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Théme

Effectiveness of Natural Inhibitors extracted from Moringa and Alagua Plants Against Industrial Inhibitor CHIMEC 1038 under Corrosive Conditions in the Berkaoui Region: A Comparative Study

Publicly defended on: 24/06./2024
In front of the jury:

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Appreciation

At first, we would like to thank Allah, who gave us the strength and courage to complete this modest task.

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Dedication To:

My parents: source of my courage and inspiration.

To my grandfathers; and my grandmothers

To my sisters;

To my uncles and aunts;

To my close ones who passed away

And To all my family;

As well as all my friends without exception.

I dedicate this work to you

Yours Mohamed Guendouzi

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the spirit of my beloved father, Tayeb, who has always been my source of inspiration and strength, and whom I hope is proud of me with every step I take. To my dear mother, Sheikh Boubker Zahra, who has always been my support and encouragement, and who never withheld her love, care, and motivation. To my brothers Mounir and Hamza, my sisters Abir, Doaa, and Hayat, and my aunt Hida, who have always been a source of joy and support for me, and who shared with me my joys and sorrows. To my friends and colleagues, who have been partners in this long academic journey, and who have added unforgettable moments to my academic path. To my esteemed professor, Chouicha Samira, who spared no effort in guiding and teaching me, and who has had a significant role in achieving this accomplishment. To everyone who supported me and believed in my abilities, I dedicate this work as an expression of my gratitude and appreciation. _ With sincere thanks and appreciation, [Mohamed Laib]

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Abbreviation	Significance
PC	**Production center**
FPC	**Fissile Material Production Center (Gas)**
CND	**Non-Destructive Testing**
HBK	**Haoudh Berkaoui**
pH	**Potentiel d’Hydrogène**

Table of Significance

Symbole	Signification	Unité
Beta a	Anodic Tafel Coefficient	mV
Beta c	Cathodic Tafel Coefficient	mV
C	Concentration	Mg/L ou Ppm
Δ Div	Differences in Read Divisions	
ΔT	Interval between two divisions	jours
Ecorr	Corrosion Potential	mV.
Icorr	Corrosion Current	mA/cm^2
N	Normality	Mol/l
P	Pressure	Bar
Rp	Polarization Resistance	Kohm.cm2
S	Salinity	g/l
T	Température	C
T	Time	an
v	Volume of the prepared solution	ml
corrosion	Corrosion Rate	Mm/an OU MPY

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II.1.Geographical Location of the Region (HBK):

ملخص :

هذه الدراسة تدرس التآكل في معدات الإنتاج في حوض بركاوي. تركز على الحساسية تجاه ثاني أكسيد الكربون وكبريتيد الهيدروجين في التركيبات السطحية. يمكن أن تتسبب التفاعلات التآكلية في التعطيل الإنتاجي للغاز عبر تسربات المنتجات السائلة. لتسلط الضوء على الحاجة الحرجة لفهم هذه الآليات.هذا البحث يهدف إلى توضيح عمليات التآكل، تقييم تأثيراتها، واقتراح استراتيجيات مخصصة للوقاية والسيطرة في هذا المجال. النتائج تظهر ان المثبط الصناعي شيماك1038 يظهر فعالية عالية بنسبة 97.39% . مما يقلل بشكل كبير من معدلات التآكل وكثافات التيار الكهربائي. كما أن الخلاصات الطبيعية من نباتات المورينجا والعقة تظهر أيضًا قدرات واعدة في منع التآكل,بتحقيق نسبة 82,44%.تؤكد هذه النتائج على إمكانية استعمال المثبطات الطبيعية كبديل صديق للبيئة، مما يوفر حماية فعالة ضد التآكل في البيئات الصناعية الصعبة. يُوصى بإجراء المزيد من الدراسات لتحسين كفاءتها ودمجها في ممارسات إدارة التآكل في حوض بركاوي.

كلمات مفتاحية :

التآكل، مثبط طبيعي، مثبط صناعي، شيماك1038، المورينغا، العقة، فعالية.

ABSTRACT

This study investigates corrosion in production equipment at Haoud Berkaoui, focusing on susceptibility to carbon dioxide and hydrogen sulfide in surface installations. Corrosion-induced perforations can disrupt gas production through effluent leaks, highlighting the critical need for understanding these mechanisms. The research aims to elucidate corrosion processes, evaluate their impacts, and propose tailored prevention and control strategies for the field. results reveal that the industrial inhibitor CHIMEC 1038 demonstrates high effectiveness 97,39%, significantly reducing corrosion rates and electrical current densities. Natural extracts from Moringa and Alagua plants also show promising corrosion inhibition capabilities, achieving an efficiency of 82.44%. These findings underscore the potential of natural inhibitors as environmentally friendly alternatives, offering effective protection against corrosion in challenging industrial environments. Further optimization and application studies are recommended to enhance their efficacy and integration into corrosion management practices at Haoud Berkaoui.

KEY WORDS :

Corrosion , Natural inhibitor , Industriel inhibitor , Chimec 1038 , Moringua , Alagua Effectivness

RÉSUMÉ :

Cette étude examine la corrosion dans l'équipement de production à Haoud Berkaoui, en se concentrant sur la susceptibilité au dioxyde de carbone et au sulfure d'hydrogène dans les installations de surface. Les perforations induites par la corrosion peuvent perturber la production de gaz par des fuites d'effluents, soulignant le besoin critique de comprendre ces mécanismes. La recherche vise à élucider les processus de corrosion, évaluer leurs impacts, et proposer des stratégies adaptées de prévention et de contrôle pour le champ. Les résultats révèlent que l'inhibiteur industriel CHIMEC 1038 démontre une grande efficacité de 97,39 %, réduisant significativement les taux de corrosion et les densités de courant électrique. Des extraits naturels des plantes Moringa et Alagua montrent également des capacités prometteuses d'inhibition de la corrosion, atteignant une efficacité de 82,44 %. Ces résultats soulignent le potentiel des inhibiteurs naturels en tant qu'alternatives respectueuses de l'environnement, offrant une protection efficace contre la corrosion dans des environnements industriels difficiles. Des études supplémentaires d'optimisation et d'application sont recommandées pour améliorer leur efficacité et leur intégration dans les pratiques de gestion de la corrosion à Haoud Berkaoui.

Mots clés :

Corrosion, inhibiteur naturel, inhibiteur industriel, CHIMEC 1038, Moringa, Alaga, efficacité

General Introduction

Gas production in Algeria plays a pivotal role in its economy and global energy markets. Algeria ranks among the top natural gas producers globally, with extensive reserves concentrated primarily in the Hassi R'Mel and haoud berkaoui field . The country's gas industry is integral to meeting domestic energy demand and fulfilling international export commitments Haoud Berkaoui, situated in the Algerian Sahara, is a significant region for gas production, contributing substantially to Algeria's hydrocarbon sector. The development of gas fields in Haoud Berkaoui involves advanced drilling techniques and reservoir management strategies to optimize production rates and maintain reservoir integrity. Challenges include managing production costs, enhancing recovery rates from mature fields, and ensuring environmental stewardship in the Sahara desert environment. [1]

Corrosion poses a significant problem in this region due to the corrosive nature of produced fluids, high temperatures, and desert environment. Corrosion in Haoud Berkaoui's gas production infrastructure affects various components, including well casings, pipelines, valves, and processing equipment. The corrosive elements present in produced fluids, such as hydrogen sulfide (H2S) and carbon dioxide (CO2), exacerbate corrosion rates, necessitating robust corrosion management strategies. [2]

Industrial Inhibitors serve as essential tools in mitigating corrosion and maintaining the integrity of critical infrastructure in this hydrocarbon-rich region. The selection of corrosion inhibitors at Haoud Berkaoui considers factors such as fluid composition, operating conditions (temperature, pressure), metallurgy of equipment, and environmental impact. Inhibitors may include organic compounds, film-forming amines, phosphates, and surfactants tailored to specific corrosion challenges encountered in the region.

The strategic application of inhibitors in Haoud Berkaoui is integral to sustaining operational reliability, minimizing downtime due to corrosion-related issues, and ensuring safe and efficient gas production. Continued research and development in inhibitor technologies are essential to address evolving corrosion challenges and enhance asset integrity in Algeria's critical hydrocarbon fields.

The utilization of natural inhibitors presents a sustainable approach to mitigate corrosion and preserve the integrity of essential equipment and pipelines in this hydrocarbon-rich area.Natural inhibitors, derived from plant extracts, bio-based compounds, or minerals, offer several advantages in corrosion management: environmentally Friendly, cost-effectiveness:. compatibility effectiveness

Incorporating natural inhibitors in corrosion management strategies at Haoud Berkaoui supports the dual goals of environmental stewardship and operational reliability in Algeria's gas production sector. Continued innovation and investment in natural inhibitor technologies are crucial for enhancing corrosion resistance, extending asset lifespan, and ensuring sustainable development practices in this vital hydrocarbon region.

This work aims to assess and compare the effectiveness of two types of inhibitors—industrial and natural (extracted from Moringua and Alaga plants)—in safeguarding equipment against corrosion in this corrosive environment.to achieve our purpose, we propose. to determine which inhibitor type (industrial or natural) provides superior protection against corrosion, contributing to prolonged equipment lifespan and reduced maintenance costs in berkaoui field and to evaluate the sustainability credentials of natural inhibitors, potentially promoting environmentally friendly corrosion management practices in the hydrocarbon industry.

Our thesis is divided into three chapters: The first chapter presents the state of the art on corrosion, covering generalities on corrosion and the main corrosion inhibitors used in the oil industry. The second chapter addresses the corrosion issue in Haoud berkaoui field, the analysis methods, and monitoring applied in this region. The third chapter presents the general overview of industrial inhibitor CHIMEC1038 and the extraction method of two natural inhibitors extracted from Moringa and Alagua plants to test these inhibitors under corrosive conditions similar to operational conditions in the Berkaoui region. Chapter four provides a comparative study evaluating the effectiveness of natural inhibitors extracted from Moringa and Alagua plants against the industrial inhibitor CHIMEC at varying concentration, we conclude our work with a general conclusion.

Chapter I : Generalities on Corrosion

I. General Overview of Corrosion :

I.1 Definition :

Corrosion is a natural process of destruction, comparable to earthquakes or floods, but with a key distinction: it can be prevented or controlled. It occurs when materials, especially metals, interact with their environment, resulting in gradual deterioration. Several definitions of corrosion exist:

(A) Surface wastage due to exposure to reactive environments.

(B) The gradual destruction of metals through environmental interaction.

(C) Material decay caused by chemical or biological agents.

(D) Corrosion as a reverse of extractive metallurgy, completing the life cycle of materials.

(E) Deterioration of materials due to environmental reaction.

(F) Destructive attack of metal by chemical or electrochemical reaction with the environment.[3]

I.2 Cause Of Corrosion :

- Exposure to reactive environments: Corrosion often occurs when metals are exposed to environments containing moisture, oxygen, acids, or salts, which facilitate chemical reactions leading to corrosion.[4]
- Electrochemical reactions: Corrosion can result from electrochemical processes, such as galvanic corrosion, where two dissimilar metals in contact with an electrolyte undergo a corrosion reaction.[5]
- Chemical agents: Certain chemicals in the environment can accelerate corrosion processes. For example, exposure to acidic or alkaline substances can increase corrosion rates.[6]
- Biological agents: Microorganisms, such as bacteria, fungi, or algae, can contribute to corrosion by producing corrosive byproducts or promoting the formation of corrosive environments.[7]
- Mechanical factors: Mechanical stresses, such as tension, compression, or abrasion, can exacerbate corrosion processes by creating localized areas of vulnerability on the material surface.[8]

I.3 Types of corrosion : 4 [9]

Depending on the nature of the surrounding environment with which the material interacts, corrosion can be classified into three main types :

I.3.1 Chemical Corrosion:

This is the reaction between the metal and a gaseous phase. If this corrosion occurs at high temperature, it is then called "dry corrosion" or high-temperature corrosion. During chemical corrosion, the oxidation of the metal and the reduction of the oxidant happen in a single action, meaning the metal atoms directly form chemical bonds with the oxidant, which removes the valence electrons from the metal atoms.

I.3.2 Electrochemical Corrosion:

Electrochemical corrosion, also known as wet corrosion, is the most important and common mode of corrosion. It essentially involves the oxidation of the metal in the form of ions or oxides. Electrochemical corrosion of a material corresponds to a redox reaction, which includes:

- The oxidation reaction of a metal, called the "anodic" reaction:

  $M \rightarrow Mz^{+} + ze^{-}$ anodic reaction, negative pole (-), with loss of electrons

- The reduction reaction of an oxidizing agent, called the "cathodic" reaction:

  $Ox + ze^{-} \rightarrow Red$ cathodic reaction, positive pole (+), with gain of electrons

Electrochemical reactions are redox reactions involving electron transfer. Both reactions occur simultaneously so that the total electric current appears to be zero; however, it does actually exist. It is called the corrosion current.

I.3.3 Bacterial Corrosion:

This is the bacterial attack on metallic materials, particularly in buried pipelines and tanks. Indeed, the metabolism of certain bacteria leads to the formation of sulfuric acid, which attacks the metal. In the oil industry, bacterial corrosion is always induced by sulfur-reducing bacteria in anaerobic environments. These bacteria transform sulfates into hydrogen sulfide, which combines with ferrous salts to form iron sulfide.

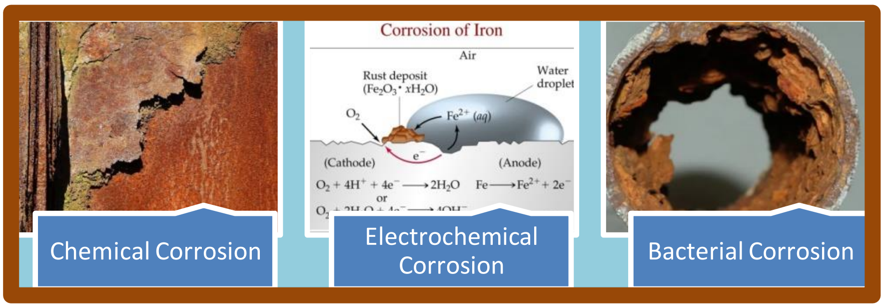


Figure I-1: types of corrosion

I.4 Formes of Corrosion : [10]

I.4.1.General Corrosion:

It is also known uniform corrosion or dry corrosion; it is the type of corrosion which perishes the barren metal surface more or less, uniformly. It can also be defined as a type of corrosion which proceeds at same rate over the entire barren area. Oxygen acts as a foremost cause of this corrosion. The most common materials which show general corrosion are cast iron and steel. When they are exposed to moist atmosphere, they give rust-like appearance.

Where, A is any metal.

Experiments on the behavior of dry metals show that no corrosion occurs when they are kept over sulfuric acid and only show superficial corrosion when they are kept over water

and only show superficial corrosion when they are kept over water.

I.4.2.Stress Corrosion Cracking:

Stress corrosion cracking is a phenomenon that is of interest to a wide range of metal users. When it occurs under service conditions, often without any prior indication of impeding collapse, its effect may be catastrophic.

It is the type of corrosion which results from the stress applied on the material (present initially in inert environment) and thus results in emergence of crack in corrosive environment. It can be accelerated by either residual internal stresses in the metal or externally applied. It mostly occurs at high temperatures. It is more common in alloys than in metals. SCC can only occur if the following three factors are fulfilled:

- Presence of susceptible material
- subjection to corrosive environment and
- tensile stresses.

