

Review Article

Corrosion Strategy in Oil Field System



Ihssin Abubaker Abdalsamed^{a,*}, Ibrahim Ali Amar^a, Fatima Ali Altohami^a, Fatma Ali Salih^a, Mazek Salh Mazek^b, Masood Abdusalam Ali^c, Abubaker Ahmed Sharif^d

^a Department of Chemistry, Faculty of Sciences, Sebha University, Sebha, Libya

^b Department of Chemistry, Faculty of Sciences, Sirte University, Sirte, Libya

^c Department of Geology and Environment, Faculty of Sciences, Bani walid University, Bani walid, Libya

^d Advanced Laboratory of Chemical Analysis, Authority of Natural Science Research and Technology, Tripoli, Libya

Receive Date: 23 August 2019, Revise Date: 18 November 2019, Accept Date: 01 December 2019

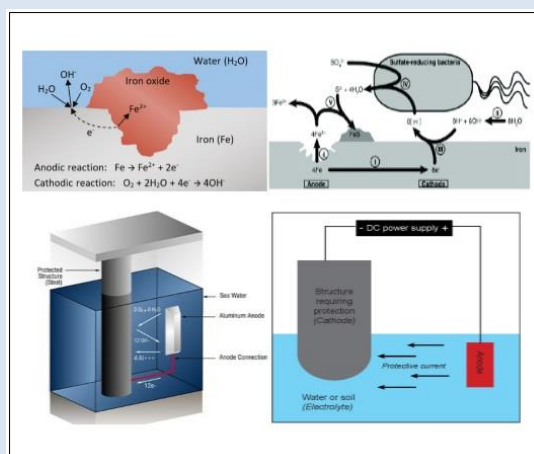
Abstract:

Crude oil is the main economic supply in many countries. Corrosion has been considered as the first fatal factor destroying the crude oil plants such as crude oil equipment, oil wells, separation vessels, storage tanks, and pipelines. This is the main reason encouraging many companies and researchers to develop new technological methods to manipulate corrosion. In this review, we discuss the types of corrosion, corrosion control methods (chemical and non-chemical methods), corrosion removal methods and corrosion monitoring process (direct and indirect measurement of corrosion). In addition some perspectives on SRB bacteria, types of inhibitors and gases removal methods were provided.

DOI: 10.33945/SAMI/JCR.2020.1.2

Keywords: Corrosion. Scale corrosion; Corrosion inhibitor; Corrosion coupons; Sacrificial anodes; Cathodic protection; SRB bacteria; H₂S scavenger; O₂ scavenger.

Graphical Abstract:



Biography:



Ihssin Abdalsamed: He has completed his BSc degree from Sebha University in 1996, Libya. His MSc degree obtained from Robert Gordon University in 2002, UK. His research area is chromatography, corrosion, electrochemistry, nano technology and water treatment. Currently he is working at Sebha university as lecturer (staff member).

*Corresponding author: Ihssin Abdalsamed, Email: ihs.abdalsamed@sebhau.edu.ly





Ibrahim Ali Amar: He obtained his BSc degree from Sebha University Libya, his MSc degree from P. J. Safarik University, Kosice, Slovakia. He has PhD degree in Chemistry from Strathclyde University at Glasgow/Scotland, UK, in 2014. His research area focused on the environmental applications of nanomaterials. Presently he is working at Sebha university as lecturer and published more than 25 papers.

Fatima Ali Altohami She is obtained her BSc and MSc (2008) degree from Sebha University at Libya. Her research area is corrosion and water analysis. She is currently working at Sebha university as lecturer.

Fatma Ali Salih: She is obtained her BSc (2003) and MSc (2008) degree from Sebha University at Libya. Her research area is nanotechnology and ceramics area. She is currently working at Sebha university as lecturer.



Mazek Salh Mazek: He obtained his BSc degree from Benghazi University at Libya in 1991. He completed his MSc degree from University of Manchester, UK, in 2004. His research area is contain chromatography, corrosion and water analysis. Currently he is working at Sirte university as lecturer.



Masood A Ali: He has completed his BSc degree from Benghazi University, Libya, in 1991. His MSc degree Glasgowcaledonian University, UK, School of Engineering and Built Environment in July 2008. He obtained his PhD degree in Environmental Engineering from Southampton University School of civil engineering and environment in September 2014. His research area is corrosion and water analysis. Presently he is working at Sirte Bani walid University at Libya as staff member.



Abubaker Sharif: He has completed his BSc degree from Sebha University Libya; his MSc degree from P. J. Safarik University, Kosice, Slovakia, and his PhD degree in chemistry. His research area is heavy metals, corrosion and water analysis. At present he is working as a staff member at Sebha University and as a researcher at the Advanced Laboratory of Chemical Analysis. Also, He published more than 10 papers.

1. Introduction

Scientists defined corrosion as destruction or damage of metals by electrochemical reaction with its surroundings area (Figure 1). Corrosion is seen in all areas of life and in all industries to some extent. For instance, air oxidation of hot steel results in formation of a film of red-brown ferric oxide [1].

