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**Use of the corrosion inhibitors in the petroleum  
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# *Dedication*

*First and foremost, thank you, Allah, for always being there for us.*

*Thanks to our parents for their love and support throughout our lives. Thank you for giving us strength to reach for the stars and chase our dreams.*

*To our sisters and brothers our family's (Mekhloufi's and Rebih's) because they deserve our wholehearted thanks as well.*

*To all our friends, thank you for your understanding and encouragement in many, many moments of crisis. we cannot list all the names here, but thanks all.*

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*LISTE OF ABBREVIATIONS*

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- **ISO :** International Organization for Standardization
- **API :** American Petroleum Institut
- **SRB :** Sulfate-Reducing Bacteria
- **TFT :** Tin Fouye Tabnkourt.
- **EPS :** Extracellular Polymeric Substances
- **BTR:** Bacteria Thiosulfato-Reducing
- **VCI :** Volatile Corrosion Inhibitors
- **LNG:** Liquefied Natural Gas
- **LPG :** Liquefied Petroleum Gas
- **TAM:** Tin Amassak, a name for a water well area.
- **TFNE:** Tin Fouyé Nord Eau, a name for a water well region.
- **NORUST CR486:** commercial name of an inhibitor.
- **Biocide CHIMEC 7162:** commercial name of a bactericide

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## الملخص

يعد التآكل من اهم المشاكل التي تتعرض لها الصناعة البترولية والتي لحد ساعة لم يجد لها الخبراء حلول نهائية ولكن بالمقابل استطاعوا وضع بعض طرق الوقاية منه. ومن بين انواع التآكل الكثيرة نجد التآكل الذي تسببه بكتيريا الكبريتو والتي تنجم عنه خسائر مادية ضخمة تقدر بملايين الدينارات.

الهدف من هذا العمل هو دراسة مشاكل التآكل للأنابيب الموصلة للمياه في منطقة TFT ، ويعرض التقنيات الصناعية المستخدمة لقياس هذه المشاكل والتحكم فيها.

تم اجراء التجارب بمنطقة الصناعية TFT حيث تم حقن نوعين من المثبطات NORUST CR 486 و المبيد الحيوي CHIMIC 7162 في الانابيب البترولية وذلك للحد من التآكل و لدراسة سرعته استعمل تقنيات مختلفة مثل قسيمات التآكل و جهاز AquaMate . بعد مدة من المعالجة ( حقن المستمر , حقن بالصدمات ) اظهرت النتائج ان المثبط NORUST CR 486 فعال و يعمل بصورة اكبر في محاولة تبطيء سرعة التآكل .

.**الكلمات المفتاحية:** مثبطات التآكل ، بكتيريا الكبريتو، تآكل البكتيري ، مبيد الجراثيم ، سرعة التآكل .

## Abstract

Corrosion is one of the most important problems affecting the petroleum industry, for which up to an hour experts have not found definitive solutions, but have been able to develop some methods of prevention. Among the many types of corrosion, the corrosion caused by the sulphate-reducing bacteria results in huge material losses of millions of dinars.

The aim of this work is to study corrosion problems of pipes conducting water in the TFT region, and presents the industrial techniques used to measure and control these problems.

Experiments were conducted in TFT industrial area, where two types of inhibitors NORUST CR 486 and biocide CHIMIC 7162 were injected into petroleum pipelines in order to reduce corrosion and to study its speed using different techniques such as corrosion coupons and AquaMate device. After a period of treatment (continuous injection, shock injection) the results showed that the inhibitor NORUST CR 486 is effective and works more in an attempt to slow down the corrosion rate.

**Key words:** corrosion inhibitor, sulphate reducing bacteria, bacterial corrosion, bactericide, corrosion rate.

## General introduction

The transport of hydrocarbons by pipeline remains the most used means to transport large quantities of oil and gas, over long distances. In the oil and gas industry, corrosion in all its forms constitutes a permanent danger for metal installations. It is in this context that the double importance of the study of corrosion appears. The first is economic, it concerns the reduction of material losses resulting from sudden deterioration or rupture of tubing, tanks, marine structures ect... the second is conservation applied first to the metal resources, whose world reserves are limited, and whose destruction involves corresponding losses of energy and water reserves accompanying the production and manufacture of metal structures.

Algeria's oil wealth is one of the leading oil-exporting countries, producing around 1,483.8 Kbbbl/d [1]. This brings us back to the importance of transportation systems. However, low-alloy steel pipes carrying water used for oil extraction may be subject to corrosion caused by sulfatoreductive bacteria. These can cause huge damage in transport lines. Due to this there are many ways to avoid or control corrosion hazard.

Amongst all the techniques, the use of corrosion inhibitor in controlling problems related to corrosion, is an old, reliable method employed by industries. Corrosion inhibitors make possible to use ordinary metallic materials of construction in very aggressive and hostile environments where even especially designed expensive materials catastrophically fail. An added advantage in using of the inhibitors to control corrosion is that no major alternation in existing plant and machineries is required while switching over from one -inhibitor to another improved product [1].

The aim of this project is to study corrosion problems of pipes conducting water in the TFT region, and presents the industrial techniques used to measure and control these problems.

This work has four chapters. The first is devoted to a description on the theory of corrosion. in the second chapter we talked about the bacterian corrosion. general informations and how can we deal with it. In the third chapter we presented information about inhibitors and its different types. Then we proceed to the techniques of prevention against this problem in the fourth chapter where we have explained the different methods of surveillance and inspection accompanied by an interpretation of the results, this allowed an evaluation of the treatment against the corrosion problem. Finally, concludes with a general conclusion and some recommendations.

**Chapter One:**  
**GENERAL INFORMATION OF**  
**CORROSION**

## I. Introduction

The importance of corrosion is no longer to be proved. It can affect many structures, especially those made of metallic materials. In fact, metallic materials and more particularly steels, which are the basic materials in the construction of many structures, are highly exposed to corrosion when contact with aggressive environment. This chapter presents a revision of the General information of corrosion.

### I.1. Definition

According to international standard ISO 8044:1999, corrosion is defined as the physical-chemical interaction between a metal and its surrounding environment resulting in changes in the properties of the metal and which may lead to a significant degradation of the function of the metal, the surrounding environment or the technical system of which they are a part [2].

Corrosion of a material is the degradation of the material or its mechanical properties under the influence of the immediate environment, atmosphere, water or other fluids oxygen and/or air constituents ( $H_2O$ ,  $CO_2$ ,  $SO_2$ ,  $H_2S$ ,...etc), a hot gas ( $O_2$ ,  $CO$ ,  $CO_2$ ,...etc), a solution (acid, basic, molten salt). Given the large number of parameters involved in the electrochemical process, corrosion is a very complex phenomenon and can be seen in its overall form as a spontaneous reaction of electron exchange at the interface (metal/ environment). It is a natural phenomenon, which tends to return the metals to their oxide state by a more or less rapid attack of the corrosive medium [3,4].

### I.2. Adverse economic and social effects of corrosion

The corrosion affects severely on the safe, reliable and efficient operation of equipment and structures than the simple loss of a mass of metal. Failures of all kind of machineries and the need for expensive replacements may occur even though the amount of metal destroyed is quite small. Some of the major harmful effects of corrosion can be listed below nuclear plant shutdown due to failure, for example, nuclear reactor during decontamination process [5,6]:

- Replacement of corroded equipment resulting in heavy expenditure.
- High cost preventive maintenance such as painting.
- Loss of efficiency and product from a corroded container.
- Safety requirement measures from a fire hazard, explosion, or release of toxic product.
- Health problems, for example, drinking water contamination with lead is likely due to corrosion

### I.3. The types of corrosion

Corrosion can develop according to different processes that characterize each type of corrosion:

#### I.3.1. Chemical corrosion

It occurs when the metal has a perfectly homogeneous surface and the reaction mixture in contact with it is perfectly homogeneous. The metal in this case is attacked in the same way; there is no flow of electrons within the metal. For example, oxidation of ordinary steel at high temperature by air oxygen [6].

#### I.3.2. Biochemical corrosion

It is the bacterial attack of metallic materials (Figure I.1), especially in underground pipes and tanks. Indeed, the metabolism of the development of certain bacteria causes the formation of sulphuric acid that attacks the metal [7].



Figure I.1: Biochemical corrosion [7].

#### I.3.3. Electrochemical corrosion

Metals are generally not single-phase. When immersed in a reagent, they are thus most often the site of electrochemical corrosion, which is produced mainly by the oxidation of a metal in the form of ions or oxides and the reduction of existing corrosive agents in the electrolyte solution. In addition, it results in electronic transfers between a metal and an electrolytic solution at its contact (circulation of an electric current). This type of corrosion can be caused by heterogeneity either in the metal or in the reagent. The existence of heterogeneity determines the formation of an electric battery; thus an electric current circulates between anodes and cathodes in the reagent and the areas that make up the anodes are attacked (corroded). It requires the presence of a reducer,  $H_2O$ ,  $H_2$ ,...etc, without it, the corrosion of the metal (anodic reaction) cannot occur

Electrochemical corrosion must therefore combine some factors at the same time [8,9] :

- **An anode:** this is the part of the metal where the oxidation reaction develops leading to the dissolution of this part in the form of positive cations in the aqueous medium.
- **A cathode:** It is the part of the metal where the reduction reaction of a species contained in the electrolyte develops (release of hydrogen by reduction of  $H^+$  ions, formation of water by reduction of oxygen in an acidic medium, formation of  $OH^-$  ions by reduction of oxygen in a basic medium, deposition of a metal by reduction of one of its cations) an electrical conductor, which

can transport the electrons released from the anode to the cathode. The metal itself ensures this role.

- **An ionic conductor:** which can allow the migration of the cations released from the anode to the anions released at the cathode to ensure electric neutrality and close the electrical circuit. This role is played by the electrolytic medium itself.

### **I.3.4. High-temperature corrosion**

is a mechanism of corrosion that takes place in gas turbines, diesel engines, furnaces or other machinery coming in contact with hot gas containing certain contaminants. Fuel sometimes contains vanadium compounds or sulfates which can form compounds during combustion having a low melting point. These liquid melted salts are strongly corrosive for stainless steel and other alloys normally inert against the corrosion and high temperatures. Other high-temperature corrosions include high-temperature oxidation, sulfidation and carbonization. High temperature oxidation and other corrosion types are commonly modelled using the Deal-Grove model to account for diffusion and reaction processes [10].

### **I.3.5. Low Temperature corrosion**

Using fuels with sulphur in steam generating units yields a potential hazard of sulphur corrosion at the cold end of the boiler, Sulphur in the fuel is oxidized chiefly to sulphur dioxide during combustion. Some sulphuric trioxide is also formed, and combines with water to form sulphuric acid, which condenses on and attacks low temperature boiler surfaces [10].

### **I.3.6. Dry and wet corrosion**

Dry corrosion occurs when there is no water or moisture to aid the corrosion, and the metal oxidises with the atmosphere alone.

Wet corrosion of metals occurs through electron transfer, involving two processes, oxidation and reduction. In oxidation, the metal atoms lose electrons. The surrounding environment then gains the electrons in reduction. The metal, where electrons are lost, is called the anode. The other metal, liquid or gas which gains the electrons is called the cathode [10].