The problem cannot be said to be a diminishing one, since the number of alloys known to be susceptible to stress corrosion cracking and the number of environments that cause cracking have both risen till now. Over the last 25 years or so a large, widely dispersed and mainly un-coordinated effort has been made in the Western World to cope with stress corrosion cracking An additional factor of all cracking processes that must be included in determining the mechanisms of stress corrosion cracking is the role of time. A quantitative determination of a stress corrosion mechanism must include not only what is happening either in metallurgical or electrochemical terms but, perhaps more importantly, it must indicate the rates at which such occurrence is operating. It has been suggested in very general terms that the important feature in a stress corrosion crack propagation process is the time in which a sequence of events occurs, e.g. the rate of slip step emergence or the rate of re-passivation

I.4.3.Localized Corrosion:

Localized corrosion is quite different from general corrosion. General corrosion takes place at a relatively larger area whereas localized corrosion takes place comparatively at a smaller area. This corrosion occurs when the small areas of a metal surface are corroded much easily as compared to the whole in a corrosive environment. These small areas are partially corroded from the metal surface due to the presence of corroding medium at a faster rate. The area with limited supply of oxygen becomes anode whereas the other with full supply becomes cathode. It is further of two types:

- Pitting corrosion
- Crevice corrosion

I.4.4.Pitting Corrosion :

Pitting corrosion is an important type of localized corrosion. This type of corrosion initially occurs in a comparatively small area on a material. After sometime, the area gets larger and deeper, which forms pits in the surface. In this type of localized corrosion, pits (or holes) are established on the surface of material. An area covered by impurity or water has lower concentration of oxygen so it acts as anode while the other acts as cathode. It is supposed that electrochemical mechanism is responsible for the dissolution of the metal. Till now, two theories are widely used: One is suggested by Hoar. He linked the emergence and growth of the pits with the effect of increase of acidity level of the solutions at active sections Another is suggested by Russian investigators. They linked the formation of pits with the displacement from the metal surface by anions. The ratio of deepest pit to the average penetration is known as pitting factor. Pitting factor can be used to check the intensity of pitting corrosion. It is much harmful type of corrosion as it is strenuous to detect, foretell and design against. It is usually observed in passive materials. The presence of non-uniformities adds fuel to the rise of this corrosion. The reaction may proceed as:

I.4.5. Crevice Corrosion:

Crevice corrosion is one of the major practical problems especially in marine applications It mainly affects Stainless Steels. Presence of chloride adds more difficulties while handling with crevice corrosion). It is a restricted space corrosion to which the approach of working fluid from the corrosive environment to the space (crevices) is inadequate. The joint area has comparatively lower content of oxygen as compared to the outer area, so joint area acts as anode whereas the outer area acts as cathode. This corrosion is started by concentration gradients. The grouping up of chlorides ions inside a crevice will begin it. It occurs at comparatively lower temperature than pitting corrosion. Various factors that impact crevice corrosion are as follow.

- The type of material i.e. alloy, metal.
- Geometric characteristics of crevices such as surface roughness
- Environmental conditions such as pH level, temperature, etc.

I.4.6 Inter Granular Corrosion :

It is also called Inter granular attack (IGA), this corrosion occurs when the margins of the metal surface are more prone to corrosive environment than at the core. This corrosion helps to veil the material's corrosion resistance under many circumstances. This is known as IGA Test. The Inter granular corrosion of aged Al-4%Cu alloys has been the subject of numerous investigations. It is generally agreed that the microstructure of the aged Al-Cu alloy is the one represented below in the Inter-granular Corrosion is not affected with the addition of impurities like C, N, O, Mn and S whereas addition of Si and P affects the corrosion .

I.4.7 Galvanic Corrosion :

According to electrochemistry, the galvanic corrosion reaction is caused at discrete portions on the metallic surface by an anodic portion and a cathodic portion .The preferential corrosion of one metal (in presence of a suitable electrolyte) over the other, when both are having an electrical contact is known as galvanic corrosion. It is also known as bimetallic corrosion. It is an electrochemical phenomenon of two unlike metals electrically connected and placed in a suitable electrolyte. The metal at cathode is protected while the metal at anode is corroded. Only unlike metals show galvanic corrosion. The less reactive metal is assigned as cathode while the other is assigned as anode. The rate of galvanic corrosion is directly proportional to the potential difference between the two metals. It increases with the increase in potential difference between the two metals. The reaction of galvanic corrosion is represented in Fig.7. This potential difference is calculated by using the relation: P.d.= -dG/nF

Where; dG is the Gibbs free energy of the reaction, n is the number of moles of electrons transferred and F is the Faraday constant whose value is 23.06kcal/volt.

Let us have an example in which Zn and Cu are electrically connected. Since, in electrochemical series, Zn lies at a higher position than Cu, so Zn acts as anode whereas Cu acts as cathode. This means that Zn undergoes loss of electrons whereas Cu accepts electrons. Due to lesser noble nature of Zn as compared to Cu, Zn undergoes corrosion. In Acidic solution,

I.4.8 Erosion Corrosion :

Due to the relative movement between the metal surface and corrosive fluid, the metal surface gets corroded. This is known as erosion. When the fluid contains solid particles that are harder than the affected metal surface, erosion will occur by the combinedaction of corrosion and abrasion whereas when the fluid contains the particles which are softer than the metal, erosion will occur by corrosion and attrition. The rate of relative flow gives the idea about abrasion. The mechanism of chipping and cracking determines the cause of erosion, which occurs due to concurrent formation and removal of scale from the surface of material .

The cavitation corrosion is the special form of erosion. The vapor bubbles in liquids near the metal surface form and collapse, thus giving rise to this corrosion. Some general techniques to restrict erosion are:

- Use harder materials.
- Use lower velocity of the liquid.

I.4.9 Waterline Corrosion :

This type of corrosion occurs in the metallic tanks. When the tanks are partially filled with water, the area below the surface of water is poorly oxygenated and thus acts as anode whereas the area above the line of water has significant amount of oxygen and thus acts as cathode.. Thus the area just below the level of water is corroded and the area above the level is protected. Mostly, marine engineers face this type of corrosion. It can be reduced by using anti fouling paints to some extent.

Figure I-2 : Forms of corrosion

II Corrosion Protection:

II.1 Protection by Coatings:

II.1.1 Metallic Coatings:

Metallic coatings provide effective corrosion protection by forming a layer of metal over the substrate surface. These coatings offer excellent adhesion, durability, and corrosion resistance, making them suitable for a wide range of applications in various industries. Here are some common types of metallic coatings: Zinc Coatings- Aluminum Coatings- Nickel Coatings- Cadmium Coatings- Copper Coatings- Chromium Coatings- Tin Coatings [10]

II.1.2 Anodic Coatings:

Anodic coatings serve as a fundamental method in corrosion protection strategies, providing durable and effective shields against corrosion for various metal substrates. These coatings are formed through electrochemical processes, with the metal substrate acting as the anode in an electrolytic cell. Primarily applied to aluminum substrates, anodic coatings, often produced through anodizing techniques, generate a thick, protective oxide layer on the surface. This oxide layer not only enhances corrosion resistance but also adds durability, abrasion resistance, and aesthetic appeal. Anodized aluminum finds extensive application in architectural, automotive, and aerospace sectors due to its superior corrosion resistance, lightweight properties, and adaptability[11]

II.1.3 Cathodic Coatings:

Cathodic coatings are essential for corrosion protection, especially in industries like oil and gas and marine. These coatings, often zinc-rich or epoxy-based, create a protective barrier that shields metal substrates from corrosive agents. They can provide sacrificial protection, extending the service life of structures by corroding preferentially to protect the underlying metal. Cathodic coatings offer tailored solutions for diverse performance requirements, including adhesion, flexibility, and chemical resistance.[12]

II.1.4 Non-Metallic Inorganic Coatings:

Non-metallic inorganic coatings and organic coatings play pivotal roles in corrosion protection across various industries. Non-metallic inorganic coatings, such as ceramic or glass-based coatings, offer excellent resistance to corrosion, high temperatures, and chemical exposure. These coatings are commonly applied in aerospace, automotive, and electronic industries, where durability and thermal stability are critical.[13]

II.1.5 Organic Coatings:

organic coatings, including epoxy, polyurethane, and acrylic coatings, provide versatile solutions for corrosion protection, offering excellent adhesion, flexibility, and weather resistance. Organic coatings are widely used in infrastructure, marine, and architectural applications, where aesthetic appeal and long-term durability are essential. Both types of coatings offer tailored solutions to meet specific performance requirements, providing effective protection against corrosion in diverse operating environments.[14]

II.2 Protection by Inhibitors:

II.2.1. Definition of an Inhibitor:

a substance or compound that is added to a corrosive environment or applied directly to a metal surface to mitigate or slow down corrosion processes [15]

II.2.2 Essential Functions:

Inhibitors primarily work by interfering with the electrochemical reactions that cause corrosion, thereby reducing the corrosion rate and extending the service life of metal components. The essential functions of inhibitors may include forming a protective film on the metal surface, adsorbing onto active sites, altering the chemical composition of the environment, or inhibiting specific corrosion reactions. Understanding these essential functions is essential for selecting and applying inhibitors effectively to achieve optimal corrosion protection.[16]

II.2.3 Choice of an Inhibitor:

The choice of an inhibitor involves selecting a substance or compound that is most suitable for mitigating corrosion processes in a specific application. Several factors influence the selection of inhibitors, including the type of metal being protected, the corrosive environment, the desired level of corrosion protection, and the application method. It is essential to consider the compatibility of the inhibitor with the metal substrate and its effectiveness in the particular environment where corrosion occurs. Additionally, factors such as cost, availability, toxicity, and regulatory requirements may also influence the choice of inhibitor. Ultimately, the selected inhibitor should effectively interfere with corrosion mechanisms, reduce corrosion rates, and prolong the service life of metal components in the given application.[16]

II.2.4 Properties:

In general, a corrosion inhibitor must reduce the corrosion rate of a metal without affecting its physicochemical characteristics, especially its mechanical resistance. It must not only be stable in the presence of other constituents of the environment but also not affect the stability of the species contained in this environment. An inhibitor is definitively recognized as such if it is stable at the operating temperature and effective at low concentration. It can be used for permanent protection (primary monitoring of the device) or more commonly for temporary protection during a period when the material to be protected is particularly sensitive to corrosion (storage, pickling, cleaning, etc.) or when it is subjected to very severe machining such as drilling, tapping, drilling, threading, etc.

II.3 Classification of Inhibitors:

Inhibitors can be classified in several ways:

- By field of application,
- By partial reaction,
- By reaction mechanism.

II.3.1 By application domain :

In the classification related to the application domain, we can distinguish: corrosion inhibitors used in aqueous, organic, or gaseous environments. Those used in aqueous environments are chosen based on the pH of the environment: in acidic environments, they are used to prevent chemical attack on steel during pickling or descaling operations, and in neutral/alkaline environments, they are often used to protect pipelines in cooling circuits.

II.3.2 By partial electrochemical reaction:

According to their influence on the speed of partial electrochemical reactions, three types of inhibitors are differentiated:

(a) Anodic inhibitors:

Anodic inhibitors act to decrease the current on the anodic part of the metal surface. If this blocking is only partial, it can locally increase the current density on these surfaces. It can lead to a localized corrosion process, more intense than in the absence of an inhibitor, hence the importance of the active element content in the steel.

(b) Cathodic inhibitors:

Induce an increase in cathodic overpotential, and therefore reduce the corrosion current. If these inhibitors never completely stop the corrosion reaction, they do not present the danger of localized corrosion. These inhibitors often precipitate salts or hydroxides due to the accumulation of OH- ions on the cathodes.

(c) Mixed inhibitors:

Mixed inhibitors have both the properties of anodic and cathodic inhibitors. An anodic inhibitor decreases the partial anodic current density and shifts the corrosion potential in the positive direction. A cathodic inhibitor decreases the cathodic current density and shifts the corrosion potential in the negative direction. A mixed inhibitor decreases the speed of both reactions but has little influence on the corrosion potential.

II.3.3 By reaction mechanism:

According to the reaction mechanism, inhibition is distinguished by adsorption, passivation, precipitation of a film, and elimination of the corrosive agent. Corrosion may slow down due to the adsorption of an inhibitor on the metal surface. The degree of inhibition then depends on the balance between dissolved and adsorbed species, expressed by an adsorption isotherm. This mechanism is particularly important in acidic environments. Some oxidizing inhibitors cause spontaneous passivation of the metal, thus reducing the corrosion rate. Other inhibitors cause the formation of surface films by precipitating mineral salts or poorly soluble complexes. These films reduce the surface's accessibility to oxygen, and additionally, they partially block anodic dissolution. Inhibition by elimination of the corrosive agent only occurs in closed systems. It is practiced notably in closed hot water circuits of thermal power plants.

II.3.4 Mode of action of corrosion inhibitors:

The mode of action of inhibitors has been the subject of numerous hypotheses and remains still somewhat poorly understood. Inhibition is probably not a simple phenomenon but a series of more or less well-identified processes. Indeed, there is no single mode of action for corrosion inhibitors. Moreover, the same compound will often have a mechanism of action that depends on the corrosion system (metal + solution) in which it is present. The action of the inhibitor can be conceived as:

- The interposition of a barrier between the metal and the corrosive environment; in this case, which is essentially that of acidic environments, the role of the compound's adsorption on the surface will be paramount.
- Strengthening of an existing barrier, generally the oxide or hydroxide layer formed naturally in a neutral or alkaline environment. This reinforcement may consist of extending the oxide on the surface or precipitating salts at weak points in the oxide, these salts being corrosion products.
- The formation of a barrier by interaction between the inhibitor and one or more species of the corrosive environment, this type of mechanism also being specific to neutral or alkaline environments.
- The stabilization of protective oxide films (anodic) by nitrites, chromates, silicates, phosphates, borates, etc.
- Participation in electrode reactions by acting as a "catalyst",

- Considering these general notions, it is clear that the mechanism of action of an inhibitor can be considered from two aspects: a mechanical aspect (intervention in the fundamental processes of corrosion) and a morphological aspect (intervention of the inhibitor molecule in the interfacial structure).

- The action of inhibitors depends on conditions such as:

- Temperature: adsorption decreases as temperature increases,
- pH of the medium,
- Inhibitor concentration... etc. [17].

II.3.5 Electrochemical Protection :

II.3.5.1 Cathodic Protection :

Cathodic protection consists of imposing a sufficiently low potential on the metal so that the corrosion rate becomes negligible. In practice, this method is mainly used to protect heavy steel structures, such as offshore oil drilling platforms, boats, buried pipelines, etc. Cathodic protection is controlled by two fundamental parameters: the protection potential and the protection current density. The protection potential (Eprot) is defined by the Nernst equation:

$$\mathbf{Eprot = E^0 + (RT/nF)\ Ln\ 10^{-6}}$$

For T=25°C :

$$\mathbf{Eprot = E^0 - 0.354/n}$$

If the potential of the metal is equal to or less than the protection potential, the corrosion rate cannot exceed a value that is assumed to be negligible. Thus, one can protect a metal against corrosion by imposing a potential such that: $E \leq E_{prot}$.

The protection current (I_{prot}) corresponds to the cathodic current required to impose the protection potential. Its value depends on the surface area to be protected (A) and the protection current density (i_{prot}).

$$\boldsymbol{I_{prot} = i_{prot}\ A}$$

The principle of cathodic protection is schematically illustrated in Figure I-4. It shows that shifting the potential into the protection domain (hatched zone) corresponds to $E < E_{prot}$. The density of the partial cathodic current at the protection potential is: $i_c = i_{prot}$.

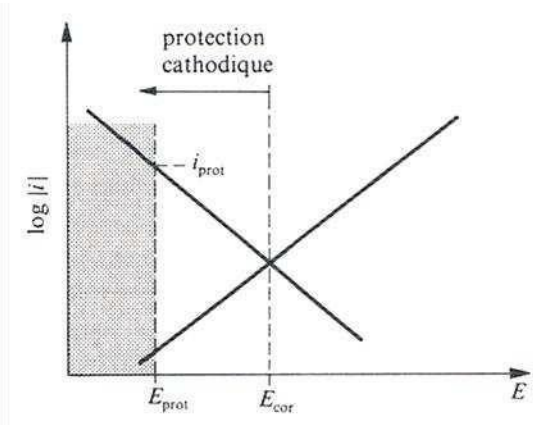


Figure I-3 : Principle of Cathodic Protection

Two methods of cathodic protection are commonly used in practice:

II.3.5.2 Sacrificial Anode Protection:

The sacrificial anode forms an electrochemical cell with the metal to be protected, which acts as the cathode. The sacrificial anode must have a reversible potential lower than that of the metal to be protected. For example, to protect steel, sacrificial anodes made of Zn, Mg, or Al and their alloys are used.

Selection of Sacrificial Anodes: Sacrificial anodes must meet the following conditions:

- They must have an electrode potential sufficiently negative to rapidly polarize the material to a sufficient value.
- They should not polarize when current passes. In particular, corrosion products should not form an adherent film that could alter the potential value.
- They should corrode uniformly in the considered environment and not be heavily attacked in the absence of current.
- They should have good conductivity, mechanical resistance, and be readily available in various shapes and sizes.
- Finally, they should have an economically acceptable cost.

