the installations through experimental Tafel and impedance curves. The experimental results demonstrate that the efficiency of the corrosion inhibitor CHIMEC 1038 is 100%, with Effi = 82.87%, and Vcorr = 34.93µm/year.

References

[1] Alicia E. Ares , 1 Rau´l B. Rebak,2 Marı´a V. Biezma , 3 and Claudia M. Me´ndez Corrosion of Nonferrous Metals and Their Alloys Advances in Materials Science and Engineering Volume 2018, Article ID 8929512, 2 pages https://doi.org/10.1155/2018/8929512

[2] MEMON SAMINA, ABDUL KARIM and A.VENKATACHALAM* CODEN ECJHAO E-Journal of Chemistry http://www.e-journals.net 2011, 8(S1), S344-S348 ISSN: 0973-4945;

[3] Renato Altobelli Advances in Corrosion and Protection of Materials Antunes Center for Engineering, Modeling and Applied Social Sciences, Federal University of ABC, Av. Dos Estados, 5001, Santo André 09210-580, SP, Brazil; Metals 2023, 13(6), 1059; https://doi.org/10.3390/met13061059

[4] V. S. Raja Grand Challenges in Metal Corrosion and Protection Research SPECIALTY GRAND CHALLENGE article Front. Met. Alloy, 25 May 2022 Sec. Metal Corrosion and Protection Volume 1 - 2022 | https://doi.org/10.3389/ftmal.2022.894181

[5] S. Harsimran Santosh Kumar K. Rakesh OVERVIEW OF CORROSION AND ITS CONTROL: A CRITICAL REVIEW Proceedings on Engineering Sciences 3(1):13-24 DOI:10.24874/PES03.01.002

[6] Hong Ju, Li Ding, Can Sun, and Jie-jing Chen Quantum Chemical Study on the Corrosion Inhibition of Some Oxadiazoles Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2015, Article ID 519606, 5 pages http://dx.doi.org/10.1155/2015/519606

[7] Suchithra Shanmughan , 1 Sampathkumar Velusamy , 1 Jothi Lakshmi Nallasamy,1 Kothai Palanisamy Selvakumar,1 Pradeep Thirumoorthy,1 M. M. Saravanan,2 Haripriya Sakthivel,3 Mageshkumar Periyasamy , 4 and Ramachandran Kasiraja Critical Study on Corrosion Inhibitors in U-Shaped RCC Beams Hindawi Advances in Materials Science and Engineering Volume 2022, Article ID 4762524, 8 pages https://doi.org/10.1155/2022/4762524

[8] I. A. Wonnie Ma, Sh. Ammar, Sachin S. A. Kumar, K. Ramesh S. Ramesh 1. A concise review on corrosion inhibitors: types, mechanisms and electrochemical evaluation studies journal of Coatings Technology and Research Review Article Published: 29 November 2021 Volume 19, pages 241–268, (2022)

[9] Abdulhadi Kadhum Ahmed Abdulamir Hussain Al-Amiery Razi Jabur Al-Azawi Ruaa H. Abbas Corrosion inhibitors. A review International Journal of Corrosion and Scale Inhibition 10(1):54-67 DOI:10.17675/2305-6894-2021-10-1-3

[10] Shaymaa Abbas Abdulsada Corrosion Inhibitors :Principles and Application Publisher: LAP LAMBERT Academic Publishing ISBN: 978-3-659-56603-5 January 2014

[11] Panel Saman Zehra, Mohammad Mobin, Ruby Aslam Corrosion inhibitors: an introduction Environmentally Sustainable Corrosion Inhibitors Fundamentals and Industrial Applications 2022, Pages 47-67

[12] Walid Daoudi , Abdelmalik El Aatiaoui , Siham Echihi , Brahim El Ibrahimi , AdylOussaid Corrosion inhibition: current trends and challenges Computational Modelling and Simulations for Designing of Corrosion Inhibitors Fundamentals and Realistic Applications 2023, Pages 3-21

[13] R. Aslam a, M. Mobin a, S. Zehra a, J. Aslam A comprehensive review of corrosion inhibitors employed to mitigate stainless steel corrosion in different environments b Journal of Molecular Liquids Volume 364, 15 October 2022, 119992