Within the petroleum producing industry, electrochemical corrosion is responsible for billions of US dollars of costs associated with the breakdown of the

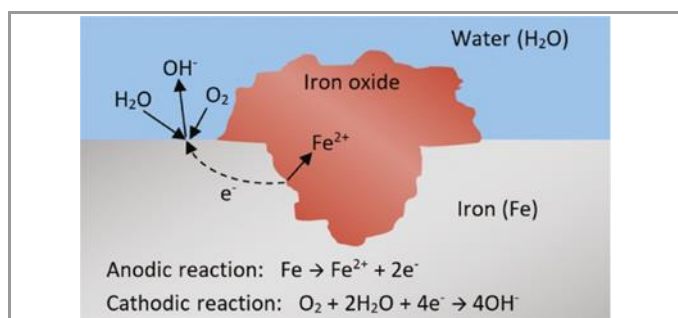


Figure 1. Schematic view of corrosion reaction [2]

equipment caused by the loss of metal from the inner and outer surfaces. Corrosion affects all stages in the exploitation of crude oil ranging from drilling of the wells through the crude production separation process export pipelines, storage tanks and refineries. All forms of corrosion are found in this industry which means that engineers have to be ever vigilant in preventing equipment downtime [3, 4].

Electrochemical corrosion occurs at the solid- fluid interface in water, water/oil and gas systems. In the production process we aim to separate the phases (Figure 2).

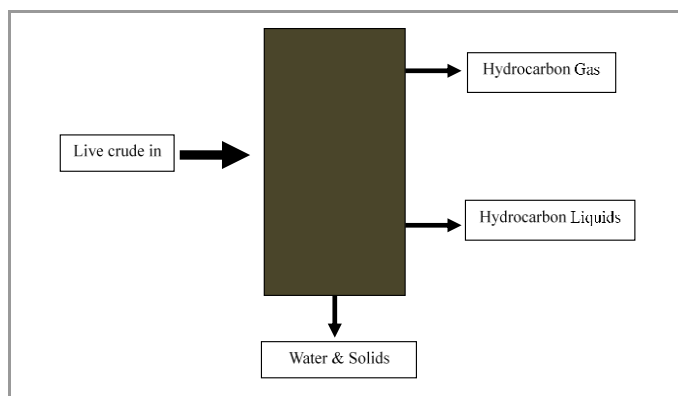


Figure 2. Diagram of separation process in oil field.

Hydrocarbons are including aliphatic paraffins $\text{C}_1\text{-C}_{50}$, branched aliphatic paraffins unsaturated paraffins saturated cyclic paraffins naphthenic acid aromatics substituted aromatics, condensed aromatics naphthas polycyclic species, maltenes asphalts, carboxylic acids and mercaptans. The aqueous phase includes water and dissolved salts containing Na, K, Ca, Mg, Ba, Sr, Fe, Al, Si and Cl. The minor solids are including quartz sand, silt

clay minerals, iron oxides, natural and product of corrosion iron sulphides and calcium carbonate (Figure 3). Oil phase produced wax and asphaltenes may intensify enhanced corrosion while water phase produced scale, corrosion and bacteria.

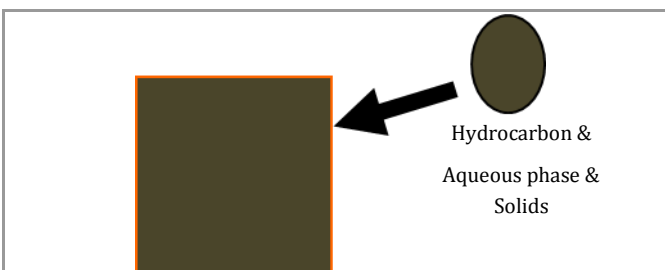


Figure 3. Crude oil content.

Purity of crude oil is classified and graded by API gravity (American Petroleum Institute). In general, oils with the API gravity of 40 – 45 most likely will possess the highest market prices. Any oils with API gravity of 45 API or higher have shorter molecular chains which are acceptable to refineries. Any crude oil with API gravity of over 31.1 degrees is considered as light crude. Oils with API gravity range between 22.3 and 31.1 degrees are classified as the medium crude oils. The heavy crude oils with the API gravity of lower 22.3 would have lower prices [5]. The official formula used to derive the gravity of petroleum liquids from the specific gravity (SG) is presented in Equation 1

$$\text{API gravity} = 141.5/\text{SG} - 131.5 \quad (1)$$

The relative density (RD) of petroleum liquids can also be uncovered by using API gravity value presented in Equation 2

$$\text{RD at } 60^\circ\text{F} = 141.5 / (\text{API gravity} + 131.5) \quad (2)$$

2. Electrochemical Corrosion

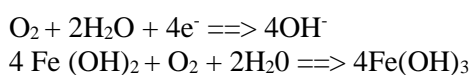
To occur an electrochemical reaction some requirements need be met: (a) must be a surface anode, (b) must be a surface cathode, (c) must be an electrolyte present, (d) there must be some form of external connection between the cathode and anode.

3. Factors affecting general electrochemical corrosion

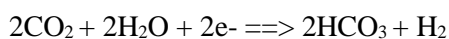
The aqueous acidity is influenced by the content of organic acids and by the dissolved carbon dioxide. Corrosion is increased as the acidity is intensified. The presence of carbonate minerals acts as buffer reducing the corrosion. At low pressures corrosion starts to increase at temperature about 65 °C. Increasing the pressure results in an increase in stress related failures. High fluid velocities may remove the protective films (corrosive product films, scale deposits or inhibitor films). Pitting and other localised corrosion is intensified as the chloride content (high salinity) is increased, assuming that same oxygen is existing. The effect is particularly noticeable at high temperatures.