In practice, only three materials meet these criteria: zinc, aluminum, and magnesium.

II.3.5.3 Protection by Imposed Current:

This method involves the use of a rectifier. This technique offers the advantage of being able to adjust the voltage or current as needed.

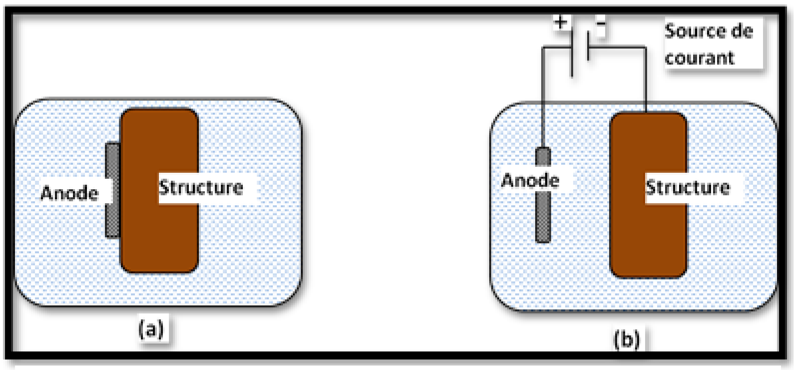


Figure I-4 : Exemple de protection cathodique

II.3.5.4 Main Areas of Application :

Cathodic protection is typically used in conjunction with another conventional protection method such as coating or painting. This is done to limit the current density provided by the anodes or the generator. Among the main areas of application are:

Buried structures: This includes pipelines, storage tanks, etc. The arrangement of the anodes depends on the size of the installations.

Immersed structures: This refers to ship hulls or fixed installations (piers, docks, offshore drilling platforms) in seawater or freshwater [17].

Conclusion :

Corrosion is a natural process of deterioration of metallic materials resulting from interaction with the environment. It can cause significant damage to infrastructure and equipment, leading to high maintenance and repair costs.

Corrosion inhibitors are substances added to metallic materials to slow down the corrosion process. They work by forming a protective layer on the metal surface, thus preventing oxidation and corrosion.

The use of corrosion inhibitors can reduce maintenance costs and extend the lifespan of equipment and metallic infrastructure. However, it is important to choose the appropriate corrosion inhibitor based on the environment in which the metal is used.

Ultimately, corrosion prevention is a continuous process that requires a thorough understanding of environmental conditions and the selection of a suitable corrosion inhibitor to effectively preserve metals.

Chapter II: Presentation of the Corrosion Problem in the HBK Field

Introduction:

The HAOUD BERKAOUI regional directorate is part of the production division of SONATRACH's exploration and production activities. The first oil processing center at HBK was commissioned in 1967; today there are three (03) oil processing centers and one gas processing unit. Each production center receives crude oil from various wells, stabilizes it, and stores it in tanks before its shipment (to the TRC pipelines). The gas recovered from the stabilization process is compressed and transported to the Guellala gas processing plant (UTG/GLA), which extracts LPG, sales gas, and lift gas from it.

II.1.Geographical Location of the Region (HBK):

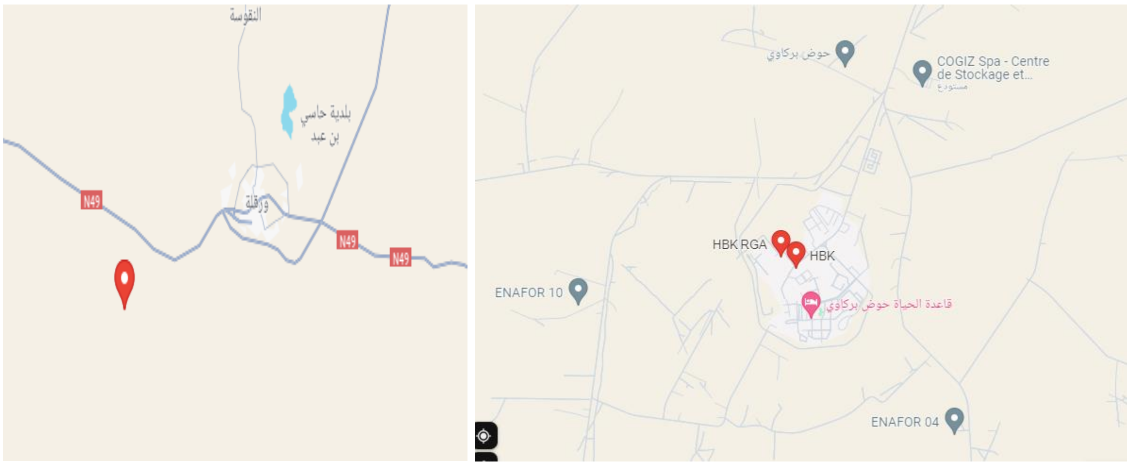


Figure II-1 : hbk from googla maps

II.2.Fields in the Region: [19]

II.2.1.The Haoud Berkaoui Field:

Covering an area of 303 km², the HBK production center consists of an oil separation unit with a processing capacity of 7500 m³/day, a storage capacity of 18000 m³, and a shipping pump station that includes two electric pumps and two turbine pumps with a shipping capacity of 7700 m³/day. It also has a gas boosting unit with a nominal capacity of 1,042,000 Sm³/day, a water injection station with a nominal capacity of 250 m³/hour, and a deoiling unit with a capacity of 100 m³/hour.

II.2.2.The Benkahla Field:

Covering an area of 286 km², the Benkahla production center consists of an oil separation unit with a processing capacity of 7000 m³/day, a shipping pump that includes two electric pumps and an auxiliary motor pump with a shipping capacity of 3600 m³/day, a deoiling unit with a capacity of 40 m³/hour, a gas boosting unit with a nominal capacity of 562,000 Sm³/day, and a water injection unit with a capacity of 250 m³/hour.

II.2.3.The Guellala Field:

This field was discovered and put into production on October 28, 1969, with the drilling of GLA1. Covering an area of 99 km², the production center consists of an oil separation unit with a processing capacity of 7500 m³/day, a storage unit with a capacity of 15000 m³/day, a shipping pump with a shipping capacity of 7200 m³/day, a water injection unit with a capacity of 250 m³/hour, and a gas boosting unit with a capacity of 765,000 Sm³/day. The station is also equipped with a deoiling unit with a capacity of 60 m³/hour and a gas processing unit with a capacity of approximately 2,369,000 Sm³/day. Its recovery capacity is estimated at 500 T/day of LPG, 90 T/day of condensates, 1,236,000 Sm³/day of sales gas, and 424,000 Sm³/day of lift gas.

II.3.1.Haoud Berkaoui Production Center (HBK):[19]

The Haoud Berkaoui production center is one of Sonatrach's centers for exploration and production activities. Its purpose is to produce oil and gas by processing crude oil from various wells through a series of operations carried out by the following units:

Separation Unit : The separator is a pressurized vessel used to separate the oil, gas, and water contained in the effluent as it exits a production well by density difference. In the most general case, the crude oil coming out of the well is a three-phase mixture comprising: A gaseous phase,A liquid hydrocarbon phase (the crude oil itself),An aqueous phase (formation water)

Boosting Unit : The gas from the separator is transferred directly to the compressors at the boosting station to increase its pressure up to 35 bar so that we can send it to the GLA gas treatment plant. There are two boosting stations at Haoud Berkaoui, which are... Old boosting station, New RGA boosting station

Storage and Shipping Unit : At the HBK field, the oil from the low-pressure separator is stored in storage tanks before being sent to northern plants such as Skikda, using pumps.

Deoiling Unit : the process of separating oil from water or other liquids that are extracted along with the oil.

Water Injection Unit : The HBK water injection unit is installed to boost and maintain the pressure of a reservoir , aiming to optimize and maximize production and increase the total crude oil recovery by maintaining pressure

Utility Unit : The unit consists of:

- Two booster pumps P02.A and P02.B.
- Two dual-layer filters S01.A and S01.B.
- One air suppressor.
- Four small chemical injection pumps.

- Three high-pressure injection pumps (P01 A/B and C).

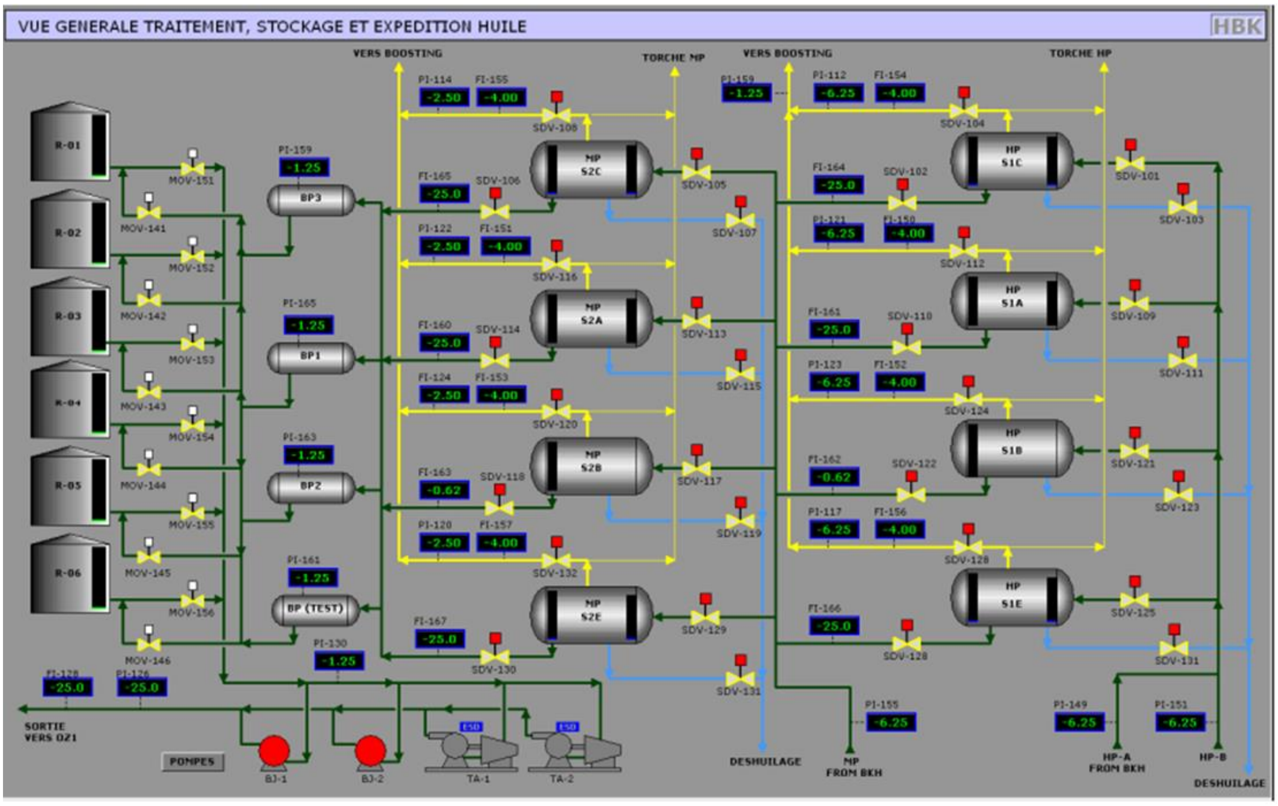


Figure II-2 : General View of Oil Treatment, Storage, and Shipping

II.3.2 Presentation of the Corrosion Issue in the HBK Field :

The corrosion phenomenon poses harmful issues both inside and outside HBK gas production equipment, such as pipe perforation and bursting, loss of effluent circulation, etc. Generally, the origin of this corrosion is quite complex; it is triggered by the presence of salts (such as NaCl) and H_2S and the presence of CO_2 in the gas in favorable operating conditions, leading to the initiation of corrosion.

II.3.3 corrosive agnents reactons :

CO2 corrosive reaction :[20]

Chemical Reactions :

CO2 Dissolution in Water:

- CO2 dissolves in water to form carbonic acid (H_2CO_3), which is corrosive to carbon steel. $CO_2+H_2O \rightarrow H_2CO_3$
- Carbonic Acid Dissociation: $H_2CO_3 \rightarrow H^+ + HCO^{3-}$
- Carbonic acid dissociates into bicarbonate (HCO3−) and hydrogen ions (H+). $HCO_3^- + H_2O - \rightarrow CO_3^{2-} + H^+$

- Bicarbonate ions can further dissociate into carbonate (CO_3^{2-}) and hydrogen ions.

Electrochemical Reactions :

Anodic Reaction (Oxidation of Iron):

Iron (Fe) is oxidized to form iron ions (Fe^{2+}), which can react with the corrosive species to form corrosion products. $Fe = Fe^{2+} + 2\ e$

Cathodic Reactions (Reduction of Hydrogen Ions, Carbonic Acid, Bicarbonate, and Water):

Hydrogen ions are reduced to form hydrogen gas (H_2) $\rightarrow 2e + 2H^+ = H_2$

, while carbonic acid, bicarbonate ions, and water are reduced to form protective corrosion products like iron carbonate ($FeCO_3$)

$Fe+CO_3+\rightarrow FeCO_3+H_2$

H2S corrosive reactions : [20]

Chemical Reactions :

H2S Dissolution in Water:

- H_2S dissolves in water to form hydrosulfuric acid, which is corOLµ£rosive to carbon steel.
- H_2S Dissociation:
- H_2S dissociates into hydrosulfide ions (HS−) and hydrogen ions (H+)
  .$H_2S+H_2O\rightarrow H_2S(aq)$
  $H_2S(aq)\rightarrow H^++HS^-$
- Hydrosulfide Ion Dissociation:
- Hydrosulfide ions can further dissociate into sulfide ions (S2−) and hydrogen ions
  $HS-\rightarrow H^++S^{2-}$

Electrochemical Reactions:

Anodic Reaction (Oxidation of Iron):

- Iron (Fe) is oxidized to form iron ions (Fe^{2+}), which can react with the corrosive species to form corrosion products.

Cathodic Reactions (Reduction of Hydrogen Ions and H_2S):

- Hydrogen ions are reduced to form hydrogen gas (H_2), while H_2S is reduced to form protective corrosion products like iron sulfide (FeS)
  $Fe+H_2S\rightarrow FeS+H2$

Nacl corrosive reactions : [21]

NaCl (sodium chloride) can contribute to corrosion in oil and gas pipelines through several mechanisms:

- **Increased Corrosion Rate**: As the weight percentage of NaCl increases up to about 5%, the corrosion rate increases rapidly. Higher NaCl concentrations lead to more corrosive conditions.
- **Formation of Corrosive Compounds**: According to the nature of crude oils, NaCl, $CaCl_2$, and $MgCl_2$ are among the dangerous corrosive compounds in piping systems, especially in the hydrocarbons. These compounds can form corrosive solutions when dissolved in water.
- **Influence on Corrosion Scale Formation**: The presence of Mg^{2+} and Ca^{2+} ions, which can be introduced by the addition of $MgCl_2$ and $CaCl_2$, can affect the initial corrosion of steel prior to the formation of protective iron carbonate ($FeCO_3$) scale. Mg^{2+} can inhibit the formation of the protective scale, while Ca^{2+} can accelerate its formation.

II.3.4. Corrosion of Above-Ground Production Installations :

Corrosion has a negligible effect on production tubing, wellhead, downhole equipment, and the first sleeve as they are made of stainless steel. For the rest of the equipment, the affected corrosion is localized inside the piping, which is caused by the chemical attack of as NaCl) and H_2S and the presence of CO_2 contained in the water. The equipment affected by this corrosion includes:

- Surface well equipment: carbon steel sleeves located downstream of the nozzle are subjected to severe hydrodynamic conditions due to the geometric variation of the pipeline.
- Junctions, manifolds of gas-producing wells, and various collectors.
- Corrosion mainly occurs at the weld seams and lower generators, particularly those connecting two sleeves through the welding of a flange. The low points of the collectors due to relief elevation differences constitute a favorable site for the stagnation of aggressive aqueous phase, and elbows where erosion phenomena reach their maximum.