## **I.4. Forms of corrosion:**

Corrosion can manifest itself in many forms (Figure I.2) such as uniform corrosion general corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, inter-granular corrosion, selective leaching, erosion corrosion, stress corrosion, corrosion fatigue and fretting corrosion

In order to improve the understanding between corrosion and design engineers it is classified into two broad categories. They are expressed in flow chart [10] :

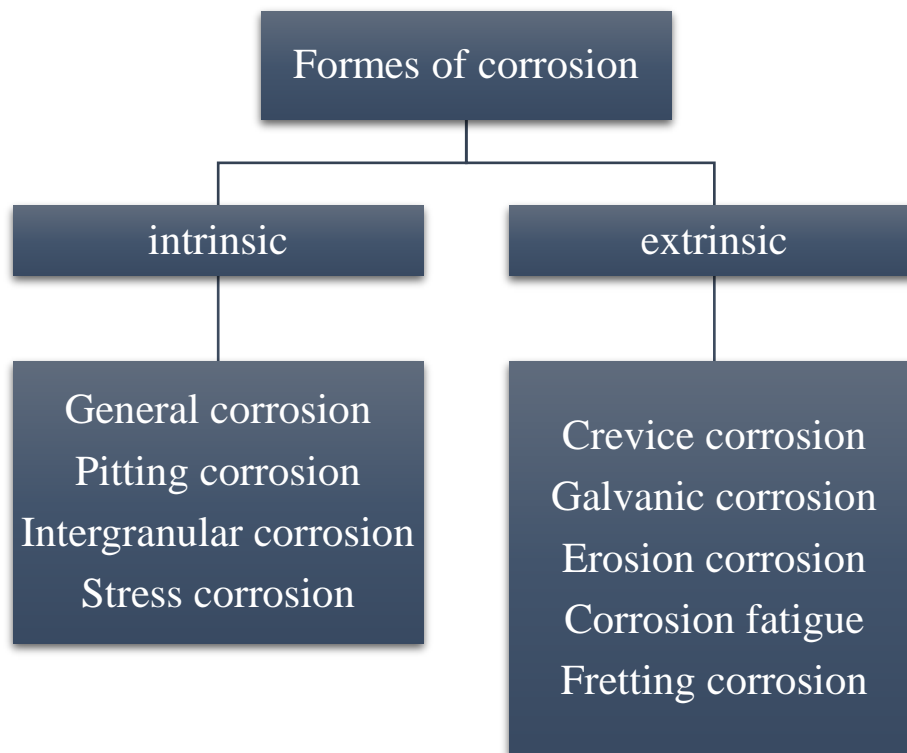


Figure I.2: Forms of corrosion

**I.4.1. Pitting corrosion**

Pitting corrosion results in irregularly shaped cavities on the metal surface that vary in diameter and depth according to several parameters specific to the metal, the medium and the operating conditions in (Figure I.3) [11]

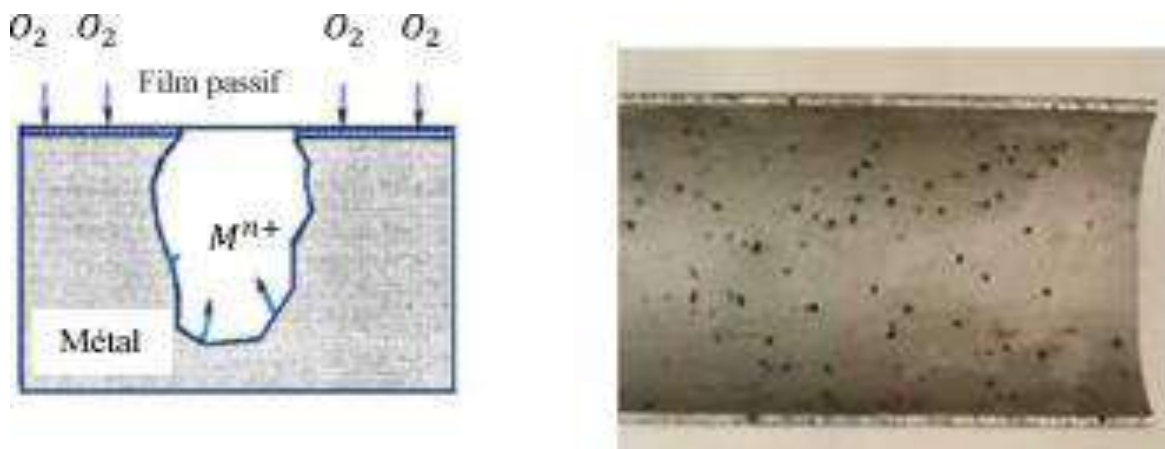


Figure I.3: Pitting corrosion [11].



It is generally produced by the presence of aggressive anions, particularly halides and especially chlorides, on metals protected by very thin oxide films. The phenomenon of burning, of stochastic nature, is often difficult to predict.

Its kinetics can be high. Pitting corrosion therefore represents a significant hazard to the metal and its functionality; hence, the large number of studies devoted to it.

A puncture may have different shapes depending on the experimental conditions. These shapes are represented schematically in (Figure I.4). There are narrow and deep forms (Figure I.4 (a)), cavernous pits (Figure I.4 (b)) or hemispherical forms (Figure I.4(c)), often described in the literature. [11].



**Figure I.4: Pitting forms (a) deep cavity (b) cavernous cavity (c) hemispheric [11].**

#### **I.4.2. Crevice corrosion**

Cavernous corrosion or crevice corrosion is a form of differential aeration corrosion (difference in oxygen accessibility between two parts of a structure) thus creating an electrochemical battery.

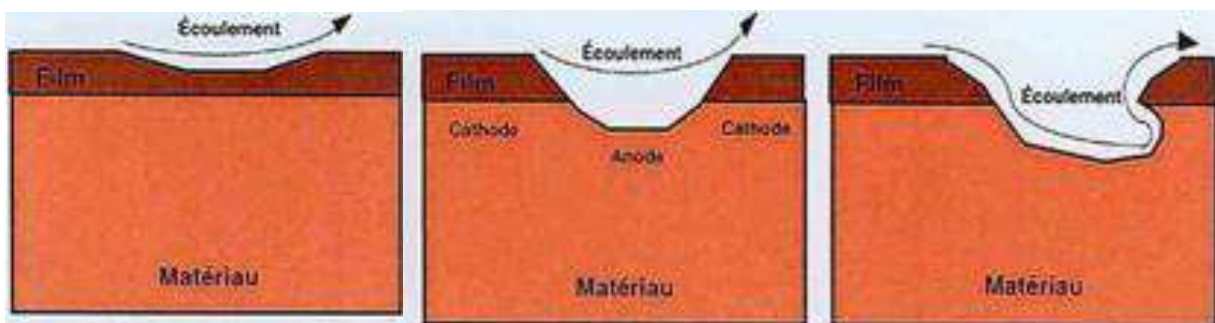
A selective attack of the metal is observed in slots and other places not easily accessible to oxygen in (Figure I.5). The first recommendation to avoid cavernous corrosion is to optimize the design of the part to avoid any artificial cavern. An artificial cavern can be created by a loose joint, an unassembled or bad weld, deposits, gaps between two sheets. [10].



Figure I.5: crevice corrosion [6]

### I.4.3. Erosion corrosion

Erosion Corrosion affects many materials (aluminum, steel, etc.) and is caused by the combined action of an electrochemical reaction and mechanical removal of material .It often occurs on metals exposed to the rapid flow of a fluid and gradually develops in three stages as shown in (Figure I.6)[7].



1: Erosion

2: Corrosion of material

3: Evolution of attack

Figure I.6: Corrosion erosion of a water-carrying copper tube [4].

### I.4.4. galvanic corrosion

The formation of an electrochemical battery between two materials in which one of the electrodes (the anode) is consumed to the benefit of the other (cathode) which remains intact (This selectivity of the reactions is due to heterogeneity either from the material or from the medium or physical-chemical conditions at the interface showing in (Figure I.7). [4,8]

This form of corrosion is often related to poor plant design.

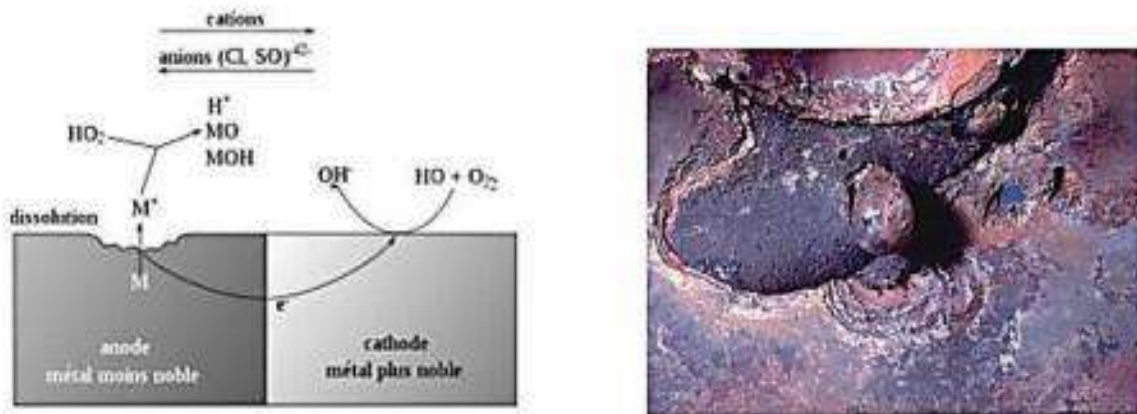


Figure I.7: galvanic Corrosion [4].

#### I.4.5. Stress corrosion

Stress corrosion is a cracking of the metal (Figure I.8) that results from the joint action of mechanical stress and an electrochemical reaction. This particularly dangerous phenomenon occurs by the combined effects of three parameters [3.10]:

- Temperature: stress corrosion rarely develops below 50°C.
- The applied or residual stresses experienced locally by piece.
- Corrosivity of the environment: presence of Cl, H<sub>2</sub>S or NaOH.



Figure I.8: Stress corrosion[5]

#### I.4.6. Intergranular corrosion

It is a form of corrosion that spreads through the metal by consuming only the areas associated with grain joints in (Figure I.9). It can be linked to the atomic structure and composition of grain joints in the absence of precipitation (intergranular corrosion excluding precipitation) or to the decoration of grain joints by precipitation (intergranular corrosion associated with the precipitation of a second phase) [7].



**Figure I.9: intergranular corrosion[9]**

**I.4.7. uniform corrosion:**

Or a General attack is the most common form of corrosion in (Figure I.10). It is normally characterized by a chemical or electrochemical reaction, which proceeds uniformly over the entire exposed surface or over a large area [10]. The metal becomes thinner and eventually fails.



**Figure I.10: General corrosion[3]**

### I.4.8. Fatigue corrosion

It is the reduction of the fatigue strength due to the presence of corrosive environment showing in (Figure I.11). Corrosion fatigue occurs due to the combined action of tensile and compressive stress alternatively. Fatigue occurs at lower stress in corrosive environment [8].



**Figure I.11: Corrosion fatigue[5]**

### I.4.9. Fretting corrosion

Fretting is a wear phenomenon enhanced by corrosion. It involves wear of a metal or alloy when in contact with another solid material in dry or humid air. Fretting is the result of abrasive wear surface oxide films, which form a contacting surfaces under load in atmospheric air which is shown in. The factors, which affect fretting corrosion are [11]:

- Magnitude of relative motion
- Temperature
- Environment
- Metallurgical factors Due to slight motion such as vibration, surface oxide and underlying metal, is spoiled. The metal particles because of wear are oxidized to hard oxides, which act as an additional abrasive medium. Further, the motion grinds the oxides particles thus causing wear.

### I.5. Factors influencing corrosion

The extent and rate of corrosion depend on nature of the metals and the environments due to a number of factors shown in the (table I.1).[7]

**Table I.1: Factors influencing corrosion**

Nature of the metal	Nature of the environment
Volatile corrosion products.	Polarization of electrodes.
Solubility of products	Flow velocity of process steam
Nature of the surface film	Formation of oxygen concentration cell
Position of metals in EMF series	Conductance of the corroding medium
Overvoltage	Nature of dissolved gases, dissolved salts, pollutants, etc. Presence of suspended particles in atmosphere
Physical nature of the metal	Influence of pH
Purity of the metal	Impurities in water
Relative area of anodic and cathodic parts of the metal	Humidity of air
	Temperature range

### **I.6. determining the corrosion rate methods**

The metal-solution interface is a complex system, each method of determining the corrosion rate will therefore lead to a different approach of this size, depending on the nature of the hypotheses on which the technique used is based. The most common methods are:

Gravimetric, which is a very old method of direct measurement, stationary electrochemical methods (polarization curves) and transient methods (electrochemical impedance spectroscopy) [4].

### I.6.1. Classical methods

The corrosion rate can be expressed in terms of mass loss, thickness reduction or current density. It can simply be defined from the following analyses [12]:

➤ *Measures of mass loss:*

In the case of a mass loss (m) over a duration (t), the relation expresses the corrosion rate ***v<sub>corr</sub>***:

$$v_{corr} = \frac{\Delta m}{\rho \cdot S \cdot \Delta t}$$

*v<sub>corr</sub>* : corrosion rate (cm/year).

$\Delta m / \Delta t$  : loss of mass per unit of time (g/year).

$\rho$ : density of metal (g/cm<sup>3</sup>).

S: surface of the sample in contact with the liquid (cm<sup>2</sup>).

➤ *Determination of the concentration of Mn<sup>+</sup> cations in solution:*

$$v_{corr} = \frac{\Delta c}{\rho \cdot S \cdot \Delta t} V$$

$\Delta C / \Delta t$  : change in metal ion concentration in the solution per time unit (g/L.year).

V: volume of solution (L).

➤ *Exploitation of the reduction reaction:*

provided that there is only one corrosion engine. Measuring the hydrogen release makes it possible to quantify the damage.

$$v_{corr} = \frac{\Delta v_{H_2} \cdot M}{V_{mol} \rho \cdot S \cdot \Delta t} \quad (\text{For a rambling cation})$$

$\Delta V_{H_2} / \Delta t$ : volume of hydrogen released per unit of time (L/year).

V<sub>mol</sub>: molar volume (22.4 L/mol, under normal temperature and pressure conditions)

M: molar mass (g/mol).