The imposed electric currents can be a problem if electric heating is used. Direct current and low frequency alternating current are likely to increase the general corrosion rate. It is difficult to control the oilfield corrosion at the presence of oxygen and even low levels (<5 ppm) can be quite corrosive. Water can contain up to 10 ppm oxygen under the normal conditions of temperature, pressure, and salinity. Oxygen reacts at cathode (depolarisation) and oxidizes the ferrous iron to ferric hydroxide (rust).



Flow rate is an important factor in CO₂ water corrosion. At high flows, it is possible to remove protective carbonate films. Stainless steel is resistant to CO₂ under low-pressure conditions.



H₂S is relatively soluble in water, creating a weak acid which is corrosive. However, H₂S is roughly 200 times more soluble than and about three times soluble than carbon dioxide, under the normal conditions of temperature and pressure [6-8].

4. Forms of corrosion

General corrosion is the most acceptable form of corrosion, which can be controlled by using some chemicals. When general corrosion occurs, the anodic and cathodic areas are continually changing which causes all areas to be evenly corroded. Localised corrosion is more serious, leading to early failure [9]. Pitting corrosion occurs in the form of spots or pits on metal surface, leading to a damage of metal layers. Crevice corrosion is a form of localised corrosion occurs due to the presence of dust and clay or gaps on the metal's surfaces [10, 11]. Stress corrosive cracking (SSC) caused by sulphides can occur in acidic waters. Dissolved sulphide in water may attack the metal and produce FeS rust and hydrogen. Hydrogen can penetrate the metal creates high internal pressures. Hydrogen embrittlement, in which the metal becomes glass-like (brittle), is a consequence of hydrogen invasion. Optical microscope (OM) and scanning electron microscope (SEM) are the valuable tools for assessing the cracking phenomena [12]. Galvanic corrosion is the result of immersing dissimilar metals in electrolytes. At the junction of the two metals there will be a flow of electrons which leads to electrochemical pitting. Nickel and other corrosion resistant alloys can increase the likelihood of galvanic corrosion and embrittlement [13]. Erosion corrosion might be accelerated at high fluids velocity which can either physically remove the protective films or mechanically disturb the surface itself. Particles of sand or iron sulphide cause erosion corrosion even at moderate velocities. Cavitation is a special form of

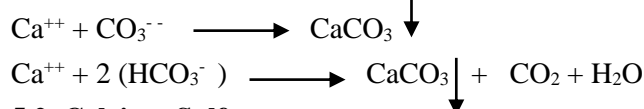
attack caused by the collapse of bubbles formed at the areas of low pressure in a flowing stream [14].

5. Scales form

Solubility is defined as the limiting amount of a solute which can be dissolved in a solvent under a given set of physical conditions. The chemical species of interest to us are presented in water solution as ions. Certain combinations of these ions are compounds which have very little solubility in water. Saturated water has a limited capacity for maintaining compounds in solution and once this capacity or solubility is exceeded, the amount of compound precipitate from solution as solids particles [15].

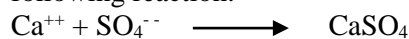
5.1. Calcium

Calcium Carbonate scale can be formed by the combination of calcium ion with either carbonate or bicarbonate ions as follows:



5.2. Calcium Sulfate

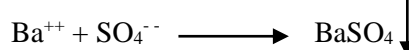
Calcium sulfate precipitates in accordance with the following reaction:



Most calcium sulfate deposits found in the oilfield are gypsum. CaSO₄·2H₂O is the predominant form at temperatures of 100° F or less.

5.3. Barium sulfate

Barium sulfate is the least soluble of the scales.



6. Bacteria

6.1. Sulfate Reducing Bacteria (SRB)

Sulfate reducers probably cause more serious problems in oilfield injection systems than any other bacteria. They reduce sulfate ions in water to sulfide ions, resulting in formation of hydrogen sulfide H₂S as a by-product (Figure 4). They cause corrosion, and the iron sulfide produced as a product of the corrosion reaction is an excellent plugging material. Sulfate reducing bacteria live in groups, or colonize on the pipe wall, and pits occur wherever they reside. Bacteria find it much easier to colonize on the pipe wall than in a moving stream of fluid. Any time you find bacteria in the water this means that there are many more securely attached to the walls of the piping and tankage.

6.2. Iron Bacteria

Iron bacteria deposit a sheath of iron hydroxide around them as they grow. The iron is obtained from soluble iron ions in the water. Examples of iron bacteria are Gallionella, Sphaerotilus and Crenothrix. They are classified as aerobic bacteria; however, they can apparently grow well with only trace amounts of oxygen



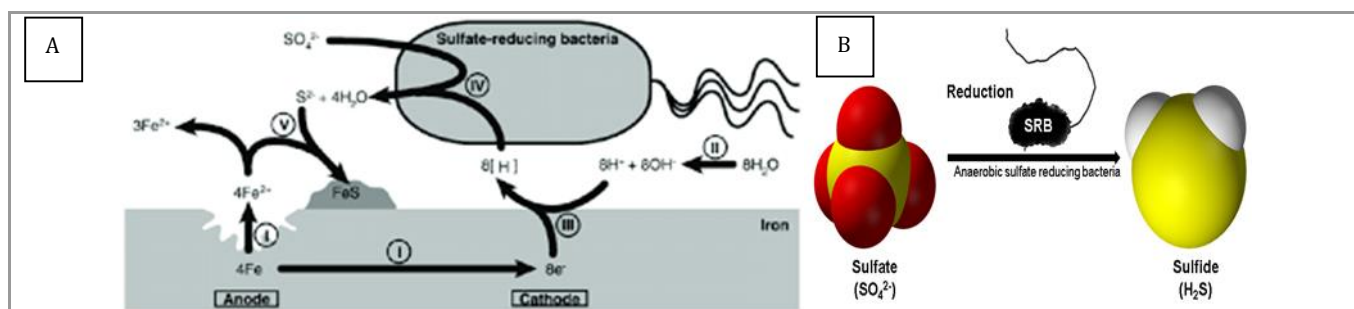


Figure 4. (A) Scheme of corrosion by SRB. (B) Scheme of hydrogen sulfide formation by SRB [16].