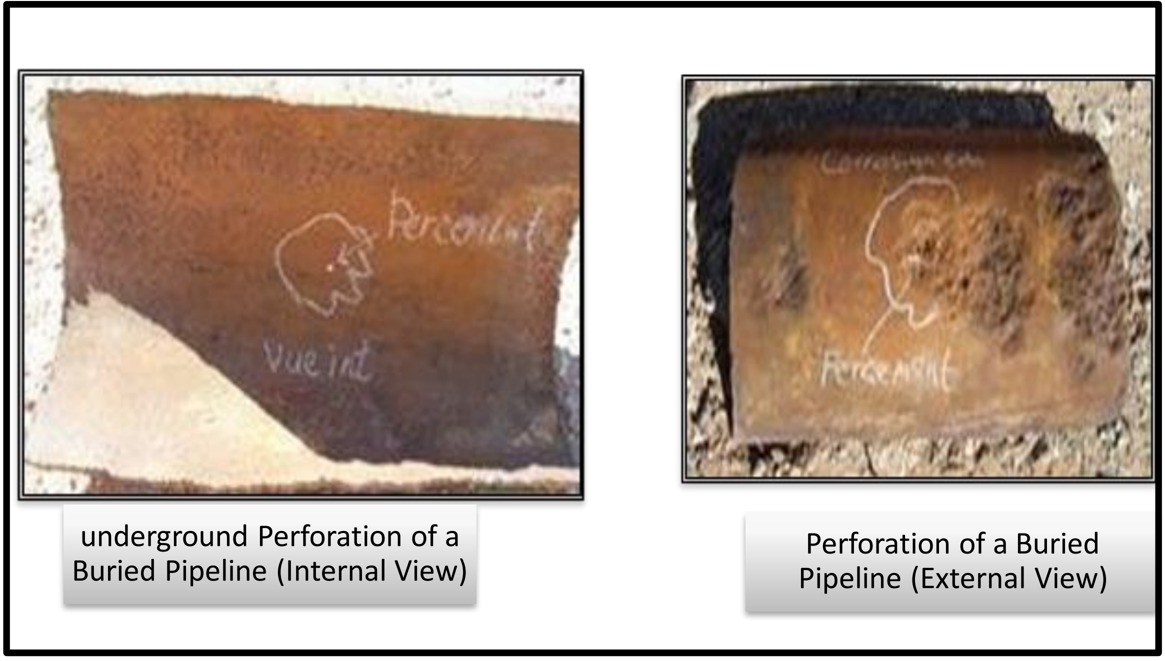
Figure II-3 : Corrosion of Above-Ground Production Installations

External corrosion does not form on these equipments, thanks to their external coating with paint, as well as the dry climate in this region.

II.5 Corrosion of Buried Pipelines :

Buried pipelines can undergo external corrosion due to:

- The formation of an electrochemical cell between the ground and the pipeline caused by the heterogeneity of the soil.
- The aggressive attack of chemical products infiltrated into the subsoil, which come from drilling mud or cement discharged on the ground surface.
- The crossing of two pipelines, where one is protected and the other is unprotected, leading to the formation of an electrochemical cell by transforming the unprotected pipeline into an anode relative to the protected pipeline.



underground Perforation of a Buried Pipeline (Internal View)

Perforation of a Buried Pipeline (External View)

Figure II-4: **External Corrosion of a Buried Pipeline** .

II.6.Inspection and Detection of Corrosion :

Corrosion has multiple causes and its effects are varied. Consequently, no single method provides all the answers. However, a combination of several methods allows for a better understanding of the problems and identification of solutions. Periodic monitoring must be very rigorous to avoid failures, as it is necessary for the long lifespan of our equipment.

II.6.1 Inspection Techniques:

The inspection/corrosion department at HBK has established a control program to aid in the detection of corrosion, which includes the following control methods:

- Visual inspection
- Non-destructive testing
- Laboratory testing

II.6.1.1 Visual Inspection:

We measured the thickness at the perforation point of the 4’’ GT44 pipe at the SAT 0 entrance in the PC production center.

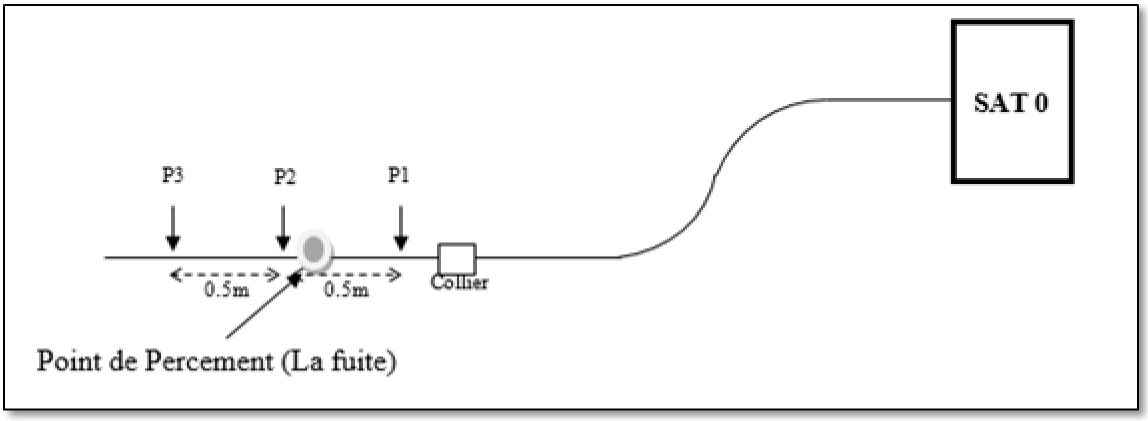


Figure II-5 : Thickness Measurement at the Perforation Point of 4'' Pipe

Table II-1: Thickness Measurement Results at the Perforation Point :

Points	12 :00	03 :00	06 :00	09 :00
P01	5.74	2.95	4.24	2.99
P02	3.43	3.06	3.47	3.47
P03	4.66	3.28	2.87	3.54

Figure II-6 : Perforation Level of 4'' Pipe

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

II.6.1.2 Non-Destructive Testing :

This involves the biannual scheduled inspection of above-ground installations for gas production, without compromising their metal structures. It allows for the detection of defects within a material using ultrasonic equipment, which relies on the transmission and reflection of ultrasonic waves inside the part to be inspected by a probe whose frequencies are higher than audible frequencies for the human ear. Frequencies between 100 kHz and 25 MHz are used for this type of test.

The ultrasonic probe is placed at 4 points upstream and downstream of the weld bead, and it emits ultrasonic waves that propagate inside the material with varying speeds depending on the medium itself and the type of waves used. The property of ultrasonics implies the presence of a coupling agent (oil, grease, glycerin) in the space between the probe and the part to be inspected. Ultimately, a direct thickness value (direct reading) is obtained, which is then compared with a threshold called the minimum calculated thickness.

If the thickness measured by ultrasonic testing is greater than the minimum calculated thickness, it means the equipment is in good condition and can be put back into service. Conversely, if the measured thickness is less than or equal to the minimum calculated thickness, it means the equipment is corroded and must be replaced with a new one.

II.7.1: The anti-corrosion measures in hbk field :

Several measures are taken against corrosion in the HBK , including the following measures: They Inject Demulsifier ,Antiparaffin and CHIMEC1038 in the Crude oil coming from the well

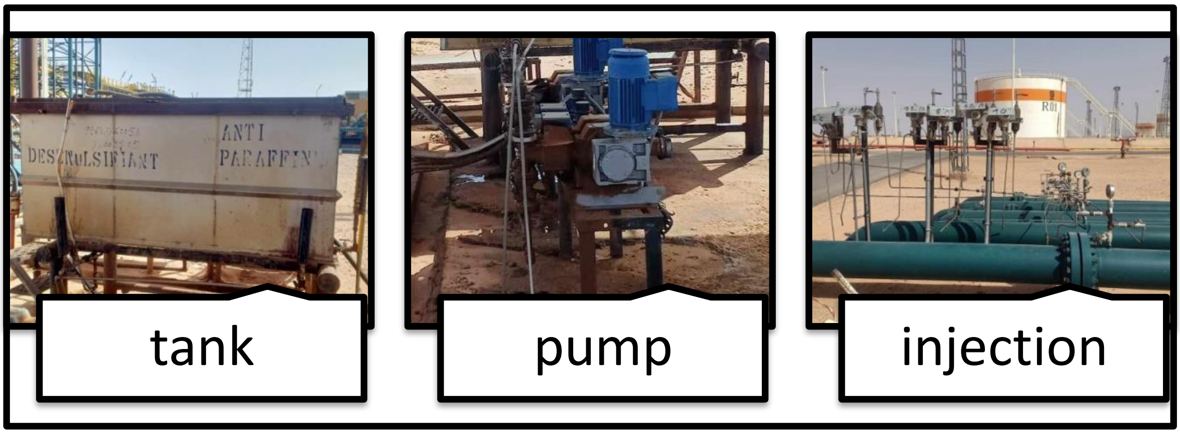


Figure II-7 : injection of of Demulsifier and Antiparaffin

II.7.2 Products used in HBK field to counter corrosion :[20]

Demulsifier(prochinor AP104) :

A demulsifier is a chemical agent or substance used to separate emulsions, which are mixtures of two or more immiscible liquids. In the context of crude oil production, demulsifiers are often used to break up water-in-oil emulsions, allowing the water and oil phases to separate more easily. Demulsifiers work by destabilizing the emulsion, causing the droplets of one liquid phase to coalesce and separate from the other phase, making it easier to remove water from the oil. They are commonly used in the oil and gas industry to improve the efficiency of separation processes and facilitate the production of cleaner oil.

Antiparaffin (chimec2935):

"Antiparaffin" refers to substances or treatments used to prevent the deposition of paraffin wax in oil wells, pipelines, and equipment used in the production and transportation of crude oil. Paraffin wax can solidify and accumulate in oil production systems, leading to blockages and reduced flow rates. Antiparaffin treatments or chemicals are applied to inhibit the formation of paraffin deposits and maintain the efficient operation of oil production and transportation infrastructure.

Anticorrosion Chimec 1038 :

Chimec 1038 is a chemical product used in the oil and gas industry as a demulsifier. It is specifically designed to break water-in-oil emulsions, facilitating the separation of water and oil phases in crude oil production processes. Demulsifiers like Chimec 1038 help improve the efficiency of separation equipment and ensure the production of clean crude oil.

Table II-2 : Safety Data Sheet for Inhibitor CHIMEC 1038, CHIMEC 2935 - Prochinor 104: [21]

PRODUCTS	**Physical properties**
Chimec 2935 (Antiparaffin)	State: Liquid Color: Amber Density at 20°C: Approximately 0.87 g/cm³ Viscosity at 20°C: Around 100 cP Flash Point: Above 60°C Solubility: Soluble in hydrocarbons and dispersible in water
prochinor ap104 (Demulsifier)	Chemical Name: Surfactants Physical Description: Aromatic solvents Appearance: Liquid Color: Amber Odor: Characteristic Density: 0.92 g/cm³ at 20°C Viscosity: 50 mPa·s at 20°C Solubility: Dispersible in water, soluble in aromatic and aliphatic hydrocarbons Flash Point: 65°C Pour Point: -15°C
Chimec 1038 (inhibitor)	Physical State: Liquid at 20°C. Color: Amber or brown. Odor: Ammonia-like. Density: 0.855 ± 0.02 g/cm³ at 20°C. Viscosity: Less than 50 cP at 20°C. Solubility: Dispersible in water, soluble in aromatic and aliphatic hydrocarbons. pH Value: 11.0 ± 1.0 in distilled water (1% solution). Flash Point: Not determined (n.d.).

	Pour Point: Not determined (n.d.). Freezing Point: Less than -20°CSolubility: Dispersible in water, soluble in aromatic and aliphatic hydrocarbons. Flash Point: Not determined (n.d.). Pour Point: Not determined (n.d.). Freezing Point: Less than -20°C. pH Value: 11.0 ± 1.0 in distilled water (1% solution)

II.7.3 Injection of chemical product in oil facilities :

Injection point of the chemical products is distributed in different position of oil production facilities as separators, ballon , manifold and pipe lines .

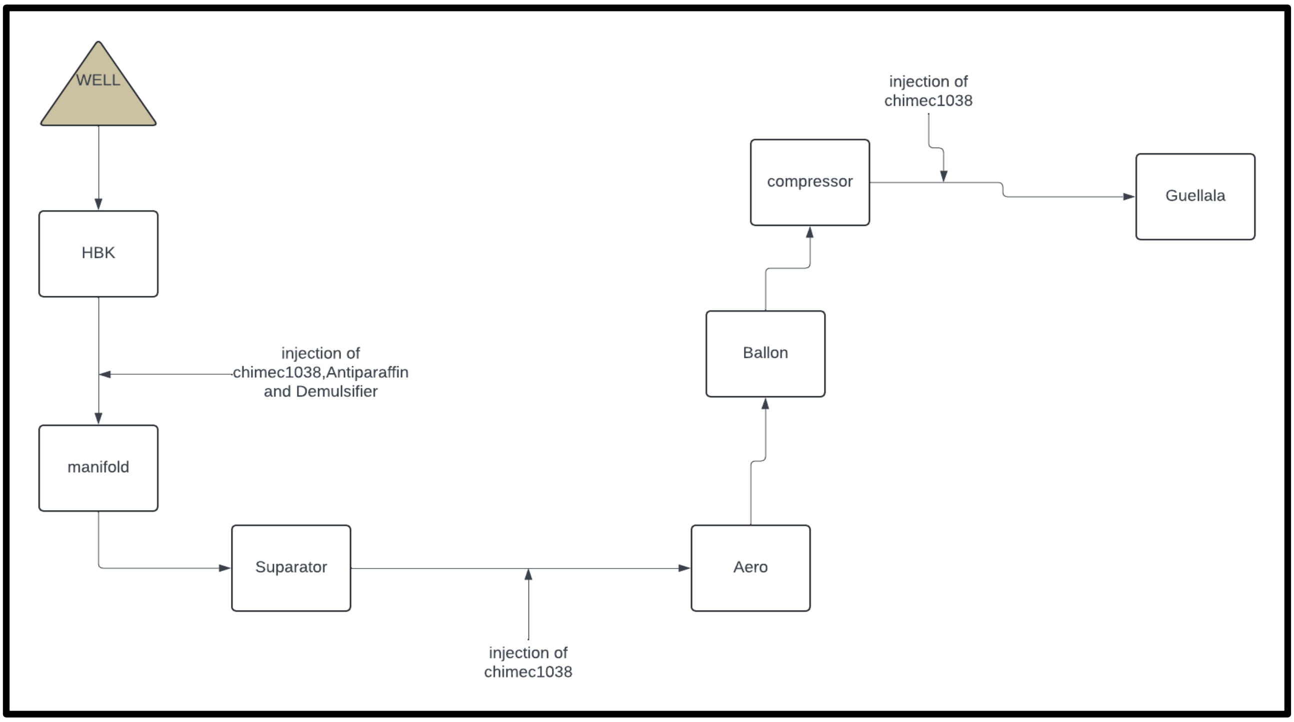


Figure II-8 : schema of chemical product inhibitor injection

II.7.3 Laboratory Tests :

II.7.3.1 Procedure for Analyzing Iron Content and PH :

This procedure applies to various sampling points at the oil and gas installations of the HBK field (Wells, Manifolds, FPC, PC). [22]

(a) Procedure for Iron Content Analysis:

1. Pour the sample into a separatory funnel for good separation between water and condensate.
2. Collect the water in a beaker.

3. Using a pipette, take 1 ml of water and place it into a 100 ml flask.
4. Dilute with distilled water up to the 100 ml mark.
5. Take 10 ml of the prepared sample into a 10 ml cuvette.
6. Place the cuvette with the prepared sample into the spectrophotometer and set it to the "zero" value.
7. Add the iron reagent and agitate.
8. Place the cuvette with the prepared sample back into the spectrophotometer for 3 minutes.
9. After 3 minutes of reaction in the spectrophotometer, press "measure" and read the result.
10. The value displayed on the spectrophotometer screen should be multiplied by 100 to obtain the iron content in (g/L) of Iron.

Figure II-9: The spectrophotometer

(b) Procedure for pH Analysis:

1. Pour the sample into a separatory funnel for good separation between water and condensate.
2. Collect the water in a beaker.
3. Turn on the pH meter.
4. Ensure that the pH meter is calibrated and gives accurate readings.
5. Immerse the pH meter probe into the water in the beaker.
6. Stir well until a stable pH value is obtained.
7. Record the obtained value.