[14] Ekemini D. Akpan a b, Ashish Kumar Singh c d, Hassane Lgaz e, Taiwo W. Quadri a b, Sudhish KumarShukla f, Bindu Mangla g, Abhishek Dwivedi h, Omar Dagdag i, Sheetal d, Etienying Edem Inyang j, Eno E. Ebenso Coordination compounds as corrosion inhibitors of metals: A review Coordination Chemistry Reviews Volume 499, 15 January 2024, 215503

[15] I. A. Wonnie Ma, Sh. Ammar, Sachin S. A. Kumar, K. Ramesh & S. Ramesh A concise review on corrosion inhibitors: types, mechanisms and electrochemical evaluation studies •Journal of Coatings Technology and Research Published: 29 November 2021Volume 19, pages 241–268, (2022)

[16] Mohd Qasim Ansari Rajpal Tyagi COMPARATIVE STUDY OF INHIBITION EFFICIENCY USING DIFFERENT TYPES OF CORROSION INHIBITORS FOR DIFFERENT ALLOYS https://www.researchgate.net/publication/369322457 IJARIIE-ISSN(O)-2395-4396 ol-4 Issue-6 2018

[17]AhmedA.Al Amiery1,2*, Abu Bakar Mohamad , AbdulAmir H. Kadhum3 , Lina M. Shaker2 , Wan Nor Roslam Wan Isahak2 & Mohd S.Takrif, Experimental and theoretical study on the corrosion inhibition of mild steel by nonanedioic acid derivative in hydrochloric acid Scientifc Reports | (2022) 12:4705 | https://doi.org/10.1038/s41598-022-08146-8

[18]panelJiakai Zhou, Xinhuan Niu, Yaqi Cui, Zhi Wang, Jianchao Wang, Ru Wang Study on the film forming mechanism, corrosion inhibition effect and synergistic action of two different inhibitors on copper surface chemical mechanical polishing for GLSI Applied Surface Science Volume 505, 1 March 2020, 144507

[19] panelEvgenyBarmatov, Trevor Hughes, Michaela Nagl Efficiency of film-forming corrosion inhibitors in strong hydrochloric acid under laminar and turbulent flow conditions Corrosion Science Volume 92, March 2015, Pages 85-94

[20] A.P. Morizot; Anne Neville A Study of Inhibitor Film Formation Using an Electrochemical Technique Paper presented at the CORROSION 2000, Orlando, Florida, March 2000. Paper Number: NACE-00108 Published: March 26 2000

[21]panelE. Szőcs a, Gy. Vastag b, A. Shaban a, E. Kálmán Electrochemical behaviour of an inhibitor film formed on copper surface Corrosion Science Volume 47, Issue 4, April 2005, Pages 893-908

[22]panelArnaud P. Morizot, Anne Neville 1 Insights into Electrodeposition of an Inhibitor Film and Its Inhibitive Effects on Calcium Carbonate Deposition Journal of Colloid and Interface Science Volume 245, Issue 1, 1 January 2002, Pages 40-49

[23] Mohammad A Jafar Mazumder* Global Impact of Corrosion: Occurrence, Cost and Mitigation Global Journal of Engineering Sciences (GJES) 2020

[24] SH-DP-Direction Régionale GTL, présentation de GTL

[25] C. J. P. BOUMERSBACH, electrochemical characterization of a corrosion inhibitor: influence of temperature on the inhibition mechanism. » 207th meeting of the electrochemical society, Quebec City (Canada, 15-20 mai 2005.

[26] Mohammad A Jafar Mazumder* Global Impact of Corrosion: Occurrence, Cost and Mitigation Global Journal of Engineering Sciences (GJES) 2020

[27] Kheira Gharbi · Samira Chouicha · Malcolm Andrew Kelland Field test investigation of the performance of corrosion inhibitors: a case study Journal of Petroleum Exploration and Production Technology https://doi.org/10.1007/s13202-021-01287-y

[28] Panel Hassan M. Hussein Farh, Mohamed El Amine Ben Seghier, Tarek Zayed A comprehensive review of corrosion protection and control techniques for metallic pipelines Engineering Failure Analysis Volume 143, Part A, January 2023, 106885