7. Chemical control of micro organisms

Chemicals used for bacterial control can be broadly classed in several ways:

a) Bactericide is a chemical which kills bacteria, b) Bacteriostat is a chemical which inhibits or retards the growth of bacteria, c) Biocide is a chemical which able to kills other forms of life in addition to bacteria, d) Bio stat is a chemical which inhibits or reduce the growth of bacteria. For the pipelines biocide treatment usually uses between two pigs to get high concentration, for vessels and tanks shock dosage with long period time while batch treatment used on down hole .

8. Corrosion control Non chemical methods

A wide range of control measures are available but not all can be adopted in any given environment. These include: (a) Engineering Solutions, (b) Sacrificial anodes (c) Coatings, (d) Cathodic Protection, (e) Treatment of the Water and (f) Process system.

8.1. Engineering

Steel pipe can be replaced by plastic and fibreglass reinforced plastic pipe. These materials are frequently used in low temperature flow lines at low or moderate pressures for carrying corrosive brines (such as H_2S). Metals are available for most corrosive environments in oilfield systems but the usual limitation is their cost.

High chrome steels, 'duplex and super duplex' are resisting to acid gases. Corrosion resistant metals are now more commonly used for pumps, meters and auxiliary fittings. Titanium and Monel are resistant to salt water attack and are used in water injection systems [20].

8.2. Sacrificial

Sacrificial anodes are used in ships, oil plants, offshore plants, platform and bridges immersed in water. The mechanism of sacrificial anodes to protect and prevent another metal from being corroded are sacrificial anodes with highly electrochemical activity compeering to the protected metal which has a lower electrochemical activity. Sacrificial anodes are created from a metal alloy with a more negative electrochemical potential than the other metal it will be used to protect (Figure 5). Usually sacrificial anodes are made of zinc alloy, magnesium, or aluminium alloys. The difference between the sacrificial anodes and cathodic protection is that, in sacrificial anodes no current is applied. The advantages of sacrificial anodes include low cost, easy to apply. However, the sacrificial anodes should be replaced frequently; they should not be affected by the microbiological corrosion [21].

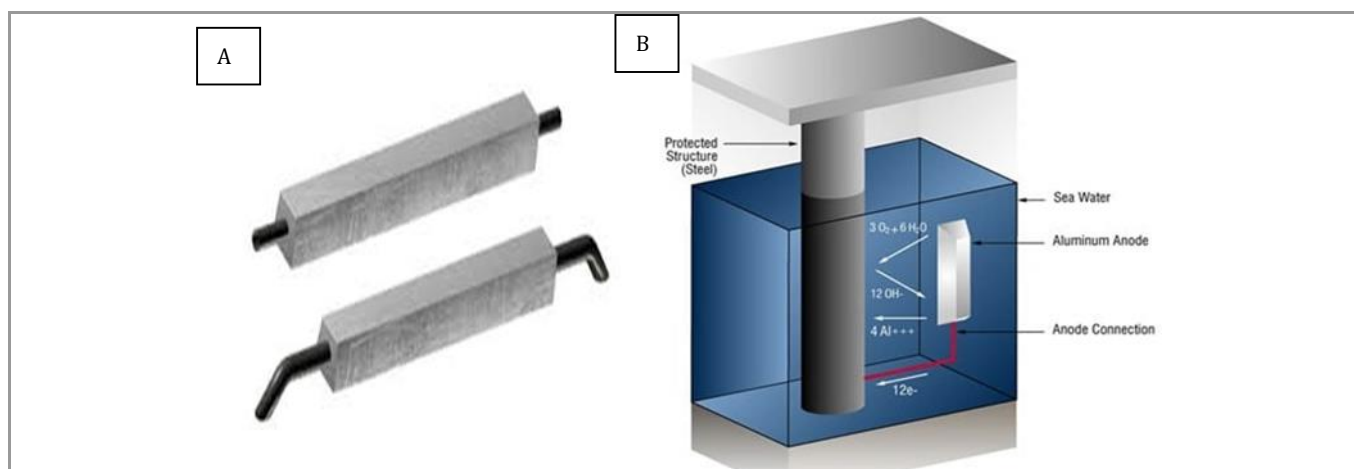


Figure 5. (A) Scheme of sacrificial anodes (B) sacrificial anode fixed to protect the metal [22].



8.3. Coatings

Corrosion can be prevented by removing the corrosive environment from the metal. This is the principle of applying coatings for corrosion protection. Choosing an appropriate coating depends on the temperature, pressure and corrosive agent. Painting and galvanising are examples of coatings that have long been applied to reduce corrosion. The corrosive environment is therefore separated from the metal at risk [23].