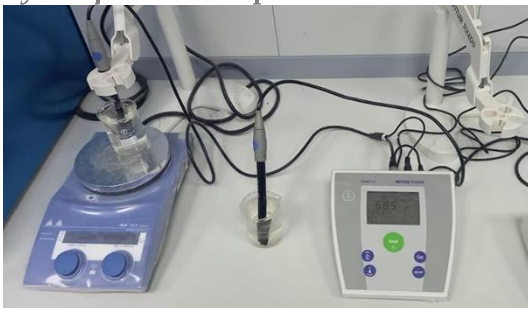


Figure II-10 : PH meter

Table II-3 : Results of Analyses of the Purge Water from the Balloons :

Mars	**1st week**		**2nd week**		**3rd week**		**4th week**	
Ballons	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**
V401	-No Water		1.2	7.78	0.8	8.27	1.0	7.94
V402			1.6	8.18	Pas d'eau		Pas d'eau	
V404			1	6.79				
V303			2.2	8.29	0.8	8.30	0.6	8.11

Avril	**1st week**		**2nd week**		**3rd week**		**4th week**	
Ballons	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**
V401	0.8	8.09	4	7.17	2.2	7.63	2.6	7.48
V402	-No water		2.5	7.27	2	7.35	2.8	7.72
V404			2	7.35	1.2	6.45	5.2	6.25
V303	Boosting à l'arrêt		2.8	7.72	2.2	7.56	2.2	8.33

Mai	**1st week**		**2nd week**		**3rd week**		**4th week**	
Ballons	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**	**Fer (ppm)**	**pH**
V401	2.02	7.85	0.8	7.77	0.9	7.83	0.8	7.90
V402	2.5	7.9	1.4	7.69	1.4	7.49	3.0	6.97
V404	4.6	6.06	7.5	7.98	9	6.82	9.5	7.21
V303	2.4	8.57	2.6	8.41	1.8	7.21	2.1	8.10

II.7.3.2 Chemical analyses of the Purge Water from the Balloons

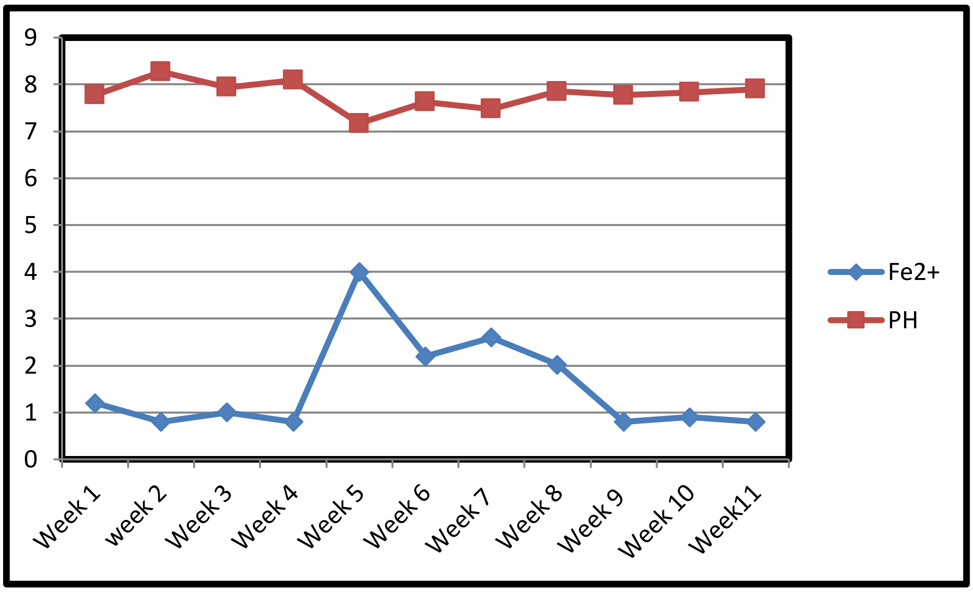


Figure II-11-1 : evolution of PH and Fe^{2+} in V401

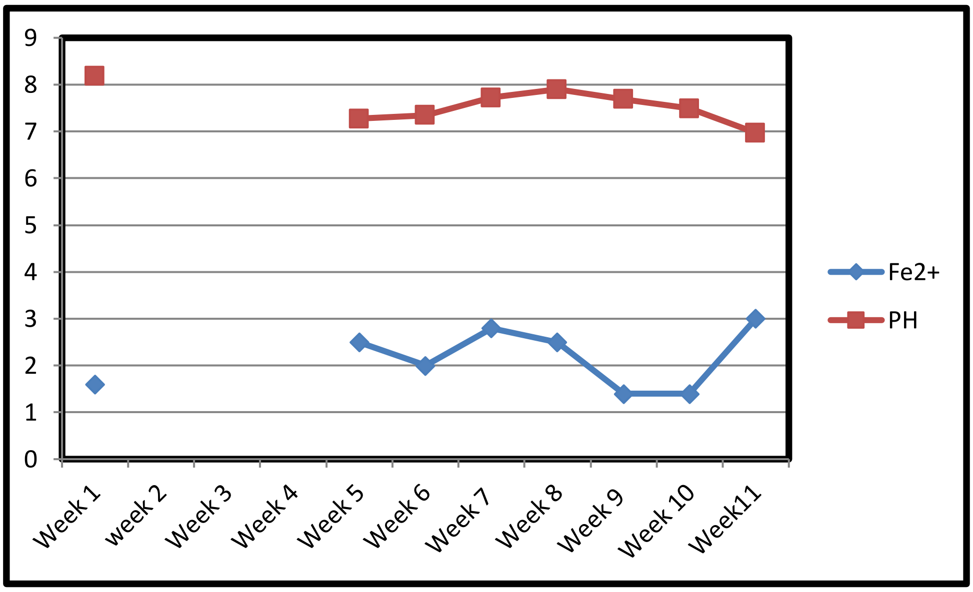


Figure II-11-2 : evolution PH and Fe^{2+} in V402

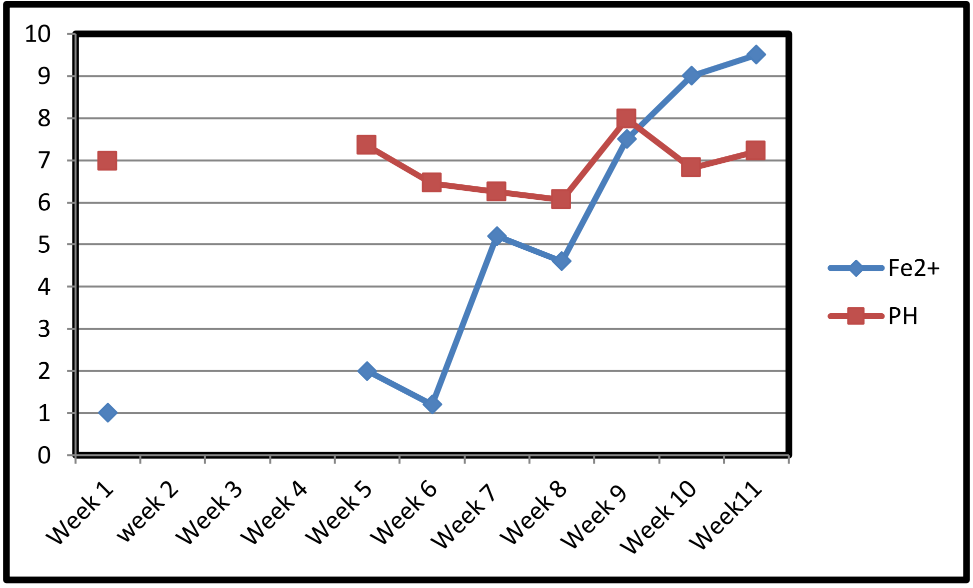


Figure II-11-3 : evolution PH and Fe^{2+} in V403

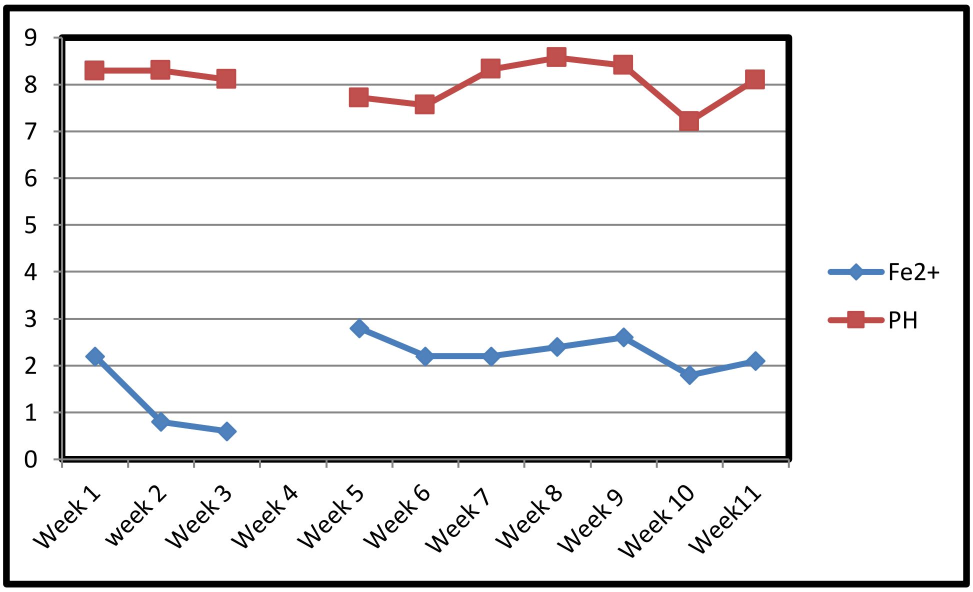


Figure II-11-4 : evolution PH and Fe^{2+} in V303

This curves (Figure II-11-1/4) present the effect of industrial inhibitor Chimec 1038 on the variation of PH and Fe+2 of the Purge Water from the Balloons

1. **Influence of inhibitor Chimec 1038 on pH:**
   - Chimec 1038 can impact the pH of the solution in which it is present. Corrosion inhibitors often contain compounds that can either increase or decrease the pH, depending on their chemical composition and reaction with water.
   - Chimec 1038, have neutralizing effects on the solution, leading to an increase in pH. This rise in pH helps to create a more alkaline environment, which can be less conducive to corrosion processes for certain metals.

2. Influence of inhibitor Chimec 1038 on Fe^{2+}

- Ferrous ions (Fe^{2+}) are often present in corrosive environments where metals are susceptible to oxidation and corrosion. Chimec 1038 interacts with these ions by forming a protective film or complexing with them.
- When Chimec 1038 is introduced into a solution containing Fe^{2+} ions, it can form a stable complex with the ions. This complexation process reduces the availability of free Fe^{2+} ions in the solution.
- By reducing the concentration of free Fe^{2+} ions, Chimec 1038 inhibits their participation in electrochemical reactions that lead to corrosion, thereby protecting the metal surfaces

Chimec 1038 affects the pH of the solution by potentially increasing it due to neutralizing acids present in the environment. This change in pH creates conditions less favorable for corrosion. Additionally, Chimec 1038 interacts with Fe^{2+} ions by forming stable complexes, thereby reducing the concentration of free ferrous ions available for oxidation and subsequent corrosion processes. These mechanisms collectively contribute to the effective corrosion inhibition provided by Chimec 1038 in the protection at berkaoui field

Conclusion

In Haoud Berkaoui presents a significant problem due to its impact on infrastructure integrity and operational efficiency in the region's oil and gas sector. The findings of our study underscore the complexity of corrosion processes in this environment, influenced by factors such as soil composition, temperature variations, and chemical interactions. Effective corrosion management strategies must integrate robust monitoring protocols, innovative materials, and proactive maintenance practices to mitigate risks and prolong asset lifespan. Moreover, fostering collaboration between industry stakeholders, researchers to advancing sustainable corrosion mitigation solutions tailored to the unique conditions of Haoud Berkaoui.

Chapter III : Presentation of Work Inhibitors

Introduction

The use of corrosion inhibitors is crucial in various industrial sectors to mitigate the destructive effects of corrosion on equipment and infrastructure. Over the years, both industrial and natural inhibitors have emerged as effective solutions, each offering distinct advantages and considerations. Industrial inhibitors, synthesized for specific applications, provide controlled and reliable corrosion protection, while natural inhibitors, derived from organic sources, offer environmentally friendly alternatives with potential biodegradability and reduced environmental impact

Our work incorporates the utilization of two specific plants [Moringa and Algua]. These plants have been selected based on their effectiveness, availability, sustainability This study delves into the application and efficacy of these plant, exploring their potential contributions protection

III.1 Use of anti-corrosion inhibitors :

The importance of using industrial and natural anti-corrosion inhibitors lies in their ability to protect metals from corrosion, which is a significant problem for various industries. Here are some key points highlighting the significance of these inhibitors:

III.1.1 Industrial Anti-Corrosion Inhibitors : [23]

- Efficacy: Industrial anti-corrosion inhibitors are effective in preventing corrosion by forming a protective layer on the metal surface, reducing the reaction between the metal and corrosive agents.
- Cost-Effectiveness: These inhibitors are often less expensive than traditional methods of corrosion protection, making them a cost-effective solution.
- Environmental Impact: Industrial anti-corrosion inhibitors can have negative environmental impacts due to their toxicity and non-biodegradability. This has led to the development of greener alternatives.

III.1.2 Natural Anti-Corrosion Inhibitors :

- Renewable and Biodegradable: Natural anti-corrosion inhibitors, such as plant extracts and essential oils, are renewable and biodegradable, reducing their environmental footprint.
- Low Toxicity: These inhibitors typically have low toxicity, making them safer for use in various applications.
- Cost-Effective: Natural anti-corrosion inhibitors can be less expensive than industrial alternatives, especially when sourced locally.
- Synergistic Effects: Natural inhibitors can exhibit synergistic effects when used in combination with other inhibitors, enhancing their overall effectiveness.

III.1.3 Importance of Both Industrial and Natural Inhibitors :

- Complementary Roles: Industrial and natural anti-corrosion inhibitors can complement each other by addressing different aspects of corrosion protection. Industrial inhibitors can provide immediate protection, while natural inhibitors can offer long-term, sustainable solutions.
- Diversified Options: Having both industrial and natural inhibitors available provides a diversified range of options for addressing corrosion issues, allowing for more effective and sustainable solutions.

III.2 Presentation of industrial product CHIMEC1038 : [24]

III.2.1 Overview :

CHIMEC1038 is a specialized industrial product designed to inhibit corrosion. It is widely used in various industries to protect metal surfaces from the damaging effects of corrosion, thereby extending the lifespan of equipment and infrastructure.

III.2.2Product Description :

- Name: CHIMEC1038
- Type: Corrosion Inhibitor
- Application: Industrial use, particularly in sectors prone to metal corrosion such as oil and gas, water treatment, and construction.

III.2.3 Key Features :

- High Efficiency: CHIMEC1038 provides excellent protection against corrosion, even in harsh environmental conditions.
- Versatility: Suitable for use in a wide range of industries and applications.
- Compatibility: Compatible with various types of metals and alloys.
- Eco-Friendly: Designed to minimize environmental impact, CHIMEC1038 meets stringent environmental regulations.
- Cost-Effective: Reduces maintenance and replacement costs by significantly extending the life of metal components.

III.2.4 Applications :

Oil and Gas Industry

- Pipelines: Prevents internal and external corrosion of pipelines used in oil and gas transportation.
- Drilling Equipment: Protects drilling rigs and equipment from the harsh conditions of oil extraction environments.
- Storage Tanks: Ensures the integrity of storage tanks used for crude oil and natural gas.

III.2.5 Benefits :

- Longevity: Increases the service life of metal components, reducing the frequency of replacements.
- Safety: Enhances the safety and reliability of infrastructure by preventing structural failures due to corrosion.
- Economic Savings: Reduces maintenance costs and downtime associated with corrosion-related repairs.
- Environmental Protection: CHIMEC1038's eco-friendly formulation reduces the environmental footprint of industrial operations.