**Noting:** in the case where the  $Mn^+$  cation is not rambling, the load balance between anodic and cathodic reactions should be taken into account.

### I.6.2. Measurement of thickness loss

Performed by direct measurement, it requires access to the corroding surface. Ultrasonic measurements make it easier to obtain information, which however remains punctual, both geometrically and temporal. [6,11]

### I.6.3. Electrochemical methods

The electrochemical methods used to study corrosion can be divided into two categories are stationary method and transient method [11].

## I.7. Method fight against corrosion

Corrosion prevention should be considered at the design stage of an installation. Preventive measures taken at the right time make it possible to avoid many problems when it comes to guaranteeing a certain lifetime to an object, in particular for industries such as nuclear, chemical or aeronautical industries, where accident risks can have particularly serious consequences for people and the environment. In terms of corrosion protection, it is possible to act on the material itself (judicious choice, suitable shape, stress depending on the applications, etc.), on the material surface (coating, paint, any type of surface treatment, etc.) or the environment with which the material is in contact (corrosion inhibition). [11-12]

#### ➤ *Cathodic protection:*

It consists in placing the metal in its domain of immunity. It is feasible either by sacrificial anode (reactive) or by imposed current. The sacrificial anode protection consists in coupling to the metal to protect a less noble metal that plays the role of the anode. In the current protection, a current passes between a cathode made up of the metal to be protected and an inert anode (graphite, lead, precious metal, etc.). The current must be sufficient to bring the metal to a potential for which the reaction is anodic [12].

#### ➤ *Anodic protection:*

It is reserved for passive metals with corrosion potential in the active domain ( $E_{corr} < E_{passif}$ ). Anodic polarization moves the potential in the passive domain. The current density required to



keep the metal in a passive state is very low. Maintaining anodic protection requires little current. On the other hand, the current density applied is significantly higher because it must be greater than the passivation current density [3].

➤ ***Coating protection:***

Naturally a coating must resist the attack of the contact medium in which it is located, as well as it must adhere perfectly to the supporting metal and must demonstrate a certain mechanical resistance. Coatings can be organic or inorganic. Organic coatings form an impervious barrier between the metallic substrate and the medium, while inorganic coatings, which are most commonly used to protect the metal from atmospheric corrosion, often perform a decorative function. They are also used as wear guards [13].

➤ ***Protection by corrosion inhibitors :***

Corrosion inhibitors have been used that can be defined as a chemical material which used to stop or reduce the corrosion when mixed with the minerals in very few amounts and do not react with the environmental components. These substances can be used in any state solid, liquid or gas such as concrete, or paints (as a solid state), solvents, or aqueous solutions (as a liquid state), and water vapor (as a gaseous state) [13].

### **I.8. Conclusion**

Corrosion is a natural process, which reduces the binding energy in metals and degrades the useful properties of materials. The result of corrosion involves a metal atom being oxidized, whereby it loses one or more electrons. The corrosion manifests itself as a break-up of bulk metal-to-metal powder.

**Chapter Two :**  
**BACTERIAL CORROSION**

### II.1. Introduction

At industrial sites perforation of piping and tank walls, pipes blocked by corrosion products... In many cases, the perpetrators are unexpected culprits. These are the bacteria or, more specifically, their proliferation in a specific area of the pipes. Which cause serious corrosion problems referred to as bacterial corrosion or bio-corrosion. In our study, we will have to elucidate the mechanism of bacterial corrosion. For this, we must first know these bacteria to better understand their mode of action. [01]

### II.2. Bacteria

Bacteria are microorganisms that adhere to the surface of metals, cause the accumulation of acids, and dissolved gases. They occur in both water and air, some develop in oxygen (aerobic bacteria), while others do not require the presence of oxygen (anaerobic bacteria). They can draw energy from both mineral and organic materials.

Different bacteria are associated with the bio-corrosion mechanism and are often characterized by their breathing techniques. The main types of bacteria associated with corrosion are:

- sulfato-reducing bacteria (SRB);
- iron and manganese oxidizing bacteria;
- bacteria oxidizing sulphides;
- iron oxy-reducing bacteria;
- Bacteria that secrete organic acids and extracellular polymers (Extracellular Polymeric Substances, EPS).

There are several other groups of bacteria that use and breathe metallic substances, contributing to bio corrosion. [13]

### II.3. Bacterial corrosion

Bacterial corrosion is the result of interactions between bacteria and the materials on which they are attached. It is caused by bacterial microbes in combination with four other environmental conditions: metals, nutrients, water and oxygen (in some cases). Bacteria can either cause primary corrosion or be aggravating factors for pre-existing corrosion. It results from the unfavorable combination of three factors [13]:

- An aqueous medium that is generally considered to be less aggressive;

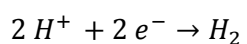
- A material deemed compatible with exposure conditions;
- Microorganisms most often unexpectedly present.

When the microorganism colonies attach themselves to the surface of the material, they create what is called biofilm. The presence of the latter may alter one of the cathodic or anodic reactions, thus accelerating the corrosion of the material. Possible actions of microorganisms include the production of corrosive compounds, the formation of concentration cells on the surface of materials, the formation of deposits on the surface of materials... [13]

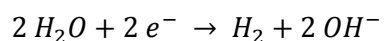
### II.3.1. Mechanism of microbial corrosion

The mechanisms of bio corrosion are varied, reflecting the diversity of different types of microorganisms, media and materials. Currently, it is accepted that sulfato-reducing bacteria (SRB) and thiosulfato-reducing bacteria (TRB) play a major role in the anaerobic biocorrosion of many types of metals such as stainless steels, mild steels, copper-nickel alloys, etc. Furthermore, the key role of hydrogenase in some SRBs has often been suspected and demonstrated under laboratory conditions.

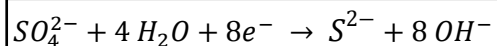
It is commonly accepted that microbial corrosion of metals in anaerobic media is due to the catalysis of proton or water reduction [13] :



Or:



SRB metabolically produce sulphide ions:



Sulphide ions combine with ferrous ions to form iron sulphide (FeS) deposits. The FeS thus formed catalyzes the reduction of proton or water on the surface of the material, which leads to an increase in electron transfer, thus accelerating the dissolution of the metal. Corrosion depends on the uniformity of the FeS deposit, its crystalline state, the nature of the steel, the surface defects of the steel, etc. In reality, biocorrosion mechanisms are certainly more complex than this simple mechanism and remain difficult to elucidate. [13]

### **II.3.2. Corrosion mechanism generated by sulfurogenic bacteria**

The bacteria responsible for this type of corrosion are mainly *Desulfovibrio*, *Desulfomonas* and *Desulfomaculatum*. They are anaerobic bacteria capable of transforming sulphates and sulphites into sulphides.

The best known mechanism to explain anaerobic corrosion involving sulfurogenic bacteria (Sulfato-Reducing Bacteria, SRB and Thiosulfato-Reducing Bacteria, TRB) is the precipitation of iron sulphide (FeS), which then catalyses the reduction of proton to hydrogen molecular creating cathodic areas next to anodic areas composed of iron (Fe) leading to a galvanic battery that causes pitting on the surface of the metal to explain that deposition of iron sulphide catalyzes proton or water reduction, it was proposed that the SRB, by their activity, can regulate pH locally. Locally, the hydrogen sulphide produced by the SRB causes the formation of FeS and causes the increase of acidity (more free protons). In areas surrounding the FeS deposit, the pH remains stable and neutral. Bacterial metabolism could therefore induce a stack by differential acidification: FeS being the cathode (lower pH) and iron anode (higher pH). In addition, in 1996, Campaignole demonstrated that in the presence of SRB using sulphate as a terminal electron acceptor, the corrosion rate can stabilize at a few mm per year while it reaches 1 cm per year, if these bacteria use thiosulfate.

Based on these results, thiosulfate and thiosulfato-reduction appear to be a major risk factor in biocorrosion, which partly supports the model of PH self-regulation, which predicts (in theory) a higher differential cell in the case of thiosulfate than in the case of sulphate.

The presence of these bacteria in various corroded places (waste water networks, cooling circuits, etc.) is attested by the particular odour emitted by the accumulated sulphides.

In parallel with this widely accepted mechanism, many studies have proposed other mechanisms, complementary or not, to explain anaerobic bacterial corrosion due to the action of SRB and TRB. [13]

### **II.3.3. Cathodic depolarization**

The oldest mechanism that attempted to explain SRB-induced corrosion was the cathodic depolarization proposed by Von Wolgozen Kühr and Van der Vlugt in 1934. Due to their hydrogenase activity, the SRB uses the hydrogen produced by reducing the proton on the material to reduce the sulphate. The consumption of hydrogen would cause a reaction imbalance and promote the reduction of proton thus increasing the oxidation of iron.

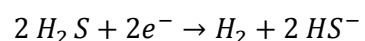
This mechanism is not correct because it apprehends corrosion as a globally balanced process. The following studies have shown that the consumption of hydrogen by the SRB can promote corrosion, but by a much more indirect path than assumed by the cathodic depolarization theory. [13]

### **II.3.4. Anodic depolarization**

This mechanism assumes that the speed of the anodic iron dissolution reaction is limited by the presence of ferrous (or ferric) ions, but this seems rather unlikely. Later, Salvarreza et al., (1980) noted that activation of the metal was increased by the presence of  $HS^-$  ions and that iron dissolution occurs through the formation of a soluble compound,  $FeHS^+$ . In a chloride-containing environment, a low concentration of sulphides is sufficient to promote steel activation. [13]

### **II.3.5. Depolarization anodic cathodic depolarization by $H_2 S$**

The term "cathodic depolarization" was used in 1974 (Costello), which is explained by the production of hydrogen sulphide ( $H_2 S$ ) by the SRB, which then acts as an electron acceptor to form  $HS^-$  and  $H_2$ .



In this case, "cathodic depolarization" is an additional cathodic reaction created by the presence of SRB. The naming of two mechanisms by the same term, one of which is not valid and the other is correct from a theoretical point of view, does not help unravel the tangle of the mechanisms. [13]

### **II.3.6. Mechanism of corrosion caused by acidogenic bacteria**

The metabolism of many bacteria leads to the transient release of organic acids (Clostridium), but also of mineral acids (Thiobacillus, Thiooxydans), the result of which is a significant decrease in the PH of the medium. This acidification leads to an acceleration of corrosion by chemical processes (complex action on iron). [13]

### **II.3.7. Mechanism of corrosion under biofilms**

Biofilms are the primary tools used by bacteria to adhere to the surface of substrates and facilitate the optimization of the metabolism/respiration couple. In the case of bacterial corrosion, biofilms are an essential part of the degradation process. When bacteria form biofilms, their adhesion to the substrate is increased by different phenomena, the most significant of which is the secretion of

extracellular polymers. These secretions have a strong propensity to trap many substances present in the environment such as colloids, and various other suspended or depository materials.

Corrosion develops under biofilms for the same reasons as described under other types of deposits, differential aeration, synergistic action of corrosive anaerobic bacteria, passivation of stainless steel. [13]

### **II.3.8. Mechanism of corrosion due to nitrifying bacteria**

Bacteria of the genera Nitrosomas and Nitrobacter that oxidize ammonia to nitrites and nitrates initiate a form of corrosion due to nitric acid from neoformed nitrites and nitrates. [13]

### **II.4. Corrosion due to algal films**

Various unicellular algae which settle and adhere strongly to different substrates benefiting from sufficient lighting, can harbor under the films they form anaerobic bacteria responsible for chemical corrosion. In addition, the death of algae releases acids which accentuate the effects of the corrosion initiated. Various single-cell algae that deposit and adhere strongly to different substrates with adequate lighting can shelter anaerobic bacteria responsible for chemical corrosion under the films they form. In addition, the death of algae releases acids that accentuate the effects of initiated corrosion. [13]

### **II.5. How to detect bacterial corrosion?**

Equipment maintenance personnel may suspect the presence of bacterial corrosion by:

- Observation of the leakage lines in the pipes.
- The amount of debris.
- Buffering, colouring, water and drool odour.
- The presence of the bacilli when the liquid is drained from the system at the time of pipe inspection.

These methods are valid for liquid pipelines. However, the best way to confirm that bacterial corrosion is degrading the piping is to remove the affected sections and have them tested by a microbiologist and metallurgical engineer. Another advantage of this analysis is that other types of corrosion can also be detected. Based on the relative types and concentrations of each species of bacteria detected, the presence of bacterial corrosion can be assessed. [13]

## II.6. Bactericides

Bactericides selected by the Research and Application Laboratory that effectively and economically solve bacterial corrosion problems and, more generally, problems resulting from bacterial blooms, whether they are aerobic or anaerobic. [14]

These agents can have two roles:

- a) Either stop the production of  $H_2S$  by sulfato-reducing bacteria.
- b) Reduce bacterial corrosion.