8.4. Cathodic protection (impressed current)

Humphrey Davy [24] evaluated how zinc anodes could be used to prevent the corrosion of copper sheathing of the wooden hulls of British naval ships. Several practical tests have been conducted on vessels in harbour and sea-going ships, such as the effect of current density on protection of the copper. Davy [24] also investigated the use of the impressed current system using a voltaic battery, but did not consider a

practicable method. The principles application of cathodic protection is applied by one of the two methods, viz. Power-impressed current. Figure 6 illustrates an external power supply which converts ordinary a.c. (alternating current) power to d.c. Electrically the protected structure acting as cathode while an external power supply acting as anode. Graphite anodes, aluminium anodes, magnetite anodes and polymer conductive anodes are most used as external power supply [25, 26].

Electrochemical reactions at the electrodes are responsible for the mechanism of cathodic protection and for the transfer of charges from the electrons to ions at the electrode surfaces. The advantage of cathodic protection method is; low cost and it can used to protect vessels, pipes and tanks moreover process is simple. However the main disadvantage is more current applied ions may be start to attack the metal.

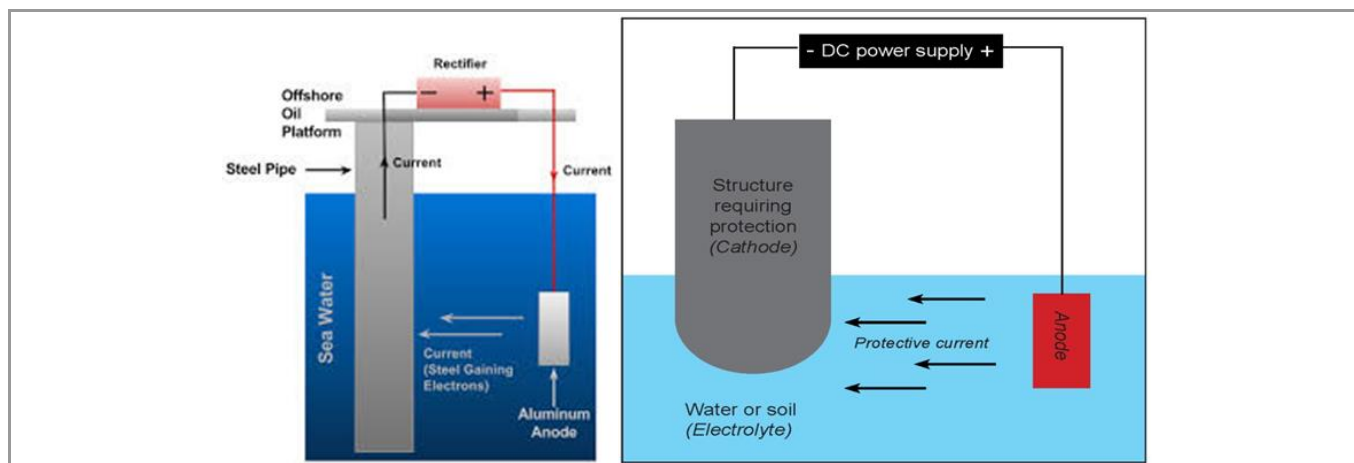


Figure 6. Cathodic protection with an external power supply in water and soil [22]

8.5. Treatment of water

Removing the main corrosive agent from water by deaeration and degasification.

8.6. Processes system

This is very important, however stagnant water it is a good condition to bacteria make kingdom, also any incorrect pressure system an hydrate well start attack the metal.

9. Corrosion control – Chemical methods

A corrosion inhibitor is a substance which, when added to an environment, decreases the rate of attack by the environment on a metal. Inhibitors are chemicals that, directly or indirectly, coat or film a metal surface to protect it from its environment. Inhibitors can be absorbed by the metal surface from a solution or dispersion or applied directly as a thick barrier coating. Inhibitors can be inorganic, organic, polymeric, simple or complex formulations. Chemicals classified

according to their reactivity with oil phase or water phase (Figure 7). For the purpose of this discussion, three classes of inhibitors will be discussed: passivating, organic film-forming, vapour phase inhibitors.

9.1. Passivating inhibitors

Passivating inhibitors are potentially the most effective of all inhibitors because they can stifle corrosion almost completely. Passivity usually refers to materials that form insoluble corrosion product films, stifling the anodic reaction but in this case it is the inhibitor that promotes the formation of an insoluble film normally on the anode.

There are two types of passivating inhibitors: Oxidising type such as chromate, nitrite, and molybdates which can passivate steel in the absence of oxygen and the non-oxidising ions such as phosphate, tungstate and silicate which require the presence of oxygen to passivate steel. These inhibitors are effective in aerated systems.



The passive oxide film is conductive and cathodic to steel; therefore passive steel consists almost entirely of cathodic areas. When the passive film is penetrated by scratching or by dissolution or if insufficient inhibitor is present to repair the film, then exposed steel becomes a small anodic area in the midst of a large cathodic area of passive film. Accelerated localised corrosion then occurs, resulting in pitting of the metal. Passivating inhibitors are not effective against H₂S induced corrosion [27, 28].

9.2. Organic Inhibitors

Organic inhibitors constitute a broad class of corrosion inhibitors which cannot be designated specifically as cathodic and anodic. They are widely used for corrosion control in crude processing and transportation flow lines. The efficient use of organic inhibitors depends on prior removal of oxygen from the system.