III.2.6 Usage Instructions :

- Surface Preparation: Ensure the metal surface is clean and free from contaminants before application.
- Application Method: CHIMEC1038 can be applied via spraying, brushing, or immersion, depending on the specific requirements of the application.
- Concentration: Use at the recommended concentration levels for optimal performance. Consult the product manual for specific guidelines.
- Safety Precautions: Always wear appropriate personal protective equipment (PPE) during application. Follow all safety instructions provided in the product's safety data sheet (SDS).

III.2.7 Technical Specifications :

- Appearance: Clear liquid
- pH: Neutral
- Density: 1.0-1.1 g/cm^3
- Solubility: Soluble in water

- Operating Temperature Range: Effective up to 200°C
- Environmental and Safety Considerations
- Non-Toxic: Formulated to be non-toxic and safe for the environment.
- Biodegradable: Components are biodegradable, reducing long-term environmental impact.
- Regulatory Compliance: Meets all relevant industry standards and environmental regulations.

III.3Presentation on Natural Products : [23]

III.3.1 Overview :

Natural (organic) inhibitors are substances derived from biological sources used to prevent or reduce corrosion in various industrial applications. These eco-friendly alternatives to synthetic inhibitors are gaining popularity due to their environmental benefits and effectiveness

III.3.2 Key Features :

- Eco-Friendly: Made from renewable resources, these inhibitors are biodegradable and less harmful to the environment.
- Non-Toxic: Generally safer for human health compared to synthetic inhibitors.
- Sustainable: Support sustainable industrial practices by utilizing naturally occurring materials.
- Cost-Effective: Often less expensive in the long run due to reduced environmental compliance costs and availability of raw materials.

III.3.3 Common Sources of Natural Inhibitors :

- Plant Extracts: Extracts from plants such as henna, ginger, and garlic contain compounds that can inhibit corrosion.
- Essential Oils: Oils from herbs like rosemary, thyme, and lavender have anti-corrosive properties.
- Biopolymers: Natural polymers like chitosan (derived from crustacean shells) and alginate (from algae) are effective corrosion inhibitors.
- Amino Acids and Proteins: Certain amino acids and proteins can form protective layers on metal surfaces to prevent corrosion.

A .Applications :

Oil and Gas Industry :

- Pipeline Protection: Natural inhibitors can be used to coat pipelines to prevent internal and external corrosion.
- Storage Tanks: Effective in protecting storage tanks used for oil and gas against corrosion.

B. Benefits :

- Environmental Protection: Reduces the environmental impact of corrosion prevention methods.
- Health and Safety: Lower toxicity levels make these inhibitors safer for workers and end-users.
- Regulatory Compliance: Easier to comply with stringent environmental regulations and standards.
- Renewability: Being derived from renewable resources, they support the sustainability of industrial operations.

C. Mechanisms of Action :

- Adsorption: Natural inhibitors adsorb onto the metal surface, forming a protective film that prevents corrosive substances from reaching the metal.
- Complex Formation: They may react with metal ions to form stable complexes that hinder the corrosion process.
- Passivation: Some natural inhibitors enhance the formation of a passive layer on the metal surface, protecting it from corrosion.

Conclusion :

CHIMEC1038 is a highly effective and versatile corrosion inhibitor, designed to provide robust protection for metal surfaces in various industrial applications. Its high efficiency, compatibility, and eco-friendly formulation make it an ideal choice for industries looking to enhance the longevity and reliability of their equipment while minimizing environmental impact.

III.4 Motivations for Choosing the Two Plants :

We have reviewed several scientific publications in which extracts of some desert plants were studied and used as corrosion inhibitors in acidic environments [25][26]. Therefore, we wanted the study to be on a mixture of oil extracts from two desert plants that grow in our region and are known by their common names, one of which is the Alaga (also known as Alagaya) and the Moringa. [27][28]

III.4.1 Characterization of the Two Plants (Alaga-Muringa) :

III.4.1 .1 Alaga (Alagaya) characterization :

Figure III-1 : the zygophyllum plant

III.4.1 .2 Systematic Classification of the Plant:

Common Name: Bean-caper

Scientific Name: Zygophyllum fabago

Family: Zygophyllaceae

Type: Herbaceous plant

III.4.1 .3 General Description of the Plant:

Zygophyllum fabago is a herbaceous plant known for its adaptability to arid environments. It has succulent leaves and produces yellow flowers. The plant can be found in various regions, thriving in dry and saline soils.

51III-2 : the Zygophyllum Plant Fruits

Figure III-3 : the zygophyllum plant Leaves

III.4.1 .4 Composition :[27]

Based on the search results, here is a summary of the key information about the chemical composition and use of Zygophyllum plant extracts as corrosion inhibitors in acidic environments:

Chemical Composition of Zygophyllum album:

The plant contains flavonoids, mono- and di-glycosides of flavonols like kaempferol, quercetin, and isorhamnetin.

It also contains saponins and essential oils, with carvacrol being the dominant compound in the essential oil.

Other compounds identified include quinovic acid glycosides and 14-decarboxyquinovic acid glycosides.

Use as Corrosion Inhibitors:

Several studies have investigated the use of Zygophyllum album extracts as corrosion inhibitors, particularly in acidic environments. [30]

The plant extracts, rich in flavonoids, saponins, and other phytochemicals, have demonstrated effective corrosion inhibition properties.

The inhibition mechanism is believed to involve adsorption of the phytochemicals onto the metal surface, forming a protective film that prevents corrosion.

III.4.1 .5 Murgina characterization :

Figure III-4 : Moringa oleifera tree

III.4.1 .6 Systematic Classification of the Plant:

The systematic classification of the Moringa plant is as follows:

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Brassicales

Family: Moringaceae

Genus: Moringa

Species: Moringa oleifera Lam.

General Description of the Plant:

Moringa oleifera is a highly versatile and nutritious plant that is widely cultivated in the tropics for its various edible and medicinal uses, making it an important "miracle tree" in many regions.

Figure III-5 : Moringa oleifera leaves

III.4.1 .7 Composition :[31][32][33]

Phytochemicals :

- Alkaloids: Moringa oleifera contains alkaloids such as moringine, moringinine, and moringinine.
- Cardiac Glycosides: The plant contains cardiac glycosides like moringin.
- Flavonoids: Flavonoids like quercetin, kaempferol, and isorhamnetin are present in Moringa oleifera.
- Phenolics: Phenolic compounds like gallic acid, ellagic acid, and ferulic acid are found in the plant.
- Phytosterols: Phytosterols like beta-sitosterol and stigmasterol are present in Moringa oleifera.
- Saponins: Saponins like moringin and moringinine are found in the plant.
- Tannins: Tannins like moringin and moringinine are present in Moringa oleifera.
- Coumarins: Coumarins like scopoletin and scoparone are found in the plant.

- Terpenoids: Terpenoids like limonene and beta-pinene are present in Moringa oleifera.
- Carbohydrates: Carbohydrates like glucose, rhamnose, and glucosinolates are found in the plant.
- Proteins: Proteins like methionine, cysteine, tryptophan, phenylalanine, lysine, histidine, isoleucine, leucine, valine, alanine, threonine, glycine, glutamic acid, and aspartic acid are present in Moringa oleifera.
- Lipids: Lipids like fatty acids and phytosterols are found in the plant.

Vitamins and Minerals :

- Vitamin A: Moringa oleifera contains vitamin A.
- Vitamin C: The plant contains vitamin C.
- Calcium: Calcium is present in Moringa oleifera.
- Iron: Iron is found in the plant.
- Potassium: Potassium is present in Moringa oleifera.
- Magnesium: Magnesium is found in the plant.
- Zinc: Zinc is present in Moringa oleifera.
- Copper: Copper is found in the plant.
- Manganese: Manganese is present in Moringa oleifera.
- Phosphorus: Phosphorus is found in the plant.
- Fatty Acids
- α-Tocopherol: The main component of Moringa oleifera seed oil is α-tocopherol (51%).
- γ-Tocopherol: γ-tocopherol is also present in the seed oil.
- δ-Tocopherol: δ-tocopherol is found in the seed oil.
- Other Compounds
- Pterygospermin: Pterygospermin is a compound isolated from Moringa oleifera.
- Spirochin: Spirochin is another compound isolated from the plant.
- Aldotriouronic acid: Aldotriouronic acid is a compound found in the Moringa gum.

III.5 Extraction of two plants for obtention of corrosion inhibitors :

III.5.1 Extraction Method of Alaga and Moringa :

- Collect the plant material.

- Dry without light at an appropriate temperature.
- Grind to obtain a powder.
- Sieve with a mesh size of 250 µm.
- Weigh the powder.
- Add 100ml of separator S2D MP Water for every 10 grams of tha plant powder
- Mix them in the magnetic stirrer for 24 hours at a temperature of 40°C.
- Afterwards, filter the solution.

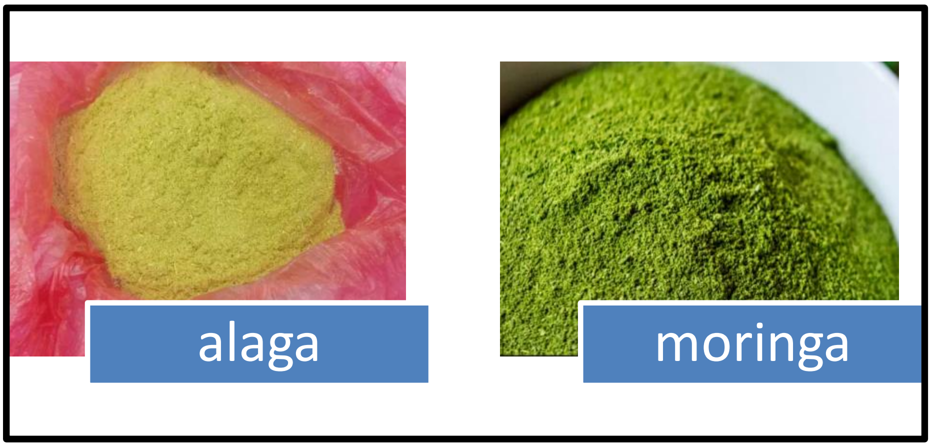


Figure III-6 : Plantes powder

Alaga

Moringa

Figure III-7 : Magnetic Stirrer

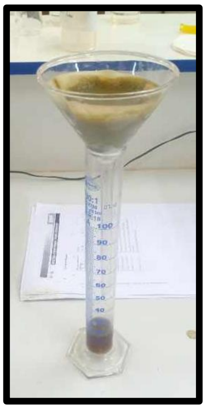


Figure III-8 : Solution filtration

Figure III-9 : Final Plants Extraits

Conclusion

the comparison between industrial and natural inhibitors highlights distinct advantages and considerations for each. Industrial inhibitors often offer precise control and effectiveness under varied conditions, while natural inhibitors present environmentally friendly alternatives with potential biodegradability and reduced toxicity. The choice between them depends on specific operational needs, environmental impact assessments, and regulatory compliance, ensuring optimal corrosion protection in diverse industrial applications."

Chapter IV :

Electrochemical Study of the Inhibitors

IV.1 Electrochemical Study of Corrosion :

This is one of the most important tests to measure the corrosion rate in the laboratory, as well as to understand the mechanism of the corrosion process and study the development of the alloy. The polarization method is one of the most important methods for determining the corrosion rate, discovered in 1951. [30]

The electrochemical system is affected by external stimuli, which are signals of a physical nature, such as: external signals, optical, thermochemical, magnetic, and then the response to this effect is recorded.

The input signal is often electrical, either causing a change E(t) in latency or a change in current I(t), and then the resulting response is measured, which is, respectively, the change in current or potential, depending on whether the input signal E(t) is fixed over time or variable.

Electrochemical methods are divided into two types:

- **Stable method**: polarization curves.
- **Variable method**: electrochemical impedance spectroscopy. [23]

IV.1.1 Polarization Curve :

The intensity-potential curves (I-E) represent the evolution of the current intensity of the working electrode subjected to a potential difference, represented by a curve I = f(E), which is the sum of the currents of the electrochemical reactions occurring at the electrode surface (Figure IV 1-1). By using a potentiostat, we impose a potential difference between the working electrode (WE) and the reference electrode (RE) and measure the current density passing through the working electrode and the counter electrode (CE) (or auxiliary electrode).

The slope of the line allows the calculation of the polarization resistance RpR_pRp (inverse of the slope). It is defined by the classic Stern and Geary formula:

$$I_{corr} = \frac{\mathrm{B\ anod} \times \mathrm{B\ cathod}}{2 \times 3(\mathrm{Banod} + \mathrm{Bcathod})} = \frac{\Delta}{\Delta E}$$

$$\frac{\Delta}{\Delta E} = \frac{-2 \times 3(B\ anod + B\ cathod)}{B\ anod \times B\ cathod} = \frac{1}{Rv}$$

In this expression, bab_aba and bcb_cbc represent the anodic and cathodic slopes of the Tafel lines, respectively, and $\Delta i / \Delta E$ being the slope of the $i = f(E)$ curves at the corrosion potential.

The interpretation of these measurements is often delicate, due, on one hand, to the determination of the Tafel coefficients ba and bc and on the other hand, its application is mainly limited to comparative studies.

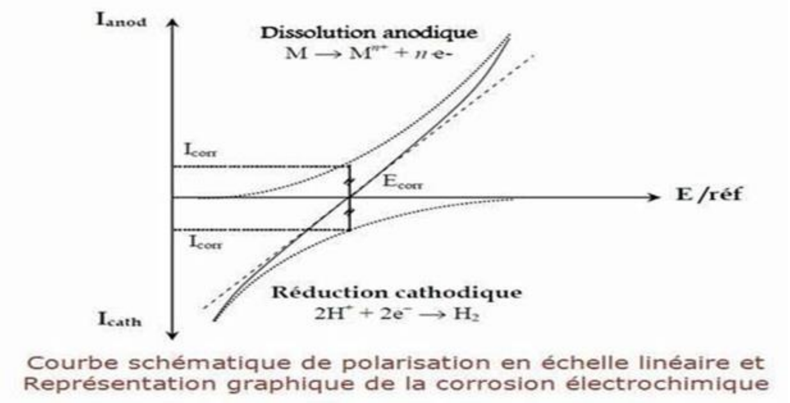


Figure IV 1-1: Polarization curve $I = f(E)$

IV.1.2 Tafel Lines :

One of the most commonly used methods for determining the corrosion rate is the extrapolation of the Tafel lines to the corrosion potential. It is essentially an extrapolation method based on the equation $i = f(E)$ of Butler-Volmer

$$I = Icorr\,[e^{\frac{2.303}{Qa}\boxed{?}} - e^{\frac{2.303}{Qc}\mu}]$$

Icorr is the corrosion current, and Qa and Qc the Tafel slopes of the anodic and cathodic reactions, respectively. $logi = f(E), (\eta = E - Ecorr)$ and the relationship between the measured transfer current and the electrode overpotential; with :

$$\text{Qa} = \frac{2.303\ RT}{a\boxed{?}f} \qquad \text{Qa} = \frac{2.303\ RT}{(1-a)\boxed{?}f}$$

Where f is the Faraday constant, R is the universal gas constant, T is the absolute temperature, η is the number of electrons transferred, and α is the charge transfer coefficient.

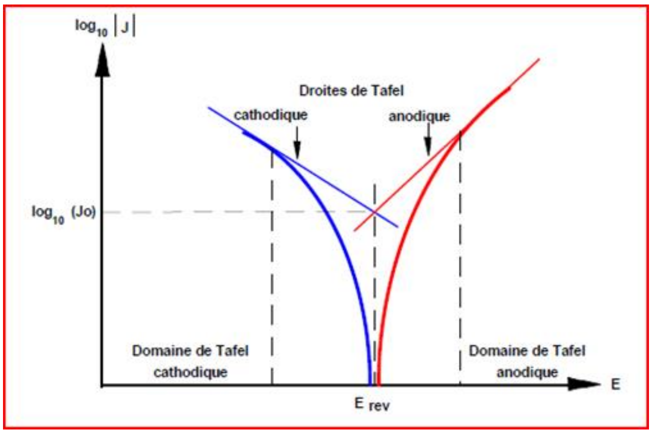


Figure IV-1-2: Tafel Lines

If we represent the polarization curve obtained in log i (current density) = f(E) coordinates (Figure IV 1-1), the intersection of the anodic and cathodic lines, extrapolated to the corrosion potential, gives the corrosion current density I_{corr} (A.cm^{-2})

From Faraday's law, and assuming that the observed corrosion is uniform, it is then possible to define a relationship to estimate the corrosion rate

$$Vcorr = \frac{Icorr \times t \times M}{n \times F \times \rho}$$

M: the molar mass of the metal (g/mol)

ρ: the density of the metal (g/cm³)

t: the duration of the metal immersion in the solution (seconds)

n: the number of electrons exchanged globally in the solution

F: Faraday's constant (96500 C/mol)

This method can be easily implemented in the laboratory (using a potentiostat), but it has several limitations:

- The potential differences imposed on the electrode must be relatively large (generally more than 100 mV); therefore, a noticeable modification of the metal surface state and hence of I_{corr} is likely to occur during the plotting of these curves.
- The $E = f(logi)$ curves must be linear over at least one decade in current, which cannot always be verified due to the presence of gas evolution or a diffusion polarization process.