The product will block bacterial metabolism by adsorbing to bacteria. The contact time is necessary for the bacterium to be killed and to determine the efficacy of the product. Therefore, it is necessary to ensure that the quantity of bactericide in the fluid is sufficient because if the contact time is reduced, the blocking of the metabolism is done without causing the death of the bacterium. [14]

## II.7. Different type of treatment

There are three types of treatment are possible:

### II.7.1. Continuous treatment

Bactericide is injected continuously at low doses into the effluent. The injection doses (5 to 15 ppm) are determined in the field by bacterial tests and the injection points should, if possible, be upstream of the bacterial colonies. The injection methods used for corrosion inhibitors and anti-depeds are also applicable to bactericides (in the annular space, in the lift gas circuit, in squeeze, etc.) [13]

### II.7.2. Cork treatment

This is a method of treatment applicable in certain specific cases (hydraulic tests for example). The installation is traversed by a concentrated solution of bactericide cap followed by continuously treated test water. [13]

### II.7.3. Shock treatment

The injection is no longer continuous, but sequenced and the injected concentrations are much greater (a few tens to a few hundred ppm). The frequency and doses of injection are determined after field tests. The injection points are the same as in the previous case and the alternation of several bactericides is also possible. The choice between continuous injection and shock treatment is linked to several criteria, it depends on the installation to be treated, the operating conditions



and especially the bacterial colonies to be eliminated.(and this type of treatment which we used in our study) [14]

### **II.8. Conclusion**

Microbial corrosion in various places, in our society and industry, leads to great damage and many problems, especially by high corrosion rates. The corrosion process can be locally very fast, with perforations and leaks consequently. But also, the pipes that are plugged very quickly can cause problems. These mechanisms can also be strengthened. In short, this is a phenomenon that is difficult to penetrate and can lead to major problems.

**Chapter Three :**  
**CORROSION INHIBITOR**

### **III.1. Introduction**

The Great damage of the corrosion progression have grown into a problematic of global importance, because its reasons plant shutdown, wastage of very important incomes, product corruption, efficiency decreasing, expensive repairs, and costly overdesign. Corrosion also endangers the safety and obstructs the progression of the technology, where corrosion can destroy the substances by reaction with their surroundings[13]; there are many ways to protect from corrosion like inhibitors, which are substances, which added to the metallic materials to keep them from the destructive surroundings. Presently, inhibitors have been used in many industrial regions such as chemical and oil production because they are easy to modify their chemical structure according to their needs.

This chapter presents a revision of the corrosion inhibitors, his properties and general uses, the different classification of it, and finally we will see the mechanism of corrosion inhibition.

### **III.2. Definition of inhibitor**

An inhibitor is a substance which when added to an environment in small concentration, minimizes metal losses, reduces the degree of hydrogen embrittlement, protects the metal from pitting, reduces excessive etching and acid fumes from overreaction of acidic and basic metals, and reduces acid consumption. They reduce corrosion, either by acting as a barrier, creating an adsorbed layer, or by delaying cathode or anode processes or both. Any process of delaying corrosion or reducing the rate of oxidation of a metal by adding a chemical to the system is caused by corrosion inhibitors. Inhibitors are often easy to apply and offer the advantage of in-situ use without causing any significant process disturbance. The use of corrosion inhibitors is one of the best methods of combating corrosion. [14]

### **III.3. Corrosion inhibitors**

Corrosion inhibitors can take any form (solids, liquids and gases). The corrosion inhibitors to be inhibited are selected based on their solubility or dispersibility in the fluids. Corrosion inhibitors have been found to be effective and flexible corrosion mitigation agents. The use of chemical inhibitors to reduce the rate of corrosion processes is quite diverse. Corrosion inhibitors are used in oil and gas exploration and production, oil refineries, chemical production, heavy production,

water treatment and the product additive industry. In the oil extraction, processing and chemical industries, corrosion inhibitors have always been considered the first line of defense.

A great number of scientific studies have been devoted to the subject of corrosion inhibitors. [12-14]

### **III.3.1. Properties**

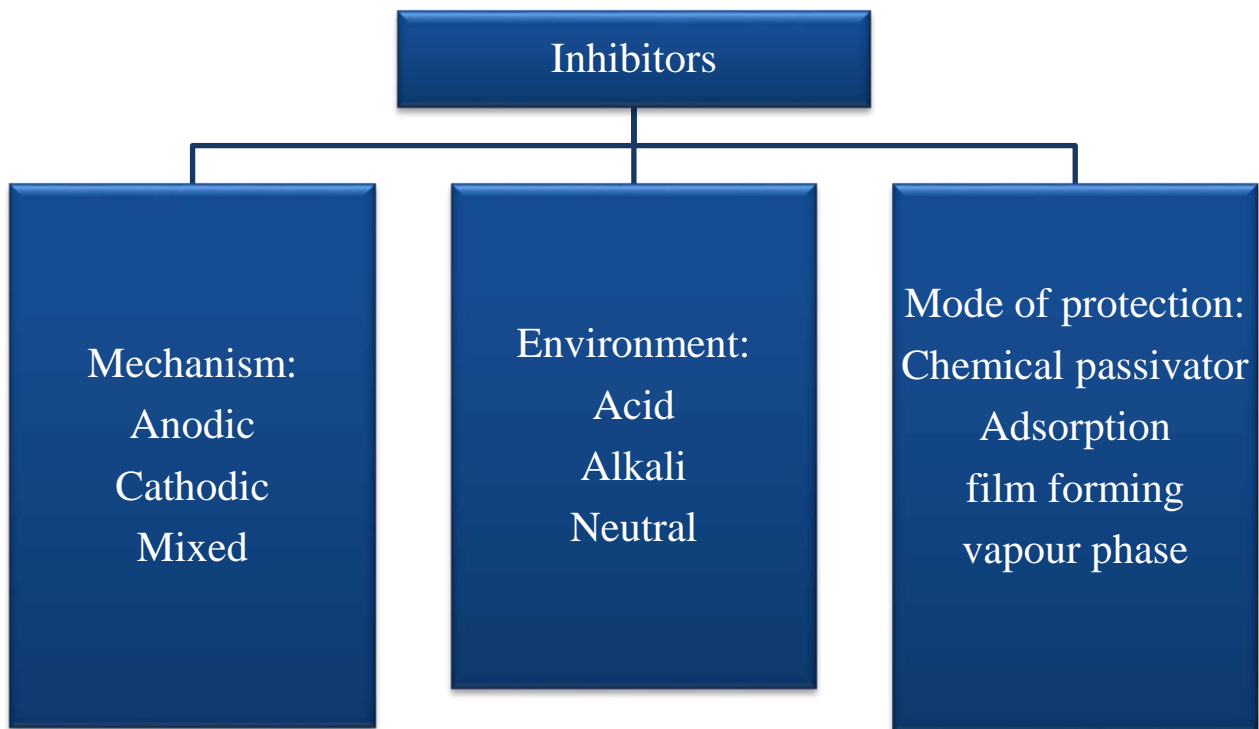
Starting from this definition, a corrosion inhibitor must therefore check a number of fundamental properties: [15]

- Lower the corrosion rate of the metal while maintaining the physico-chemical characteristics of the latter.
- Must to be stable in the presence of other constituents
- Must to be stable in the temperature range used.
- Must to be effective at low concentration.
- Must to be effective in the conditions of use.
- Inexpensive compared to the savings it makes.
- Must to be compatible with the current standards of non-toxicity and environmental protection.

It should be noted that non-toxicity is the weak point of the inhibitory molecules currently used. Indeed, a number of them are about to be banned and that is why research tends to propose molecules that are less dangerous for the environment.

### **III.4. Inhibitors classifications**

Corrosion inhibitors can be classified into different categories depending on how they protect the structure from being corroded in the aggressive media. the classification of the inhibitors shown on the. Figure III.1



**Figure III.1. Classification of inhibitors**

#### III.4.1 Based on electrode process

##### a) *Anodic inhibitors*

The anodic inhibitor increases the anodic polarization and thus shifts the corrosion potential towards the cathodic direction and is therefore called passivation inhibitors. Anode inhibitors, such as chromates, phosphates, tungstate's and other transition element ions with high oxygen content, are those that suppress the corrosion reaction taking place at the anode by creating a sparingly soluble compound with the newly formed metal ion. They are adsorbed on the forming surface of the metal surface a protective layer or barrier, thus reducing the corrosion rate. Anode inhibitors they build a thin protective layer along the anode and increase its potential, thus slow down the corrosion reaction [15]. There are two types of passivation inhibitors:

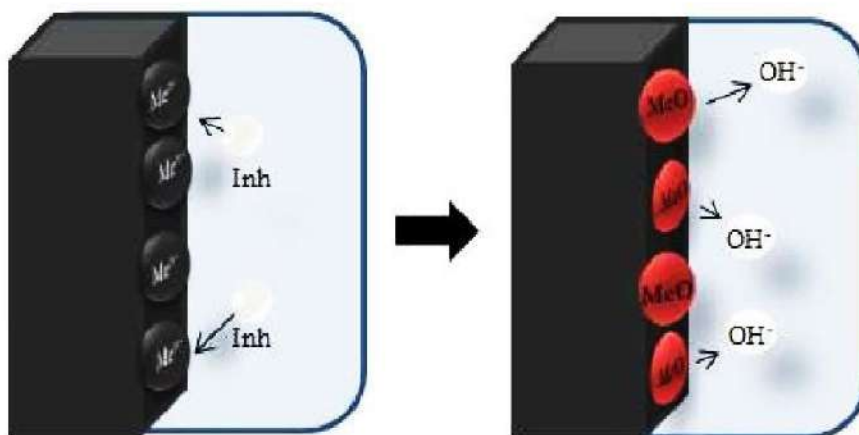
- Oxidizing anions, such as chromate, nitrite and nitrate, can passivate Steel without oxygen.
- Non-oxidizing ions such as phosphate, tungstate and molybdate the presence of oxygen is required to passivate steel.

Generally speaking, when the concentration is below the minimum, the passivation inhibitor will actually cause pitting and accelerate corrosion. For this, it is necessary to monitor the inhibitor

concentration for the anode inhibitor effect, it is very important that the inhibitor concentration in the solution should be high enough. Improper amount of inhibitor will affect the formation of the protective film, because it will not completely cover the metal, exposing the metal part, which will cause

local corrosion. Concentrations below the critical value are worse than no inhibitor. Due to the reduction of the anode area relative to the cathode, pitting corrosion will result, or due to complete destruction of passivation, corrosion will be accelerated, such as general corrosion. [16,17]

Some examples of anode inorganic inhibitors are nitrate, molybdate, sodium chromate, phosphate, hydroxide, and silicate. (Figure III.2 shows how the mechanism of the anodic inhibitory is effect).



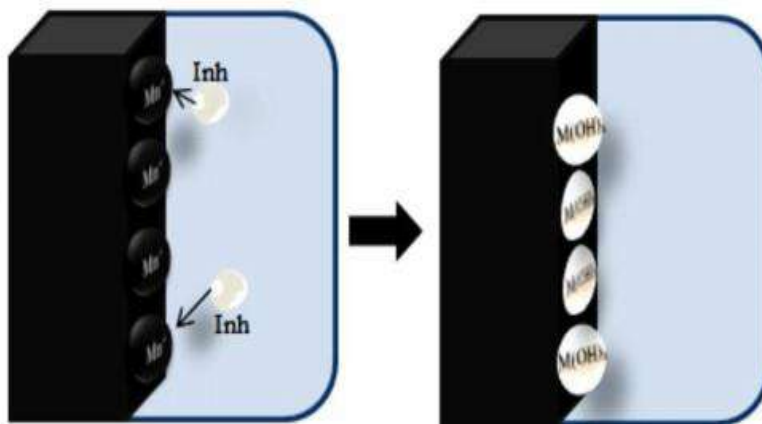
**Figure III.2. Illustration of anodic inorganic inhibitors.[17]**

***b) Cathodic inhibitors***

During the corrosion process, the cathodic corrosion inhibitor prevents the cathodic reaction of the metal. The metal ions of these inhibitors can produce cathodic reactions due to their alkalinity, thereby producing insoluble compounds that are selectively precipitated on the cathode sites. A dense adhesion film is deposited on the metal to limit the diffusion of reducible substances in these areas. Therefore, the resistance of the surface and the diffusion limit of reducible substances, that is, oxygen diffusion and electron conduction in these areas are increased. These inhibitors lead to high cathodic inhibition. [17]

A few instances of inorganic cathodic inhibitors are the particles of the magnesium, zinc, and

nickel that respond with the hydroxyl ( $OH^-$ ) of the water forming the insoluble hydroxides as ( $Mg(OH)_2$ ,  $Zn(OH)_2$ ,  $Ni(OH)_2$ ) which are stored on the cathodic site of the metal surface, protecting it. Also, can be referred to polyphosphates, phosphonates, tannins, lignin's and calcium salts as models that presents a similar response instrument. It seen in hard waters a sort of this system of hindering, because of the impact of the magnesium or calcium bicarbonate on it. At the point when brief hard water streams over the metal it can help on the nucleation of carbonates, permitting the responses close to the balance and forming precipitations on the metal surface. These precipitations, similar to a  $CaCO_3$ , cover the cathodic area, protecting the metal. So these cathodic inhibitor relies just upon the science of the water, isn't expected the metal arrangement, in light of this they are relevant to all metals. As example, might be referenced the oxides and salts of antimony, arsenic and bismuth, which are stored on the cathode locale in corrosive arrangements. These cathodic inhibitors limit the arrival of hydrogen particles because of a wonders that can troublesome the release of the hydrogen, called overvoltage. ( Figure III.3 shows the illustration of mechanical effect of cathodic inhibitors to restrain the corrosion process). [17]



**Figure III.3. Illustration of the cathodic inhibitors. [17]**

*c) Mixed inhibitors*

These inhibitors delay the anode and cathode processes involved in the corrosion process, so they are called mixed inhibitors. They are usually film-forming compounds that cause deposits to form on the surface, indirectly blocking the anode and cathode sites. In most cases, anode inhibitors are dangerous inhibitors, especially when their concentration is too low. But cathodic

inhibitors are generally safe. Mixed corrosion inhibitors are less dangerous than pure anodic corrosion inhibitors, and in many cases they may not increase corrosion strength. The most common inhibitors of this category are silicates and phosphates. Such inhibitors will have more advantages because they can control the cathode and anode corrosion reactions [18].