Organic inhibitors form films that are water repellent. Hydrocarbons are sometimes added to inhibitor formulations that will wet the adsorbed inhibitor forming a secondary barrier. By replacing and repelling water away from the metal surfaces, the oil films are able to stifle corrosion much like other physical barriers such as paints.

Nitrogenous inhibitors are the main active constituents in more oilfield inhibitor compositions. In water or acids the terminal primary, secondary and tertiary amines groups are protonated, are cationic in nature. Quaternary amines show considerable cationic behaviour: are excellent surfactants, can be demulsifiers, have good biocidal activity and have corrosion inhibiting properties. Imidazolines and ethoxylated amines can be quaternised. Non-nitrogenous organic inhibitors are certain alkyl half esters of phosphoric acid are claimed to be good inhibitors of carbon dioxide or naphthenic acid induced corrosion. Napthenic acids cause problems in high temperature refinery operations. These inhibitors have been used for crude oil systems. They have much lower toxicity characteristics than amine but the adsorbed inhibitor film is more easily removed by water [29].

9.3. Vapour Phase Inhibitors

Vapour phase inhibitors (VPI) are compounds which are transported within a closed system to the site of corrosion by volatilisation from a source. In boilers, volatile basic compounds such as morpholine and ethylenediamine are transported in the stream to prevent corrosion in condenser tubes by neutralising acidic carbon dioxide. Compounds of this type inhibit corrosion by making the environment alkaline. The organic amine portion of the VPI may serve to aid inhibition by adsorption and providing alkalinity [30]. Incorrect inhibitor on process system may be enhances

emulsions this is the main disadvantage using chemical methods.

Table 1. Common types of chemical are used in oil field.

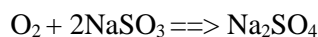
	Gas
Indigenous Surfactants	Oil
Antifoam	
Demulsifiers	
Corrosion Inhibitor (soluble in oil)	
Wax Crystal Modifiers	
Gas Scavenger(H ₂ S, O ₂)	
Scale Inhibitors	Water
Corrosion Inhibitor (water soluble)	
Biocides	
Reverse Emulsion Breakers	
Flotation Agents	

10. Gas scavengers

10.1. Oxygen scavenger

Corrosion of steel in brine is enhanced by increasing the dissolved oxygen. Neutral water with a low salt content in equilibrium with air at 21°C will contain around 9 ppm of dissolved oxygen. The concentration of oxygen decreases with increasing the salt content and increasing temperature.

The most commonly used scavengers of oxygen are sodium and ammonium bisulphate solutions. They react to form stable sulphates.



The reaction rate of sodium sulphite with oxygen at low temperature is very slow, so a catalyst is usually added. While cobalt, manganese and copper salts are good catalysts, cobalt gives the greatest increase in reaction rate. However ammonium bisulphate requires no catalyst.

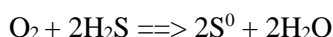
10.2. Sulphide Scavenger

Some producing wells are characterised by high and potentially hazardous levels of sulphides. A sulphide ion is a natural constituent of many produced fluids. The activity of sulphate reducing bacteria, particularly in water flood operations, is another common source of sulphide. It is not unusual for sweet production systems to turn sour with time as a consequence of reservoir souring [31].

The use of the word 'sulphide' implies all three water-soluble forms: H₂S that predominates in the acid range, HS⁻ which is present between pH 7-13. Sulphides are an unwanted constituent of crude oil and water. Their presence in the separated crude has a detrimental effect on the sales value and performance of refineries. In the acid form, hydrogen sulphide is toxic to health and accelerates corrosion processes. In production systems with natural sour production it is normal for the processing equipment to be specified to resist the



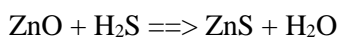
corrosive nature of sulphides. The basic oxidising scavengers reaction can be summarised:



Oxidants are very rapid acting, water soluble and irreversible in action. Amines react with sulphides/ H_2S to form acid/ base salts in a fully reversible reaction. The 'scavenger' can be regenerates for reuse. Ethanolamines have been used extensively to remove H_2S from gas streams in sweetening towers. Diglycolamine[2-(2-Aminoethoxy)ethonal] has been used since 1965 for the industrial removal of hydrogen sulphide and /or carbon dioxide from gas streams. Other reactive amines that have been used include hexahydrotriazines. These triazine products react irreversibly and are relatively low cost. Reaction with H_2S at low temperatures is less efficient.

H_2S reacts with aldehydes across the $\text{C}=\text{O}$ double bond in a reversible process. The most common use of formaldehyde. Disadvantages include potential for solids formation and toxicity of aldehydes. Glyoxal, gluteraldehyde, and acrolein have been used. Iron sponge (solid) is probably the earliest sulphide-precipitating agent. The material is formulated by impregnating wood chips with iron oxide and is primarily used in drilling fluids. Zinc compounds, as slurry in contractor towers, rapidly precipitate as sulphide [32, 33].

When H_2S is presence in the gas stream:



11. Corrosion Monitoring Methods

The objective of monitoring is to obtain information about the corrosion process and thereby to assess options for controlling corrosion and its consequences. The main reasons for monitoring are security of assets/ investments (economic reason) and security of personnel safety (health and safety reason). Corrosion control means controlling the rate of corrosion to a level that economically justifiable taking into account plant profitability and planned life, whilst at the same time minimising environmental and safety risks.