IV.2 Électrochemical Study of the Inhibitor at the Laboratory Level :

The purpose of our work is to study the inhibitory effectiveness of CHIMEC 1038 on the corrosion of X42 steel in the corrosive environment of the HBK field.

The study was conducted using electrochemical methods at the laboratory level at CRAPC in Ouargla, with the assistance of a Voltalab 40 (PGZ 301) controlled by a microcomputer (Voltamaster 04 Software), using a three-electrode setup.

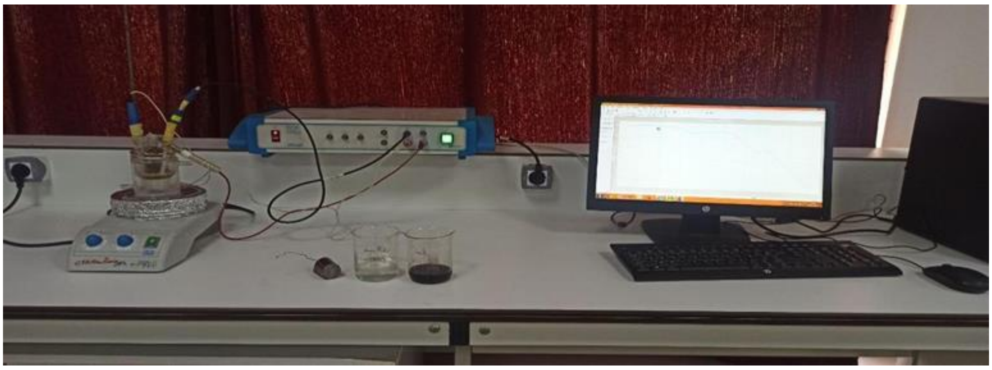


Figure IV 2-1: Experimental setup

IV.2.1 Description of the Setup:

In all experiments, we used a three-electrode setup: a reference electrode, an auxiliary electrode, and a working electrode.

Voltalab 40:

Used to trace potential curves, impedance, and Tafel curves.

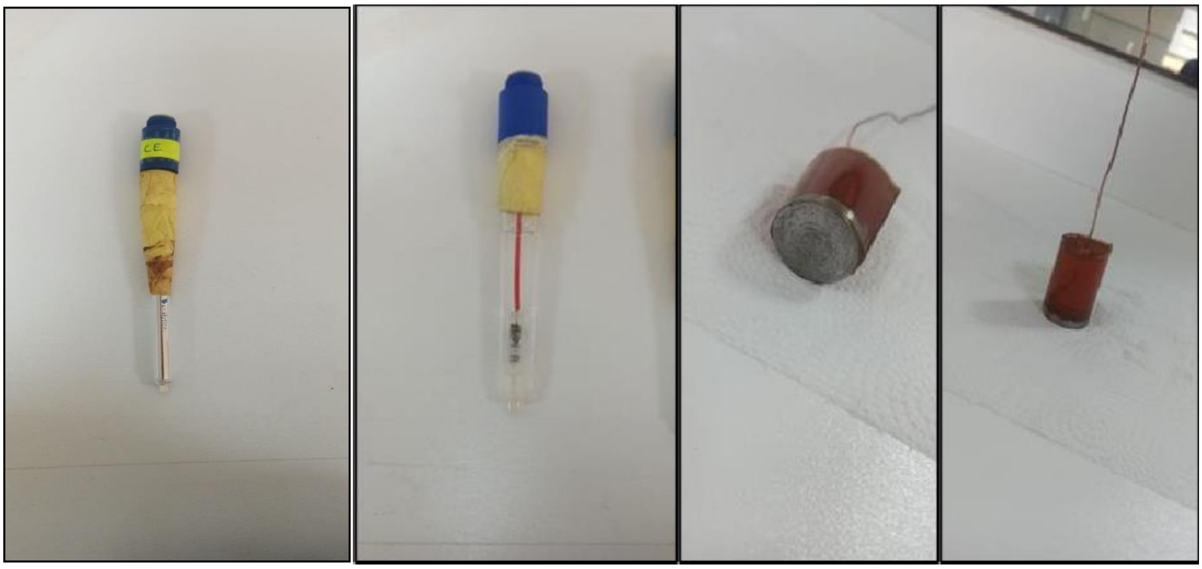
Figure IV 2-2: The Voltalab apparatus

The Electrochemical Cell: The cell used is made of PYREX glass, with a capacity of 100 ml, a sufficient volume to ensure that the concentration of electroactive species remains constant during manipulation. It is equipped with a double wall and a cover with 5 holes to accommodate the three electrodes and the degassing tube.

Figure IV 2-3 : Electrochemical cell

The Electrodes:

1. Working Electrode: Consists of a clean X42 steel plate with a surface area of 3 cm², prepared with sandpaper.
2. Auxiliary Electrode (Counter Electrode): We used a platinum wire as the counter electrode.
3. Reference Electrode: All potential measurements are taken relative to a saturated calomel electrode (SCE) in potassium chloride (KCl).



Auxiliary Electrode Reference Electrode Working Electrode

Figure IV-3 : The Electrodes

The preparation of the working electrode :

After rolling carbon steel into discs with a diameter of 3 cm and a thickness of 1 cm, they were cut into squares using a saw, welded to copper conductors, and coated with thermosetting resin. The resin mold is made of plastic. Leave the mold open for 24 hours to allow the resin to harden. Before handling, the working electrode must be sanded on the working surface using low-grit silicon carbide sandpaper under running water. After polishing, degrease it with acetone and distilled water

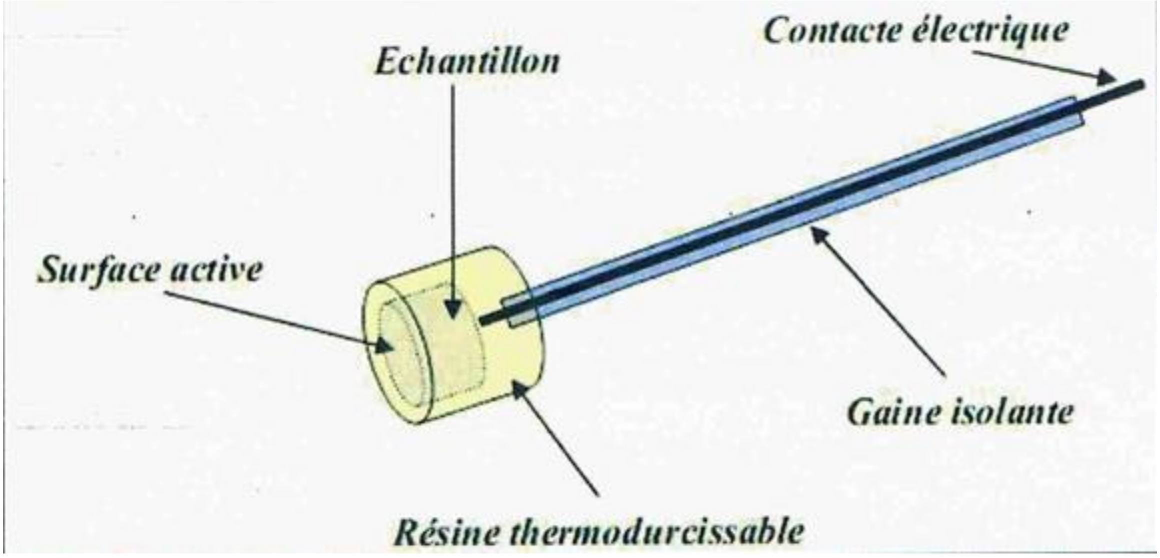
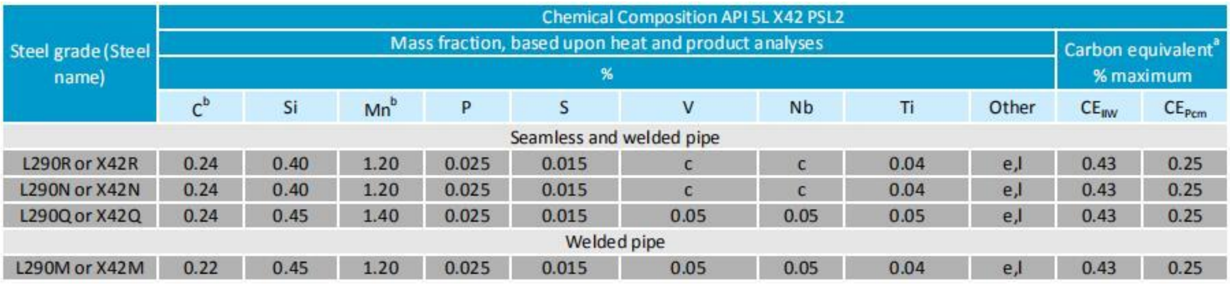


Figure IV-4 : Diagram of a working electrode

Table IV-1: Chemical composition (in %) of X45 steel:



Steel grade (Steel name)	Chemical Composition API 5L X42 PSL2										
	Mass fraction, based upon heat and product analyses									Carbon equivalent^a % maximum	
	%										
	C^b	Si	Mn^b	P	S	V	Nb	Ti	Other	CE$_{IIW}$	CE$_{Pcm}$
Seamless and welded pipe											
L290R or X42R	0.24	0.40	1.20	0.025	0.015	c	c	0.04	e,l	0.43	0.25
L290N or X42N	0.24	0.40	1.20	0.025	0.015	c	c	0.04	e,l	0.43	0.25
L290Q or X42Q	0.24	0.45	1.40	0.025	0.015	0.05	0.05	0.05	e,l	0.43	0.25
Welded pipe											
L290M or X42M	0.22	0.45	1.20	0.025	0.015	0.05	0.05	0.04	e,l	0.43	0.25

IV.2.2 Experimental Products and Procedures:

The products used:

- **Corrosive environment**: a sample of HBK suparator water taken from suparator MP S2D, with a salinity of 1.69 g/L and pH of 5.66 and Fe^{2+} of 258 mg/L.
- **Corrosion inhibitor**: we are using chemical inhibitor 1038, the properties of which have already been mentioned.
- **Extraction of saaharian plantes** : (alaga;moringa), the properties of which have already been mentioned.

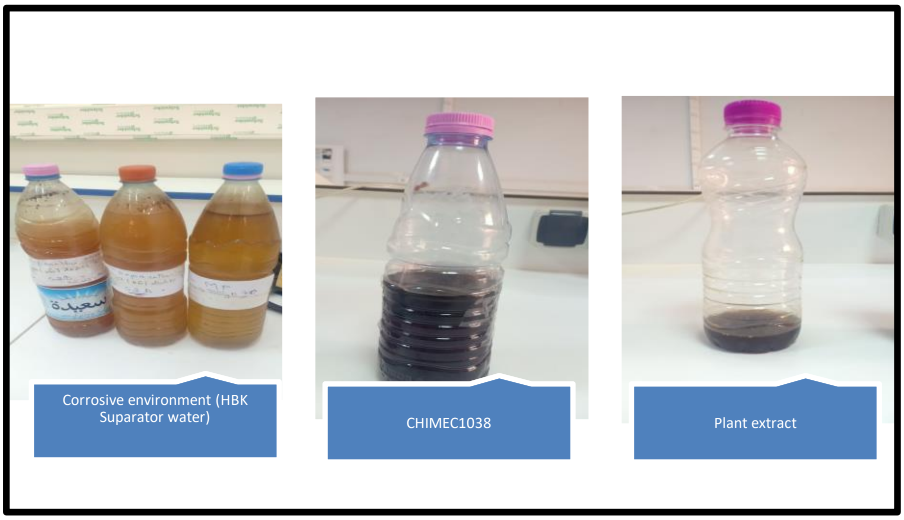


Figure IV-5 : Experience solutions

Table IV 2-1: different Corrosive solutions : Test n° 1

Solution	Experience and preparation
Solution 1	Without inhibitor, 100 ml of the corrosive medium reacts with the steel sample at temperatures of 25°C .
Solution 2	In a 100 ml beaker, we added 1ml of Chimec1038 to 99ml of corrosive environment at temperatures of 25°.
Solution 3	In a 100 ml beaker, we added 1ml of the Alaga extract to 99ml of corrosive environment at temperatures of 25°C ..
Solution 4	In a 100 ml beaker, we added 1ml of the Moringa extract to 99ml of corrosive environment at temperatures of 25°C ..

Table IV 2-2: different Corrosive solutions : : Test n° 2

Solution	Experience and preparation
Solution 1	In a 100 ml beaker, we added 1.5ml of Chimec1038 to 98.5ml of corrosive environment at temperatures of 25°C.
Solution 2	In a 100 ml beaker, we added 2ml of the Alaga extract to 98ml of corrosive environment at temperatures of 25°C.
Solution 3	In a 100 ml beaker, we added 2ml of the Moringa extract to 98ml of corrosive environment at temperatures of 25°C.

Table IV 2-3: different Corrosive solutions : : Test n° 3

Solution	Experience and preparation
Solution 1	In a 100 ml beaker, we added 2ml of Chimec1038 to 98ml of corrosive environment at temperatures of 25°C.
Solution 3	In a 100 ml beaker, we added 4ml of the Alaga extract to 96ml of corrosive environment at temperatures of 25°C.
Solution 4	In a 100 ml beaker, we added 4ml of the Moringa extract to 96ml of corrosive environment at temperatures of 25°C.

Table IV 2-4: different Corrosive solutions : : Test n° 4

Solution	Experience and preparation
Solution 1	In a 100 ml beaker, we added 10ml of Alaga extrait and 10ml of Moringa extrait to 80ml of corrosive environment at temperatures of 25°C .