### III.4.2. Based on environment

#### a) *Acidic environment inhibitors*

The compounds such as  $As_2O_3$ ,  $Sb_2O_3$  have been reported as inhibitors in acid media. In this case, the protection is due to the reduction of electro positive ions and deposition on the metal surface and lowering of the over voltage of main cathodic depolarization reaction. Recently it is shown that the addition of heavy metal ions such as  $Pb^{2+}$ ,  $Ti^+$ ,  $Mn^{2+}$  and  $Cd^{2+}$  is found to inhibit corrosion of iron in acids [19].

#### b) *Alkaline inhibitors*

Metals, which form amphoteric oxides, are prone to corrosion in alkaline solutions. Many organic compounds are often used as inhibitors for metals in basic solutions. Compounds such as thiourea, substituted phenols, naphthol,  $\beta$ -diketone, etc., have been used as effective inhibitors in basic solutions due to the formation of metal complexes [19].

#### c) *Neutral inhibitors*

Inhibitors that are effective in acidic solutions do not function effectively in neutral solutions, since the mechanism is different in the two solutions. In neutral solutions, the interaction of inhibitors with oxide covered metal surface and prevention of oxygen reduction reaction at the cathodic sites takes place. Such inhibitors protect the surface layers from aggressiveness. Some surface-active chelating inhibitors have been found to be efficient inhibitors in near-neutral solutions. [20,21]

### III.4.3. Based on mode of protection

#### a) *Chemical passivators*

Generally, substances with sufficiently high equilibrium potential (oxidation-reduction potential or electrode potential) and sufficiently low over potential will reduce the corrosion rate when they reach passivation, and are called chemical passivators. [21]

For example, nitrite is used as an inhibitor of antifreeze cooling water. Chromate is mainly used as an inhibitor of circulating cooling water. Zinc molybdate is used as an inhibiting pigment for paint.



***b) Adsorption inhibitors***

These represent the most widely used class of inhibitors. Generally, they are organic compounds that are adsorbed on the metal surface and provide a covering effect on the entire surface (that is, in the case of the cathode and the anode). In general, they have the same effect on the cathode and anode reactions, but in many cases, the effects may not be the same. These are usually used for pickling hot-rolled products to remove black oxide scale, so they are called pickling inhibitors. [22]

Example: Compounds containing lone pairs of electrons, such as nitrogen atoms in amines, quinolines, sulfur atoms in sulfur compounds, and oxygen atoms in aldehydes.

***c) Film forming inhibitors***

In contrast to adsorption inhibitors, which form a direct adsorption film for inhibiting substances, many substances called film-forming inhibitors seem to prevent corrosion by forming a block or barrier film of materials other than the actual inhibiting substance itself. This material tends to be specific to the cathode or anode. Zinc and calcium salts are the most common examples of cathode film formation inhibitors. Benzoate is a common example of anodic film-forming inhibitors, which can inhibit corrosion during sailing [22].

***d) Volatile inhibitors or vapor phase inhibitors***

Volatile Corrosion Inhibitors (VCI) are compounds that are transferred to the corrosion site by volatilizing from the source in a closed environment (See Figure III.4). If the corrosion product is volatile, it will volatilize immediately after formation, exposing the underlying metal surface for further corrosion. This leads to rapid and continuous corrosion, which leads to excessive corrosion. For example, molybdenum oxide ( $\text{MoO}_3$ ), the oxidation corrosion products of molybdenum are volatile. In closed steam, processes (transport containers), volatile solids such as salts of dicyclohexylamine, cyclohexylamine, hexamethylenamine are used as volatile corrosion inhibitors. [23]

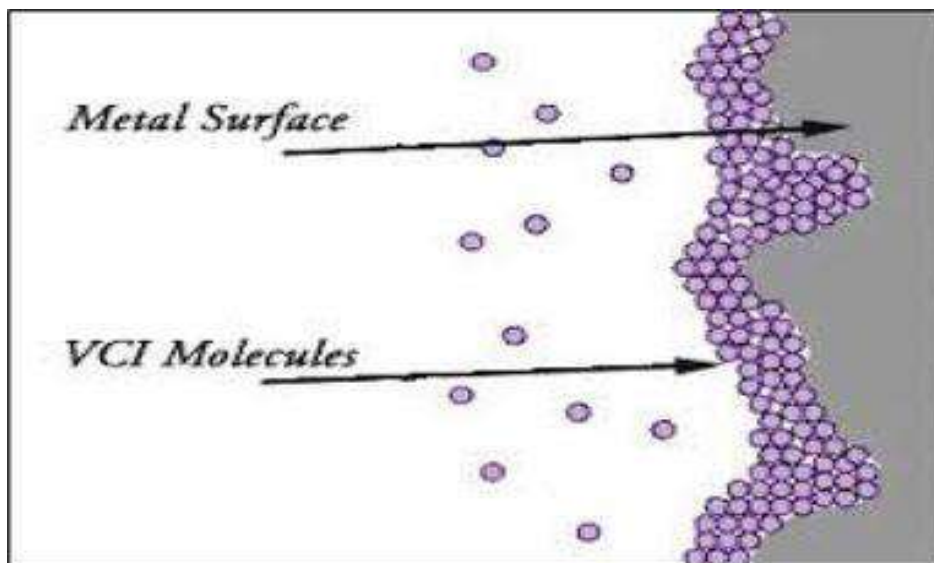


Figure III.4. Schematic representation of vapor phase inhibitors [23]

### III.5. Uses:

- Water inhibitors have several traditional fields of application.
- The oil treatment (sanitary water, industrial process water, boiler water, etc...)
- Paints where industry: drilling, extraction, refining, storage and transport, corrosion inhibitors are additives that provide corrosion protection to metals. [24]

### III.6. Mode of action of corrosion inhibitors

There is no single mode of action for corrosion inhibitors. The same compound may have different mechanisms of action. These are imposed by the corrosive medium and the nature of the metal to be protected. Regardless of the mechanism by which the corrosion inhibitor acts, there are nevertheless a number of considerations which are valid for all corrosion inhibitors:

- Corrosion being an essentially electrochemical process, the action of the inhibitor can only be carried out at one of the elementary reaction stages (transport of species in solution, formation of superficial intermediates, adsorption of species at the surface of solid phases and transfer of electronic charges).
- Since the intervention of the corrosion inhibitor in the process of transport of electro-active species (oxygen, protons, reaction products) within the solution is unlikely, the mechanism of action of an inhibitor is most often to be sought in the immediate vicinity of the metal surface (in contact with the metal). The action of the corrosion inhibitor can be conceived as:

- The interposition of a barrier between the metal and the corrosive medium; this is the case of acidic media.
- The reinforcement of a pre-existing barrier, usually the oxide or hydroxide layer formed naturally in a neutral or alkaline medium.
- The formation of a barrier by interaction of the corrosion inhibitor with one or more species of the corrosive medium, this type of mechanism is also specific to alkaline or neutral environments.

The mechanism of action of an inhibitor can be considered in two aspects:

1. A mechanistic aspect (intervention in the fundamental processes of corrosion);
2. A morphological aspect (intervention of the molecule of the corrosion inhibitor in the interfacial structure).

It is clear that the mechanism of action will differ greatly depending on the pH of the environment. [24]

### III.7. Industrial application

Acid pickling: Prevent the attack in the metal due to the acid solution in which metal gets cleaned of mill scale (bark lamination), and also prevented the subsequent hydrogen evolution inhibitors are added, typically organic, must be soluble or dispersed in the solution. Examples: thiourea and amino and its derivatives, propargyl alcohol. Oil industry: sodium carbonates or organic amines complex are employed to reduce the corrosive effect of CO<sub>2</sub>, H<sub>2</sub>S and organic acids, enabling the use of more cheaper materials and less resistant to corrosion in wells extracting crude oil. Pipes for gasoline and kerosene are employed sulphonated oils, sodium nitrite. Oil well uses up fatty amines, fatty acids, imida- zolines and quaternary ammonium salts. Internal pipe corrosion occurs in wet gas transportation due to condensation of water containing dissolved corrosive gases. Corrosion is caused by the dissolution of the corrosive gases, such as carbon dioxide and hydrogen sulfide as well as condensation of acid vapors. Water transmission and distribution systems: is used corrosion inhibitor in combination with pH adjusters and alkalinity control towards an efficient protection The most common inhibitors are phosphates, amines volatiles (cyclohexylamine, morphine) Concrete: To improve the durability of reinforced concrete structures, which are impaired due the high alkalinity, are used corrosion inhibitors, mixed with cement or concrete paste. An example is phosphate ion. Boiler: Thermoelectric use, in general, Ammonia, Cyclohexylamine, alkanol and Morpholine as

inhibitors in boilers in various processes. The inhibitors, also, are added by the hydrochloric acid used for the solubilization of limescale to prevent the attack on pipes.[25]

### **III.8. Conclusion**

- Corrosion inhibitors are a great effective method of preventing corrosion.
- The knowledge of the method of the action, facilitates the choice of the inhibitors, improves efficiency, avoids the process is impaired and side effects.
- It is important in the choice of inhibitor whatever may be the method; ascertain the subsequent effects of this towards the environment.

# **Chapter Four :**

# **IMPLEMENTATION**

## IV.1. Introduction

In engineering, sulfate-reducing microorganisms can create problems when metal structures are exposed to sulfate-containing water: Interaction of water and metal creates a layer of molecular hydrogen on the metal surface; sulfate-reducing microorganisms then oxidize the hydrogen while creating hydrogen sulfide, which contributes to corrosion, there many measurement techniques to calculate the corrosion rate in the petroleum uni like using the corrosion coupons and the AquaMate device.

This chapter is present Firstly, an overview of the region where the subject of this research was studied.and experimental methods, analyses with a description of the materials , then the results that we obtained it in our study with the discussions.

## IV.2. Materials and methods

### IV.2.1. SONATRACH

Is the Algerian company for research, exploitation, pipeline transport, processing and marketing of hydrocarbons and their derivatives. It is also active in other sectors such as electricity generation, renewable energy and seawater desalination. She works in Algeria and around the world where opportunities arise.

SONATRACH is the first company on the African continent. It is ranked 12th among the world's oil companies, 2nd exporter of LNG and LPG and 3rd exporter of natural gas . [1]

### IV.2.2. Presentation of the T.F.T region

#### ➤ *Location*

The regional management of TIN FOUYE TABANCORT (T.F.T) is part of the production division of the national hydrocarbon transport and marketing company (SONATRAC). It is responsible for the production of oil and gas in the various deposits that exist in the region. The T.F.T region is located to the north-west of the ILLIZI basin, 1300 km to the south-east of the capital, 500 km to the south of HASSI-MESSAOUD and 300 km to the north-west of IN AMENAS. (see figure IV.1) [26].