The On-line monitoring should be installed wherever it is known from experience that unacceptable levels of attack are possible and in all critical areas where corrosion could be dangerous or expensive. The position and orientation of the monitoring device are important: for example: if separated water is the most corrosive agent, then bottom-of-line monitoring is needed but it vapours on the upper surface of the wet gas line are the problem top-of -line monitoring is also necessary. In general it is advisable to use more than one method of corrosion monitoring as the different forms of corrosion respond differently to each monitoring technique. A wide range of methods are available.

11.1. Intrusive Methods Direct Measure of Corrosion

These monitoring devices are inserted into a system and provide direct information on corrosion rate, metal penetration or fluid corrosivity. Examples include: Coupons (on line), spool pieces, Electrical resistance probes(ER), Linear polarisation resistance probes(LPR) ,Calipers/Intelligent pigs.

11.1.1. Corrosion Coupons

Corrosion coupons provide the most widely used method of monitoring corrosion. The coupons can be made in any size or shape to fit into the equipment and be retrievable (Figure 7). The coupons can be mounted in different configurations to be able to evaluate various types of attack including crevice corrosion, galvanic attack, and stress corrosion. Prior to assembly on the corrosion test rack, each coupon is carefully weighed and measured. After completion of the test, the rack is disassembled and the corrosion coupons are cleaned, weighed, and measured. The following are advantages: low cost, possibility of several materials being tested at the same time, closer resemblance to actual condition, reliable information for future designs. However there is disadvantage: first incorrect location and position it well gives wrong result, second it need long period for monitoring (exposure time).

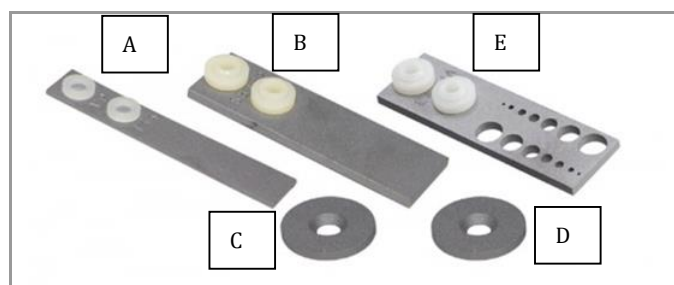


Figure 7. (A, B) Corrosion strip coupon different types.(C, D)Disc coupon.(E) Scale coupon[34].

The amount of corrosion rate can be accuracy calculated mils per year by equation:

$$\text{MPY} = \frac{\text{weight loss grams}}{\text{exposure time days}} \times \text{factor}$$

$$\text{Factor} = \frac{\frac{1000 \text{mils}}{\text{in}} \times 365 \text{days/year}}{\text{metal density} \frac{\text{gr}}{\text{cm}^3} \times 16.4 \frac{\text{cm}^2}{\text{in}^2} \times \text{coupon area cm}^2}$$

A mils is equivalent to 1/1000 inch.

On other hand we can use the following equation to calculate corrosion rate (C.R):

$$\text{C.R} = 534 \text{ WD/A.T}$$

where W is weight loss measured in mg, D is the density of alloy in g/cm^3 , A is the surface area of the specimen exposed to the solution in cm^2 , and T is the total exposure time in hour [35, 36].



11.1.2. Electrical Resistance(ER) probes

Electrical resistance(ER) probes are essentially coupons providing a continuous read-out of the penetration of their metal elements exposed to the corrosive environment. The principle is that electrical resistance of a conductor element increases as the cross section decreases. Typically a metal loop, similar to a hairpin, made of the metal of interest is mounted in a holder (probe) and exposed to the process stream (Figure 8). This system can be used in any liquid or gaseous environment and has the advantage that on-line data is obtained that can be correlated with process conditions [37].

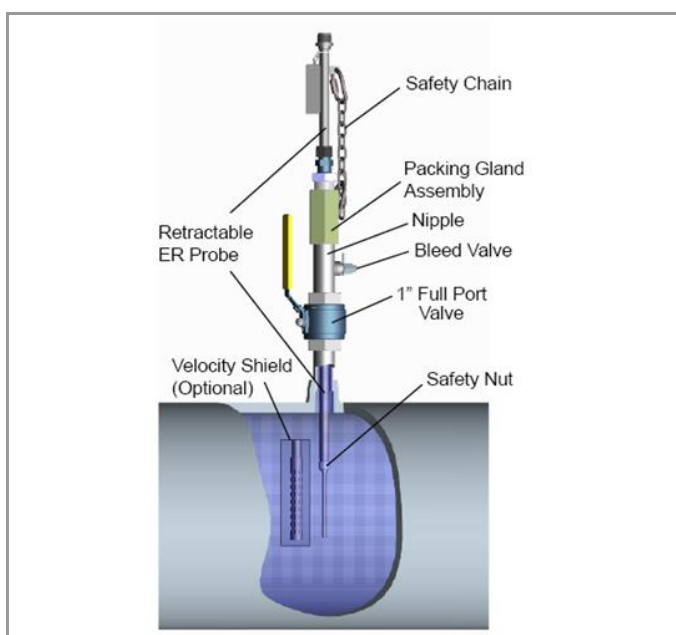


Figure 8. Electrical Resistance(ER) probes fixed into pipe [38]

ER probes are rugged and simple to operate and interpret. They will not identify local corrosion attack and do not give instantaneous corrosion rates. Portable measuring instruments designed especially for use with these probes are commercially available.