IV.3.1 Tafel curve for the test n° 1 without inhibitor

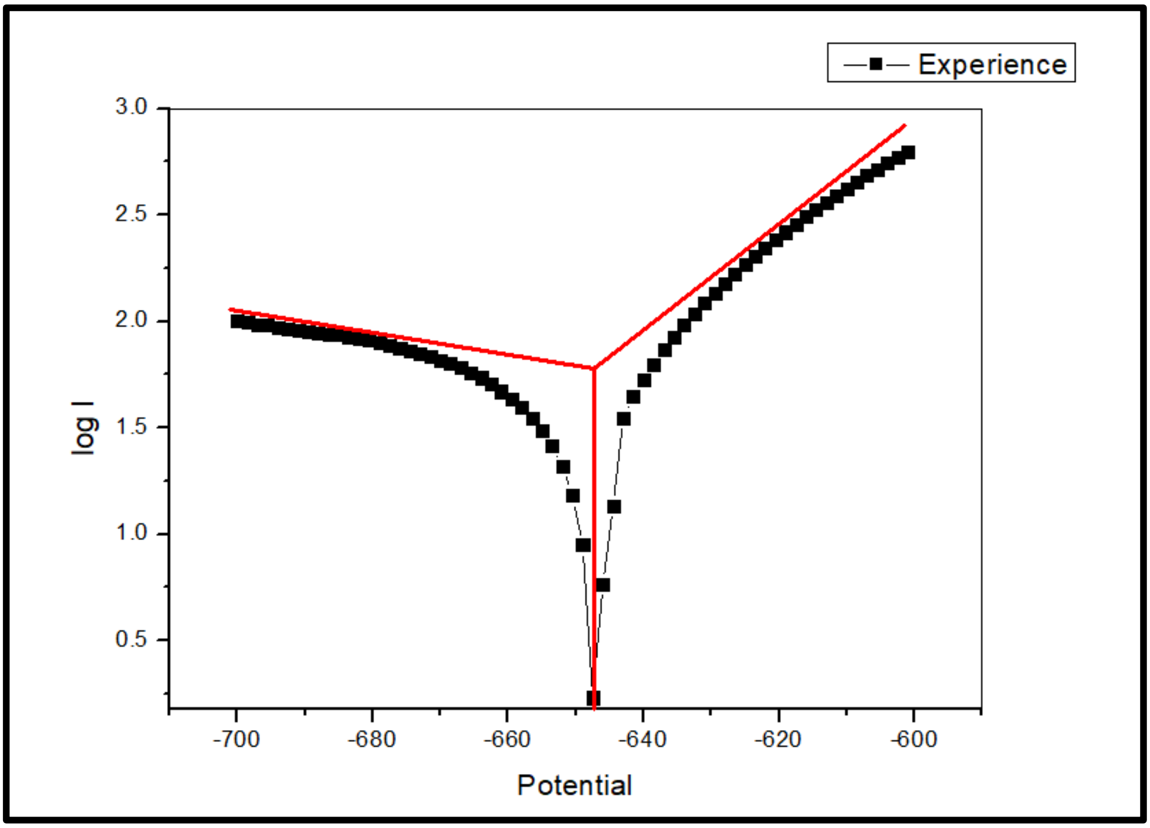


Figure IV-6 : Polarisation without inhibitor

Table IV 3-1 : Experiment 1 without inhibitor :

-650:-580	E(i=0) (mv)	Rp (kohm.cm2)	I_{corr} (µA/cm2)	Ba (mv)	Bc (mv)	Coef	Corrosion rate(µm/Y)
No inhibitor	-605.9	495.46	64.4469	68.4	-280.7	1	753.7

The figure IV-6 presents the curve of Tafel without inhibitor for steel X42 in a corrosive environment, this curve refers to a graphical representation of the electrochemical potential (voltage) and the current density of a steel sample behave under conditions where no inhibitor is present, in the presence of a corrosive environment. (Condensate water from separator) Tafel curve helps in understanding the natural corrosion behavior of steel under adverse conditions, which is important, the corrosion rate without inhibitor Vcor=753.7 µm/Y, this parameter used to assess the susceptibility of materials and equipment to corrosion and to evaluate the effectiveness of industrial corrosion protection.

IV.3.2 Tafel curve for the test n° 2

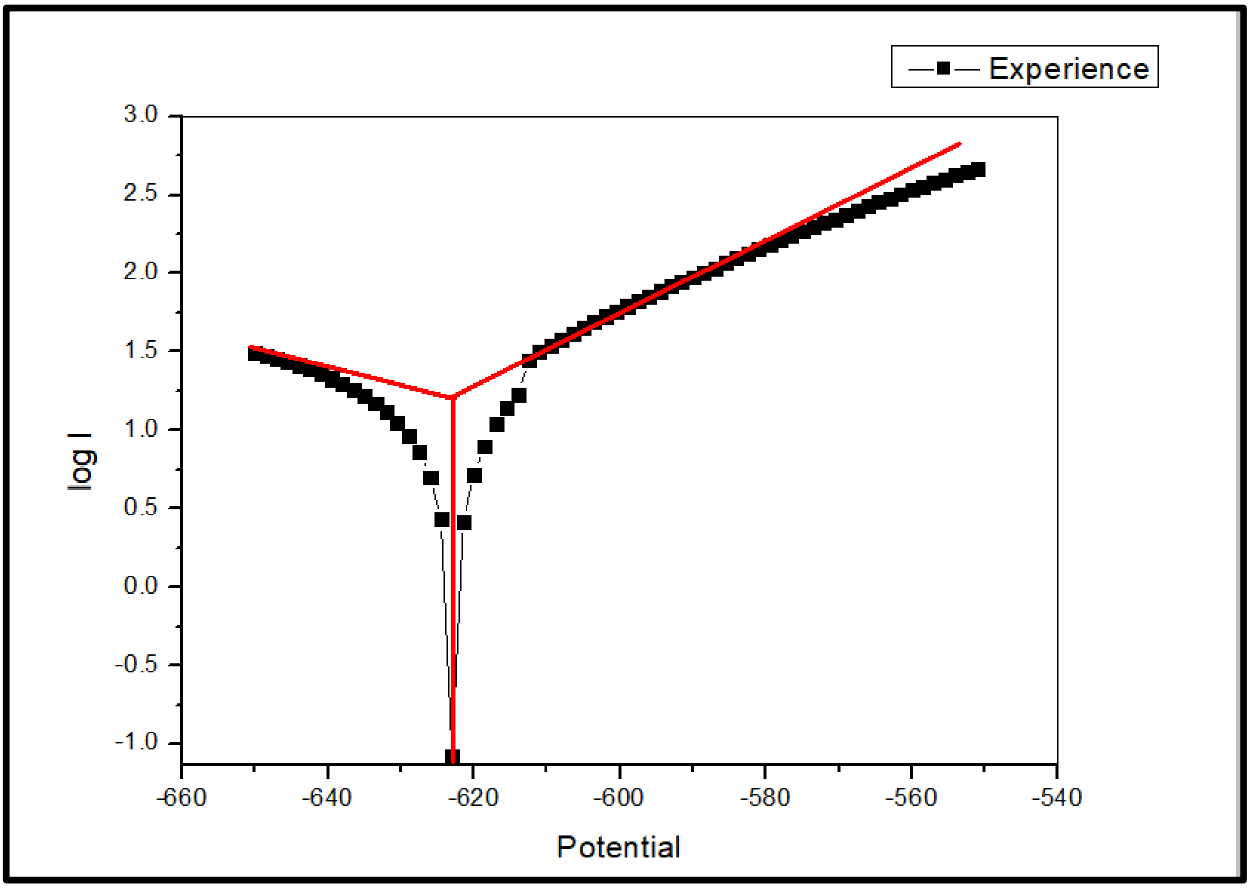


Figure IV-7-1 : Polarisation of Chimec1038 Test n° 1

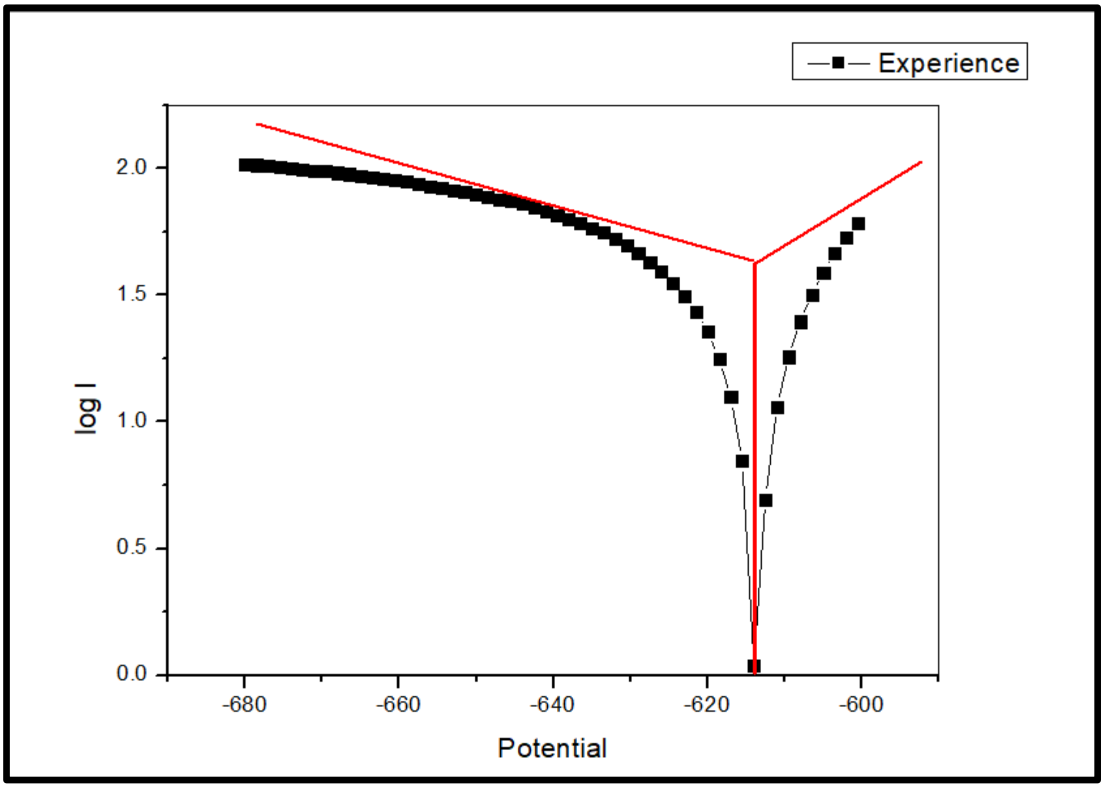


Figure IV-7-2 : Polarisation of Aga Test n° 1

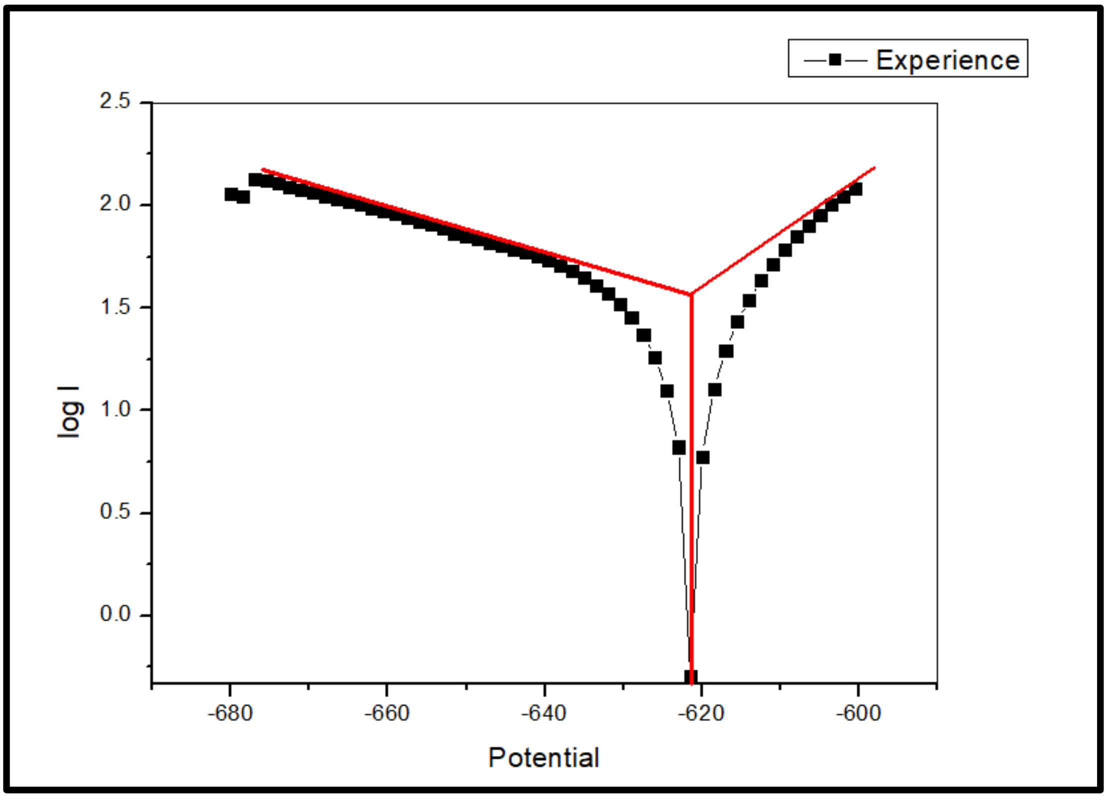


Figure IV-7-3 : Polarisation of Moringa Test n° 1

Table IV 3-2 : :corrosion parametres of test n° 1

Inhibitors	CHIMEC 1038	Alaga	Moringa
Percentage	1%	1%	1%
E(i=0)(mv)	-662.3	-614.2	-621.3
Rp(kohm.cm^2)	2.89	289.92	275.17
Icorr(µA/cm^2)	5.0545	47.92	39.518
Ba(mv)	64.8	44	39.5
Bc(mv)	-94	-167.7	-103.7
Coef	1	1	1
Corrosion rate(µm/Y)	59.11	560.5	462.2

Tafel curves (Figure IV-7) are used to compare the corrosion rates of a material X42 under the influence of two types of inhibitors: an industrial synthetic inhibitor CHIMEC 1038 and a natural industrial inhibitor (extracted from natural sources moringa and alga plants). These curves illustrate the relationship between electrochemical potential and current density, providing insights into the corrosion kinetics and effectiveness of inhibitors in protecting materials from corrosion.

The (Figure IV-8) show the effect of the corrosive (effluent) on API5LX42 carbon steel with the use of industrial inhibitors chimec 1038 and two natural extracted inhibitors of moringa and alga with concentrations of (1%).the corrosion rate varies depending on the inhibitor concentration and its types . With the using of natural inhibitors from both plants, the corrosion rate decreases gradually compared to the corrosion test without inhibitor Vcor=753.7 µm/Y, with Vmoringua =462.2 753.7 µm/Y Valaga = 560.5 753.7 µm/Y, With industriel inhibitors Chimec 1038 , the corrosion rate decreases rapidly Vchimec =.59.11 µm/Y This is explained by the effectiveness of these inhibitors in reducing the risk of corrosion through the formation of a film on the metal surface.

General Conclusion :

The focus of our study is on the corrosion of production equipment within the Haoud Berkaoui field. This region experiences corrosion primarily within surface installations due to the chemical attack of carbon dioxide and hydrogen sulfide. These corrosive agents gradually lead to perforations in the equipment, resulting in effluent leaks and significant disruptions to gas production operations in the area. Understanding and mitigating these corrosion processes are crucial for maintaining operational integrity and efficiency in hydrocarbon production at Haoud Berkaoui. This study aims to investigate the mechanisms of corrosion, assess its impacts, and explore effective strategies for corrosion prevention and control within this challenging industrial environment.

our study has provided valuable insights into the effectiveness of industrial and natural inhibitors in mitigating corrosion within the challenging environment of the Berkaoui field. Through systematic evaluation, it was found that the industrial inhibitor CHIMEC 1038 provides good corrosion protection under corrosive conditions. The extracts from Moringa and Alaga plants show good effectiveness in protecting against corrosion. Electrochemical tests have demonstrated a decrease in corrosion rates and a reduction in electrical current densities in the corrosive environment Haut du formularies

The results indicate that the combined extracts from Moringa and Alaga plants provide corrosion protection with an efficiency of 82.44%. This means that these natural inhibitors are able to reduce the rate of corrosion by approximately 82.44% compared to untreated conditions or other standard inhibitors. On the other hand, CHIMEC inhibitor shows a higher effectiveness of 97.39%, indicating it is more potent in mitigating corrosion under similar conditions. This high effectiveness suggests that CHIMEC is highly efficient in protecting equipment from corrosive damage, potentially leading to longer equipment lifespan and fewer maintenance requirements in hydrocarbon production operations.

The effectiveness of these natural extracts can be attributed to their chemical composition, which likely includes compounds known for their corrosion inhibition properties. Moringa plants are known to contain proteins, peptides, and organic acids that can form protective films on metal surfaces, reducing their susceptibility to corrosion. Similarly, Alaga plants contain antioxidants and other bioactive compounds that contribute to corrosion protection.

In practical terms, the use of natural extracts as corrosion inhibitors offers several advantages. They are often environmentally friendly, biodegradable, and may have lower toxicity compared to synthetic inhibitors like CHIMEC. Moreover, their effectiveness in reducing corrosion rates can contribute to longer equipment lifespan and reduced maintenance costs in hydrocarbon production operations.

However, it's important to note that while natural extracts can be effective, their performance may vary depending on factors such as concentration, application method, and specific environmental conditions. Further research and optimization are typically needed to fully harness their potential and integrate them effectively into industrial corrosion management strategies.

Furthermore, the assessment of natural inhibitors derived from Moringa and Alagua plants revealed promising sustainability credentials, suggesting their potential as environmentally friendly alternatives for corrosion management in the industry. Embracing such solutions not only aligns with environmental stewardship goals but also supports sustainable practices within the hydrocarbon sector.

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