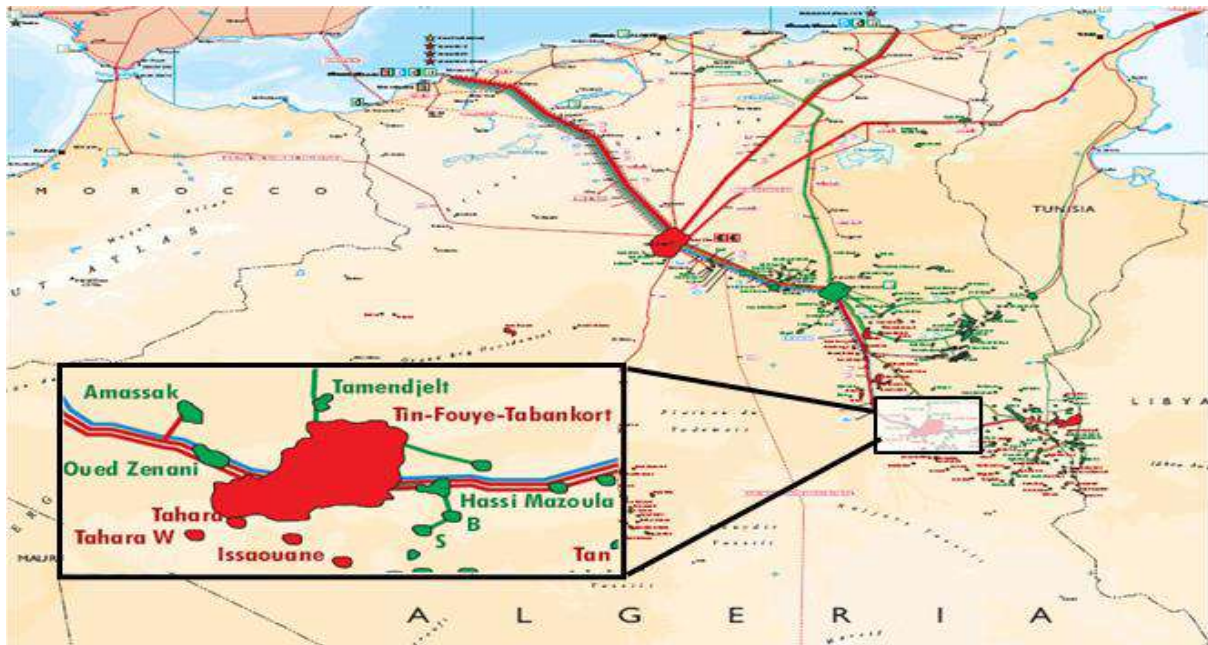


Figure IV.1: Geographical location of TFT [26]

#### IV.2.3. Theoretical reminders on Bacterial corrosion

Micro-organisms (SRB) play a very important role in the destruction and corrosion of various materials. microbial degradation of materials may occur aerobically or anaerobically (lack of oxygen) [27].

#### IV.2.4. The composition of the injection water (Lias)

The main cause of bacterial corrosion is the chemical nature of the injection water (lias); the following table presents its chemical composition.(Table 01)[27] .

**Table 01: the composition of the injection water (Lias)**

Composition	Cations/Anions	Lias (M.P) [mg/l]
Sodium	Na <sup>+</sup>	1560
Potassium	K <sup>+</sup>	77
Lithium	Li <sup>+</sup>	0.3
Calcium	Ca <sup>2+</sup>	300
Magnésium	Mg <sup>2+</sup>	73
Strontium	Sr <sup>2+</sup>	0.8
Chrome	Cr <sup>3+</sup>	< 0.1
Chlorures	Cl <sup>-</sup>	2182
Bromures	Br <sup>-</sup>	0
Iodures	I <sup>-</sup>	0
Fluorures	F <sup>-</sup>	0
Carbonates	HCO <sub>3</sub> <sup>-</sup>	2,4
Bicarbonates	HCO <sub>3</sub> <sup>-</sup>	198
Sulfates	SO <sub>4</sub> <sup>2-</sup>	1267
Extrait sec.	à 105 °C	3640
PH	à 25 °C	8,37
Sodium	Na <sup>+</sup>	1560

**Lias:** It is the geological layer that contains the injection water reservoir according to the preceding table, we note that this water composition is rich in sulphates, the pH measurement indicates that this water is alkaline, it is a favorable environment for the spread of sulfato-reducing bacteria [27].

#### **IV.2.5. Detection and counting of SRB in the field**

##### **a) SRB detection**

As SRB (Sulfato-Reducing Bacteria) are strict anaerobes, certain precautions must be taken for their detection. It is in particular essential to cultivate them in the absence oxygen and ensure that the redox potential of the culture medium is not too high. Whenever possible, it is advisable to use a culture medium with a salinity equivalent to that of the supposedly polluted water [27]

##### **b) The Composition of the culture medium**

A sterile culture medium specific to S.R.B is identified and their counting is used to conduct this assessment. This culture medium contains in 1000ml distilled water: (See Table 02 ) (Figure IV.2) [27]



**Table 02: Composition of culture the medium.**

Component	Quantity
▪ Magnesium sulphate ( $MgSO_4, 7H_2O$ )	1g.
▪ Ascorbic acid ( $C_6H_8O_6$ )	0,1g.
▪ Sodium citrate	0,5g.
▪ Ammonium chloride ( $NH_4Cl$ )	0,5g.
▪ Potassium phosphate ( $KH_2PO_4$ )	0,5g.
▪ Yeast extract	0,1g.
▪ Sodium lactate (soil. 60%)	4ml.



**Figure IV.2: The composition of culture medium.**

The prepared media are distributed at a rate of 9ml in penicillin flasks fitted with an acetone-degreased nail. After capping and crimping the vials, the vials are subjected to nitrogen bubbling to flush out the oxygen. The vials are then sterilized for 20mn at 120°C.

#### **IV.2.6. Pipeline of hydrocarbons**

A pipeline is a buried or aerial pipeline carrying goods, whether they are in liquid or gaseous form. Pipelines are most often constructed from tubes of welded steel end-to-end, coated externally or internally and generally buried in the ground. These pipelines are costly and sometimes difficult to implement depending on the characteristics of the land crossed, in seismic risk zone or politically unstable. Unlike their initial investment, their use is relatively

low. expensive compared to other competing forms of transport, at least on small and medium distances.[1]

There are three major families of tubes:

- Small welded tubes with a diameter not exceeding 219mm 8''.
- The means welded tubes whose diameter is between 228.6mm and 406.4mm (9'a16'').
- Large welded tubes with a diameter greater than 16'' (406.4mm )

In our study that allows us to calculate the internal corrosion rate of pipelines,for this we use corrosion coupons by stitching them in pipes and they composed of the same materials as that of pipes.

### IV.2.7. Corrosion measurement techniques

To calculate the corrosion rate, there many measurement techniques were used including :

#### ➤ Corrosion coupon

Corrosion coupons are the oldest method of determining speeds and types of metallic corrosion (*Figure IV.3*)

The most common forms of coupons are platelets and cylindrical. [27]



**Figure IV.3: Corrosion coupons.**

### IV.2.8. Aqua Mate device

Aqua Mate is a hand-held instrument to monitor corrosion, cooling, or drinking water systems processes. The Aqua Mate instrument has been designed to help improve the operation of the facilities by allowing the user to directly control the rate of corrosion, imbalance, conductivity and temperature. (*Figure IV 4*) [27].



**Figure IV.4: Aqua Mate device .**

This method consists of monitoring the evolution of the instantaneous corrosion rate daily using this device, as well as drawing a conclusion on the efficiency of the treatment. This corro-meter is in the form of a probe, which contains two locations where two electrodes (cathode and anode) are placed, then it is installed in a sleeve intended for this purpose in one of the stations TAM or TFNE. Immerse the tip of the probe containing the electrodes in water and the other end into the air that has a socket to place the device. [27]

Measurements are made every day for 10 to 15 days and the values displayed are in mpy (miles per year) converted into mm/year.

$$1 \frac{\text{mm}}{\text{year}} = 0.0254$$

This device works with the principle of linear polarization.

#### **IV.2.9. Presentation of biocide**

The biocide that was the subject of the industrial test come from CHIMEC. CHIMEC7162 biocide is characterized by:

- Micro biocidal organic and quaternary ammonium derivative.
- Absence of bioaccumulation ..... - broad antibacterial spectrum.
- Not carcinogenic ..... - good elimination capacity (60-80%).

➤ **Biocide CHIMEC 7162**

**Table 03: the properties physical and chemical of CHIMEC 7162**

Physical		Chemical	
<i>Color</i>	Yellow The variability of the colour of the product does not affect the efficacy.	Density at 20°C (gr/cm <sup>3</sup> ) Viscosity at 20°C(cP) pH in distilled water	1.02 ± 0.02 < 100 (1%): 6.5± 1.0

The CHIMEC 7162 is a liquid biocide with a long series of actions, it is particularly suitable for preventing and controlling the proliferation of algae and bacteria, aerobic or anaerobic, in industrial systems.

The CHIMEC 7162 also provides effective corrosion protection. If properly and systematically used, the product prevents organic fouling from developing, thus contributing to the maintenance of high efficiency in the system concerned. The product does not contain heavy metals or phenols. It therefore complies with the characteristics required by the legislation currently in force.

**a) Physical and chemical properties**

the properties of the biocide CHIMEC 7162 are presented in table bellow (table03)

**b) Application**

CHIMEC 7162 is particularly suitable in the petroleum sectors for the sterilization of storage tanks. The product can be dosed continuously or not, or diluted in water at any concentration percentage. CHIMEC 7162 can be used alone or as an integral part of a complete chemical treatment. CHIMEC technicians will recommend the most appropriate program for normal use of the product.

**c) Biocide CHIMEC 7162 industrial test**

Carried out in the Tin Fouye Tabenkort region, attached the results of the biocidal efficacy tests and corrosion inhibitors performed on the TAM-WATER-CS2 and TFNE-CS2 circuits of the TFT region. These results were obtained after 15 days of incubation at 37°C followed

by hydrogen sulphide (H<sub>2</sub>S). And for the effectiveness tests of corrosion inhibitors, we performed the measurement of the dissolved iron content in the injection water on the TAM-WATER-CS2 circuit, with the control of pH and the corrosion rate. The program of analyses was jointly established with the PD/DIV. TFT and the various suppliers CHIMEC; CECA; NALCO; on the choice of sites and sampling points for the conduct of industrial tests. two different circuits with six sampling points. Injection of biocides at a concentration of 100, and injection of the corrosion inhibitor was carried out by a prefilming followed by dosages of 20, 15, 10ppm. The results of the industrial tests obtained are recorded in the following three parts, respectively.

The region injects between 20000 m<sup>3</sup> and 21000 m<sup>3</sup> of water from Lias. The TAM station alone produces 12000 m<sup>3</sup> /d. The produced water is contaminated with sulfato-reducing bacteria "S.R.B" .To better protect the bottom and surface installations against corrosion, the region seeks to optimize it is produced by efficiency tests, and in order to improve the efficiency of treatment on the facilities the region.

the biocides was injected into the network of the two pressure-maintaining injection water plants ((TAM&TFNE)– Arrival CS2). Regarding the corrosion inhibitor the injection into the network [shipping TAM to injection station CS2 (14' pipe, 8 km long)].

**d) Sampling points**

Before starting the industrial test with biocide CHIMEC7162 and in agreement with the operators of the region, a number of points were chosen. The points were selected, depending on the mode of operation of the pressure retaining system. We selected one station for the network. The networks are equipped with three sampling points (Table 04) & (Diagram 1).

**Table 04: Sampling points selected during the CHIMEC7162 biocide industrial test.**

Station	Sampling points	Designations
TFNE	BP Outlet Separator	
	Outlet BAC	CS2 Shipping BAC
Centre Separation2 (CS2)	Arrival TFNE	Before filtration

**e) Conduct of the Industrial Test (Evaluation) CHIMEC 7162 "TFNE-CS2 Circuit"**

The efficacy of biocide CHIMEC 7162 was evaluated according to the program presented in Table 04. Control samples (blanks) were taken at the three sampling points selected. The control counts will correspond to the SRB concentrations initially present in the produced water at the TFNE and CS2 station before the start of biocide treatment.

Biocide CHIMEC 7162 is injected by shock treatment at a concentration of 100 ppm for 4 hours at Manifold Well Starts (pipe :  $\phi = 3''$  GL) (10-well treatment) and another shock treatment at the collector (  $\phi = 6''$  Well Finishes) Bacterial counting is performed before and after the biocide injection.

### **IV.2.10. Inhibitor NORUST CR 486**

NORUST CR 486 is Mixture of fatty amine derivatives and oxygen redactor and water-soluble multifunctional product with the following properties:

- Corrosion inhibitor specially developed for the petroleum industry to provide effective protection against corrosion caused by the presence of CO<sub>2</sub> and/or H<sub>2</sub>S
- Bactericidal, which makes it possible to advice for the protection of material subject to bacterial corrosion especially by reducing sulfato bacteria.
- Oxygen reducing.

#### **a) Instructions for use**

The NORUST CR 486 is used in the pure state, as a continuous injection or as a cork treatment directly in the system to be treated. The dosage varies from a few ppm to several hundred ppm depending on the type of application, local conditions and the severity of the corrosion problem.

#### **b) Chemical nature**

Preparation based on cationic surfactant and alkaline sulphite in monoethylene glycol.

#### **c) Industrial tests Corrosion inhibitor NORUST CR486**

This part presents the results of the industrial tests carried out in the TFT/DP region, for corrosion inhibitor NORUST CR486.

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The corrosion inhibitor is injected into the network of the two water generating stations Pressure Hold Injection [start shipping TAM to CS2 Injection Station (14' pipe, 8 km long)].

### d) Equipment

For the implementation of the corrosion inhibitor effectiveness test NORUST CR486, we used a DR 2000 (Portable spectrophotometry) for the analysis of iron dissolved in water and a pH meter for pH. And for the corrosion rate the AquaMate.

### e) Sampling

Before starting the industrial test with the corrosion inhibitor NORUST CR486, and in agreement with the operators of the region, a number of points were selected. The points were selected, depending on the mode of operation of the pressure retaining system. We have selected one station for the network. The network is equipped with three (03) sampling points. (see table 05).

### f) Conducting the NORUST CR486 Industrial Test

The effectiveness of NORUST CR486 was evaluated according to the program presented in. Previously, pre-treatment control samples (blanks) were taken at the three selected sampling points. The dissolved iron concentrations and pH obtained will correspond to the concentrations initially present in the produced water at the injection water pressure holding stations, prior to the start of the corrosion inhibitor treatment.

NORUST CR486 corrosion inhibitor is injected with continuous treatment, the method of injection is realized by a prefilming and with a continuous treatment of concentration 20, 15, 10ppm at the level Pressure Maintenance of the water production plant Tamendjilt (TAM) Collector 6' Shipment to CS2 Injection Station (14' pipe, 8 km long) .

**Table 05: Sampling Points Used in the NORUST CR486 Industrial Test**

Selected stations	Sampling points	Designations
TAM – Water	Outlet BAC	Separator Output HP
	Inlet BAC	BAC expedition CS2
Centre Separation2 (CS2)	TAM-Water Arrival	Before filtering

**IV.3. Results and Discussions**

The result of CHIMEC7162 biocide industrial test.

**Table 06: Concentration of S.R.B in water injection plants (TFNE. CS2) TFT region.**

Date	TFNE-WATER BIOCIDES CHIMEC 7162			Observation
	Outlet,SEP-TFNE	Outlet,BAC-TFNE	betwe,CS2-TFNE	
26/04/2021	*	*	*	*
27/04/2021	*	*	*	*
28/04/2021	*	*	*	*
29/04/2021	10 <sup>3</sup>	10 <sup>3</sup>	*	*
30/04/2021	10	10	10 <sup>2</sup>	witness sample
01/05/2021	*	*	*	Launch Trait
02/05/2021	10 <sup>4</sup>	10 <sup>3</sup>	10 <sup>2</sup>	Launch Trait
03/05/2021	10 <sup>2</sup>	10 <sup>3</sup>	10	1st day af.Trait
04/05/2021	10 <sup>3</sup>	10 <sup>3</sup>	10	2nd day af.Trait
05/05/2021	10 <sup>3</sup>	10 <sup>3</sup>	10 <sup>2</sup>	3th day af.Trait
06/05/2021	10 <sup>3</sup>	10 <sup>4</sup>	10 <sup>2</sup>	4th day af.Trait
07/05/2021	10 <sup>4</sup>	10 <sup>3</sup>	10 <sup>4</sup>	5th day af.Trait
08/05/2021	10 <sup>3</sup>	10 <sup>2</sup>	10 <sup>4</sup>	6th day af.Trait
09/05/2021	10 <sup>4</sup>	10 <sup>4</sup>	10 <sup>3</sup>	7th day af.Trait
10/05/2021	10 <sup>3</sup>	10 <sup>3</sup>	10 <sup>3</sup>	8th day af.Trait
11/05/2021	10 <sup>3</sup>	10 <sup>3</sup>	10 <sup>3</sup>	9th day af.Trait

The industrial test waters tested with bactericide "CHIMEC 7162" were subjected to a bacterial count prior to injection of the treatment product, in order to compare the different concentrations and thus assess the efficacy of the product. Thus, we can see that the bacterial concentration varies between 10<sup>2</sup> and 10<sup>4</sup> germs/ml "See Table 04" in the TinFouyé Nord-Est circuit – Separation center 2.

The injection of the bactericide CHIMEC 7162 into the 'TFNE-CS2' circuit at a concentration of 100 ppm, the results obtained over the 15 days of incubation, gives the same concentration of S.B.R as that counted before treatment.

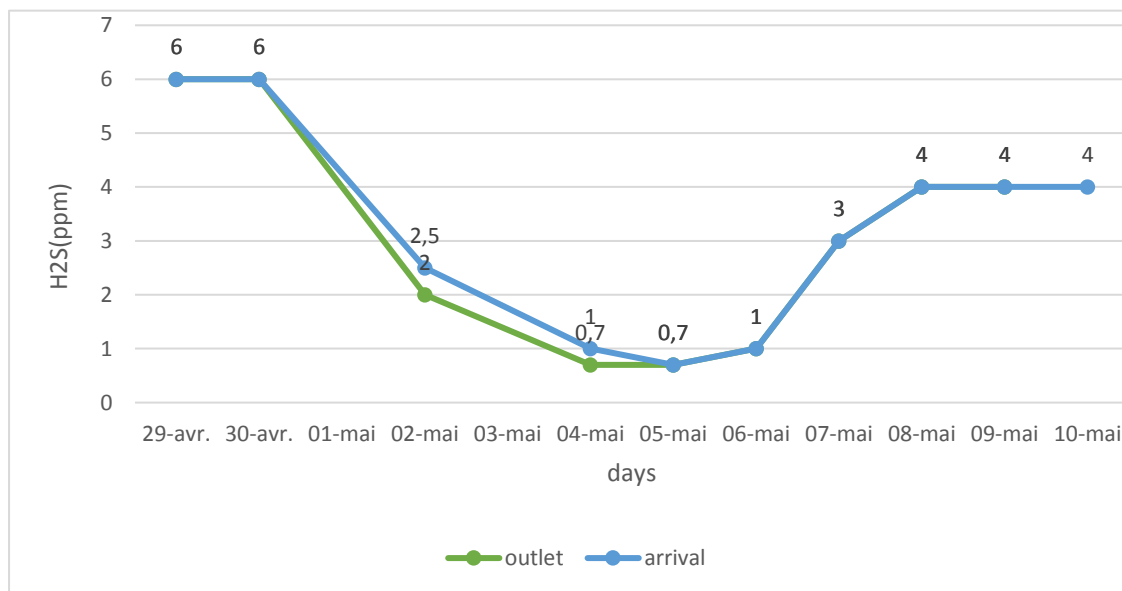


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### 1) *The result of concentration of H<sub>2</sub>S (ppm) in water injection plants (TFNE. CS2) TFT region.*

**Table 07: Concentration of H<sub>2</sub>S (ppm) in water injection plants ( TFNE. CS2) TFT region.**

Date	TFNE-WATER BIOCIDES CHIMEC 7162		
	BP Separator Outlet	Outlet - TFNE	Arrival - CS2
28/04/2021	*	*	*
29/04/2021	> 5	> 5	> 5
30/04/2021	> 5	> 5	> 5
01/05/2021	*	*	*
02/05/2021	2,5	2	2,5
03/05/2021	*	*	*
04/05/2021	*	0,7	1
05/05/2021	*	0,7	0,7
06/05/2021	*	1	1
07/05/2021	*	3	3
08/05/2021	*	4	4
09/05/2021	*	4	4
10/05/2021	*	4	



**Graph 01: Graphical evaluation of H<sub>2</sub>S in injection waters TFNE-CS2.**

We note that the H<sub>2</sub>S concentrations before the treatment are located in level 5 and above, after the treatment the H<sub>2</sub>S concentration fluctuated between 0.7 ppm and 5 ppm for the bactericide. This could be explained by the fact that the shock treatment made it possible to

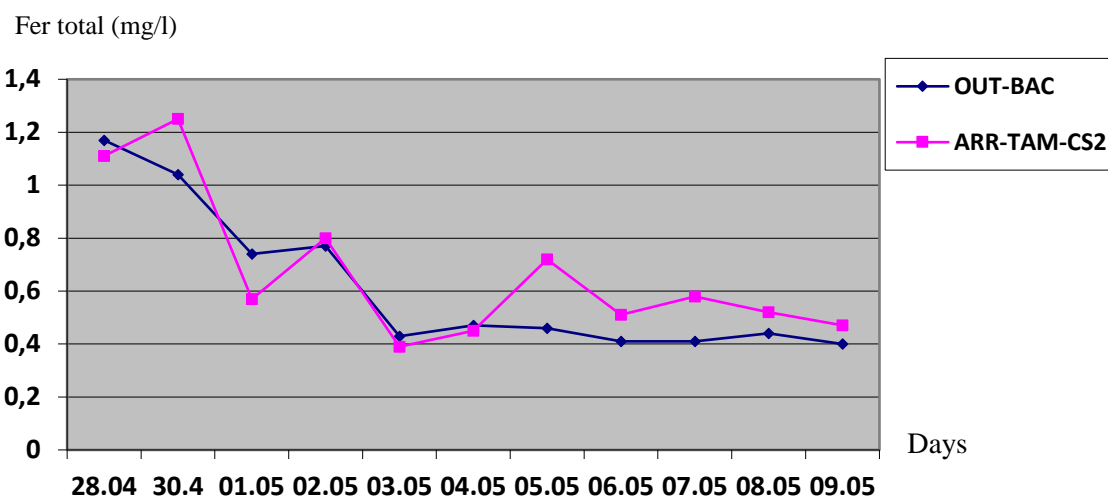
## CHAPTER IV : IMPLEMENTATION

act on the water, but as new water arrives from the wells to be treated, the bactericide concentration is diluted with the latter and decreases by the effectiveness of the products (treatment is by shock of 4 hours for 36 hours to treat all the water producing wells).

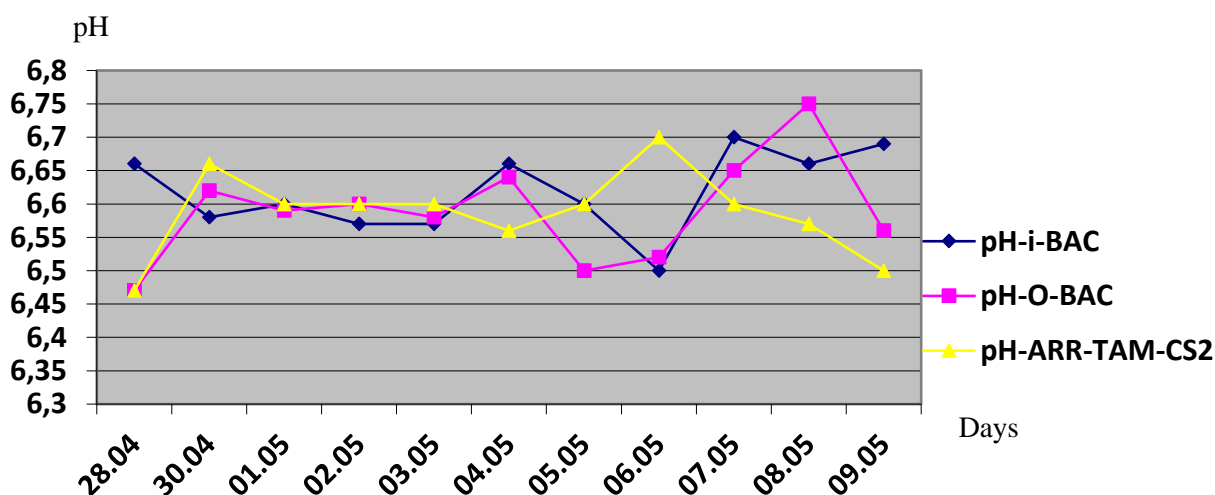
### 2) *The result obtained of NORUST CR486 at water injection stations (TAM-CS2)*

**Table 08: results obtained of NORUST CR486 at water injection stations ( TAM-CS2).**

sampling point sampling date	Inlet BAC			Outlet BAC			Arrival TAM - CS 2			Observation
	pH	T (°C)	Fer total (mg/l)	pH	T (°C)	Fer total (mg/l)	pH	T (°C)	Fer total (mg/l)	
<b>28/04/2021</b> Blanks	6,47	44	1,03	6,47	44,4	1,17	6,66	41,4	1,11	<b>blanks</b>
<b>30/04/2021</b> lanc prefilming	6,66	42,8	0,99	6,62	40	1,04	6,58	42,6	1,25	<b>Prefilming du pipe</b>
<b>01/05/2021</b>	6,6	45,3	0,66	6,59	43,2	0,74	6,6	42,4	0,57	<b>Prefilming du pipe</b>
<b>02/05/2021</b> Injec20ppm/10h	6,6	45,6	0,54	6,6	41,3	0,77	6,57	41,7	0,8	<b>injection 20 ppm à 10h</b>
<b>03/05/2021</b>	6,6	42	0,27	6,58	41,8	0,43	6,57	42,6	0,39	<b>20 ppm</b>
<b>04/05/2021</b> Injec15ppm/10h	6,56	41	0,68	6,64	40	0,47	6,66	43,7	0,45	<b>injection 15 ppm à 10h</b>
<b>05/05/2021</b>	6,6	38	0,76	6,5	42,6	0,46	6,6	43	0,72	<b>15 ppm</b>
<b>06/05/2021</b> Injec10ppm/10h	6,7	40,9	0,68	6,52	40,5	0,41	6,5	40,7	0,51	<b>injection 10 ppm à 10h</b>
<b>07/05/2021</b>	6,6	40,6	0,61	6,65	40,9	0,41	6,7	38,3	0,58	<b>10 ppm</b>
<b>08/05/2021</b>	6,57	38,5	0,74	6,75	41	0,44	6,66	37,4	0,52	<b>10 ppm</b>
<b>09/05/2021</b>	6,5	41,4	0,69	6,56	42,8	0,4	6,69	37,4	0,47	<b>10 ppm</b>



**Graph 02: Graphical evaluation of Fer tot dissolved in injection TAM**



**Graph 03: Graphical evaluation of pH in TAM injection water**

A corrosion inhibitor slows down or stops the process of corrosion of a metal in contact with injection water, responding to the condition of decreasing the rate of corrosion without affecting the physico-chemical characteristics and pH adjustment. The NORUST CR486 used on-site and organic-type molecule, it acts by adsorption to the surface of the metal, even before intervening in the reaction process to reduce the corrosion rate. The results obtained from the industrial test for its evaluation show that:

➤ **Evaluation of dissolved iron:**

The measurements obtained of the dissolved iron at different concentrations by colorimetry, result in a decrease of the dissolved iron in the water of injections after a prefilming of the

pipe, the change of concentration leaves the inhibitor to act by decreasing the level of iron until its stability.(table 08,Graph 02).

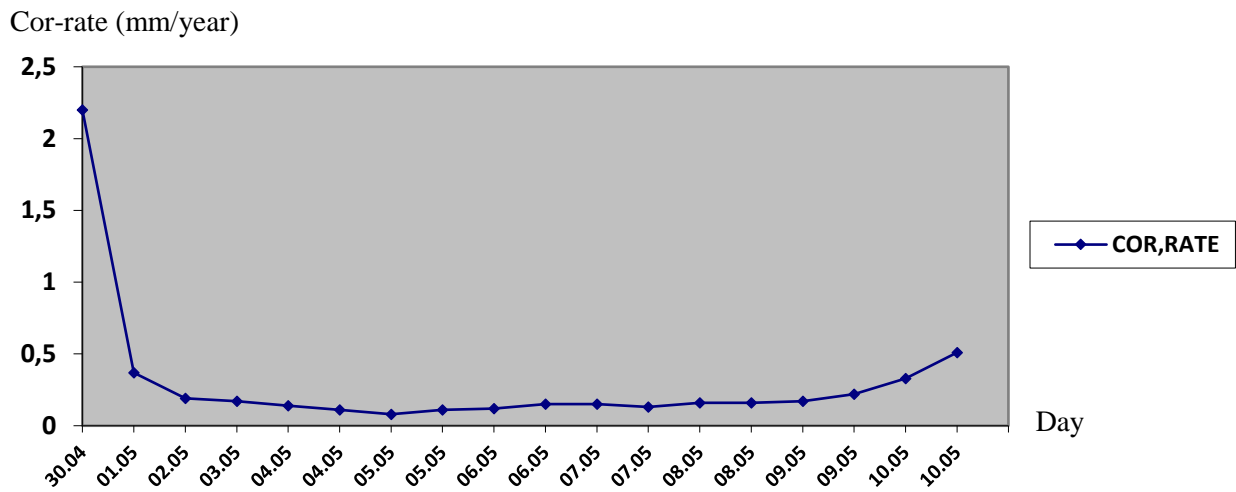
➤ *Evaluation of pH:*

The pH measurements at different concentrations, and maintained in a neutralizing area, the product almost unchanged it fluctuates between 6.5 and 6.7. This is mainly due to the action of a superficial protective layer formed by the inhibitor. (table 08, Graph 03)

3) *The result of Corrosion rate obtained at the TAM water injection plant*

**Table 09: Corrosion rate results obtained at the TAM water injection plant**

Date	NORUST CR 486		
	corrosion rate (mm/year)	Conc. (ppm)	rend (%)
30/04/21	2,2	0	0
01/05/21	0,37	40	83,2
02/05/21	0,19	40	91,4
03/05/21	0,17	20	92,3
04/05/21	0,14	20	93,6
04/05/21	0,11	20	95
05/05/21	0,08	20	96,4
05/05/21	0,11	15	95
06/05/21	0,12	15	94,5
06/05/21	0,15	15	93,2
07/05/21	0,15	15	93,2
07/05/21	0,13	10	94,1
08/05/21	0,16	10	92,7
08/05/21	0,16	10	92,7
09/05/21	0,17	10	92,3
09/05/21	0,22	5	90
10/05/21	0,33	5	85
10/05/21	0,51	5	76,8



**Graph 04: Graphical assessment of the corrosion rate in injection waters**

we note that the formation of the protective layer of the corrosion inhibitor reduces the rate of corrosion, measurements of the corrosion rate at the pipe level decrease with the first formation of a protective layer of inhibitor so it is makes it possible to slow down the passage of ferrous ion in solution.

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In this part we measured the rate of corrosion with the technique of corrosion coupon for each inhibitor **NORUST CR 486** and the biocide **CHIMEC 7162** at the region of TAM and TFNE. The results are shown in the (tables 10-11).

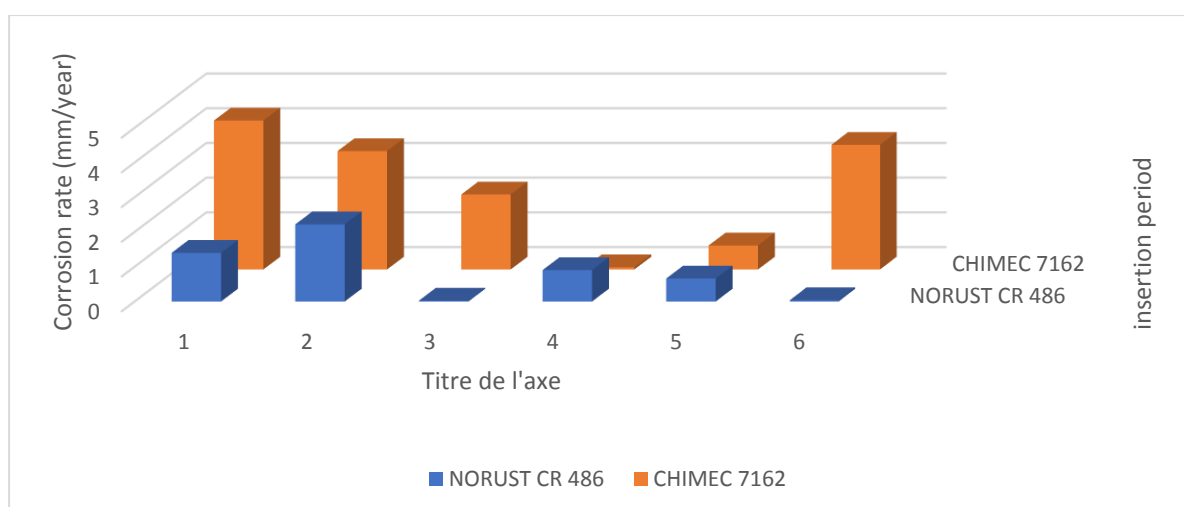
**Table 10: Evaluation of Corrosion Coupons at Pressure Holding Stations for NORUST CR 486 (TAM/TFNE) Year 21**

Location	insertion date	pick-up date	injected product	Surface of the coupon (cm <sup>2</sup> )	weight p1 (mg)	weight p2 (mg)	Corrosion RATE (mm/year)	Classification of corrosion rate
TAM	02/01	26/02	NORUST CR 486	10.76	17469.1	15941.4	1.14	Severe V corrosion
TAM	02/01	20/02	NORUST CR 486	11.63	14453.8	11590.2	2.22	Severe V corrosion
TAM	06/01 2021	23/02 2021	NORUST CR 486	11.11	14459.3	14429.2	0.025	Corrosion LOW
TAM	26/02 2021	06/04 2021	NORUST CR 486	10.34	11119.1	10596.7	0.904	Severe V corrosion
TAM	28/02 2021	10/04 2021	NORUST CR 486	12.01	14987.3	14214.7	0.662	Severe V corrosion
TAM	06/03 2021	20/04 2021	NORUST CR 486	12.01	15008.8	14960.0	0.039	Corrosion MODERATE

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**Table 11: Evaluation of Corrosion Coupons at Pressure Holding Stations for CHIMEC 7162 (TAM/TFNE) Year 21**

location	insertion date	pick-up time	injected product	Surface of the coupon (cm <sup>2</sup> )	Initial weight p1 (mg)	Initial weight p2 (mg)	Corrosion RATE(mm/year)	Classification of corrosion rate
TFNE	02/01 2021	26/02 2021	CHIMEC 7162	11.07	14012.5	10725.9	4.29	Severe V corrosion
TFNE	02/01 2021	20/02 2021	CHIMEC 7162	9.131	11593.3	8493.4	3.41	Severe V corrosion
TFNE	06/01 2021	23/02 2021	CHIMEC 7162	10.05	11000.8	8845.1	2.158	Severe V corrosion
TFNE	26/02 2021	06/04 2021	CHIMEC 7162	9.278	11099.2	11038.2	0.064	Corrosion MODERATE
TFNE	28/02 2021	10/04 2021	CHIMEC 7162	7.793	11737.2	11271.1	0.69	Severe V corrosion
TFNE	06/03 2021	20/04 2021	CHIMEC 7162	8.03	11263	7416.9	3.59	Severe V corrosion



**Graph 05: Evaluation of Corrosion rate in corrosion Coupons for the inhibitors CHIMEC 7162 and NORUST CR 486.**

In following some pictures (Figure IV.5 Figure IV.6) of coupons Extracted from the two stations before adding the inhibitor assigned to the study shows the severity of corrosion measured.



(1) Corrosion LOW

(2) Severe v corrosion

Figure IV.5: corrosion Coupon in TAM



(1) Severe v corrosion

(2) Severe v corrosion

Figure IV.6: Coupon installed inTFNE

#### IV.4. Conclusion

Biocide compounds are often added to water to inhibit the microbial activity of sulfate-reducing microorganisms, here in our reserch we tested two types of inhibitors to see how we can reduce this corrosion, the NORUST CR 486 and the biocide CHIMEC 7162 and results showed us that the inhibitor NORUST CR 486 is more efictive than the CHMIEC 7162 and doing good job for diminue the rate of corrosion.



## Conclusion

The aim of this work is to study the problem of corrosion of pipes conducting water at TFT region, and to see how certain corrosion inhibitors are used in these petroleum units.

At the level of the installations concerned, an injection water analysis has shown there is type of corrosion is mainly due to micro-organismes known as sulphate reducing bacteria. Daily monitoring of the instantaneous rate of corrosion and by technique corrosion coupons show their severity.

And for that we use corrosion inhibitors which are a recent means of combating corrosion of materials and alloys The originality of this method stems from the fact that the anti-corrosion treatment is not carried out on the metal itself, but via the corrosive medium. In particular, and for the protection of metals and ferrous alloys . so we used two types of inhibitors against this bacterian corrosion which are the biocide CHIMEC 7162 and inhibitor NORUST CR 846.

At the end of this study, we can first conclude that the bactericide" CHIMEC 7162" is not very effective against sulfato-reducing bacteria at a concentration of 100 ppm. However, it is recommended to increase the concentration of bactericide and to gradually see the evolution of the latter in order to optimize the dose to be injected as much as possible, and to conclude on its effectiveness.

In the othere hand, we can conclude that the corrosion inhibitor "NORUST CR 486" has good efficacy against electrochemical corrosion. It has a filming effect which allows it to decrease or stop the intensity of the current to prevent the dissolution of ferrous ions in the medium and reduce the FeS concentration.

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