11.1.3. Linear Polarisation Resistance (LPR) probes

Linear Polarisation Resistance (LPR) probes can respond instantaneously to changes in corrosivity within an electrolyte. A variable potential of up to 10 or 20 mV is passed through the solution using the electrodes. A sensor or probe represents (on a macro scale) the actual corrosion cell on the metal surface of interest and from the change of potential at the working electrode and the current an estimate of the actual corrosion current can be made (Figure 9).

In practice the approach is similar to the ER in that a probe is exposed to the process stream. LPR has the advantage that it provided instantaneous corrosion rate data and fast response to system upsets and can give some information about local attack. However the

probes can give errors if suspended solids are high and in the presence of sulphides [39].

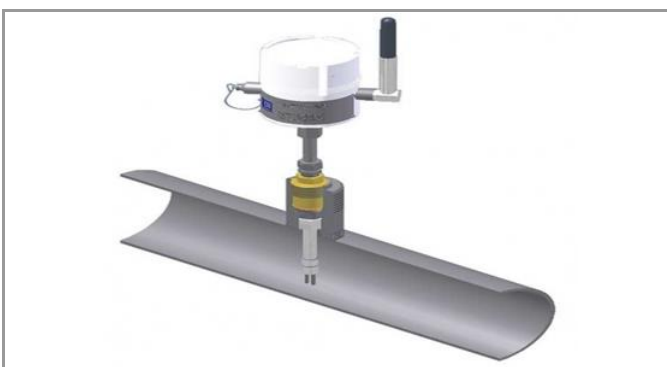


Figure 9. Linear Polarisation Resistance (LPR) probes fixed into pipe. (Figure taken from <https://www.cosasco.com/lpr-corrosion-monitoring-probe-7012-7022.html>)

11.1.4. Calipers (Intelligent Pigs)

Pipeline Calipers are Intelligent Pigs can give penetration data for the entire inner surface of the pipeline (some intelligent pigs can also detect external corrosion). Their use requires temporary shutdown of the line to allow insertion and retrieval of the equipment through pigs traps. Calipers have systems of articulated mechanical fingers, the movement of which against the inner pipe surface determines the output on the chart recorder (Figure 10). Calipers may not detect initial pitting corrosion. Intelligent pigs use either magnetic flux leakage or ultrasonic techniques to detect any change in the surface. Disadvantage incorrect process system it well scratch the pipeline [40, 41].



Figure 10. (A) Intelligent Pig, (B) Intelligent Pig moving into pipe launcher [41]

11.2. Intrusive methods indirect measure of corrosion

These are devices which are inserted into a system and provide information from which a judgement can be made on system corrosivity. Examples include: Hydrogen probes (on-line), Galvanic probes (on-line), Potential measurements

11.2.1. Hydrogen Probes detect atomic hydrogen that diffuses through a thin membrane within the pipe. Probes with cylindrical elements are the most rugged

mechanically and chemically, are least affected by temperature changes. Flush elements are used in lines which must be pigged or where it is desired to have the sensing element flush with the wall surface [42].

11.2.2. Galvanic Probes measure the possibility of corrosion between two different metals, typically carbon steel and brass. A probe containing two elements corresponding to the two metals is exposed to the corroding liquid. A zero resistance ammeter is used to measure the current produced by the galvanic cell [43].

11.2.3. Potential measurement can, if combined with LPR techniques, provide more detailed information on the corrosion process. Equipment is simple, requiring an appropriate reference electrode (exposed to the corroding medium) and a voltage measuring instrument. Readings can indicate the passivity or activity of the metal of interest, specialised corrosion knowledge is usually required to interpret the information obtained [44].

11.3 Non- intrusive methods direct measure of corrosion

The basis of eddy current inspection is the principle of electromagnetic induction. This procedure can be used to identify or differentiate among a wide variety of physical, structural, and metallurgical conditions in conductive ferromagnetic and non - ferromagnetic metal components. It can also be used to detect cracks, voids, and inclusions, to sort dissimilar metals and detect differences in their chemical composition, and to measure the depth of non-conductive coatings on conductive metals [47].

11.4 Non- intrusive methods indirect measure of corrosion

Indirect measurement methods of corrosion are acidity, oxygen content, iron counts, microbiological evaluation, and acoustic emission. PH instrument is the best tool used for measuring acidity. Dissolved iron or iron counts must be measured before and after injection of any chemical inhibitor in the system as high iron contents present in water indicated of the corrosiveness of metal. Microbiological monitoring and evaluation can be done in laboratory to estimate quantity of bacteria colonize present per mil. Acoustic emission mechanism is the pressure of stress waves hit the metal released energy can be investigating metal deforms or fractures, the monitoring measurement is calibrate thickness as reference and then calibrate after period of time [48-50].

12. Conclusion

Corrosion is the main problems investigated in many fields. The major consequences of electrochemical corrosion are including, shutdown, contamination, loss

of product and loss of efficiency. Various type of corrosion may occur in different environments. Engineering strategy plan are very important to manipulate and minimize corrosion problems such as selecting the best environment area for building plants, type of metal will using to fabricate plants and process system they can reducing corrosion rate . Moreover coating, cathodic protection and sacrificial anodes are non-chemical methods used to suppress the corrosion. In sacrificial anodes, no current is applied while cathodic technique uses some current. Sacrificial anodes are hardly used for equipment under water compared to the cathodic protection. Corrosion inhibitor works chemically as slight layer continuously coating the metal. Incorrect inhibitor may be stabilise emulsion while trial must be done to select suitable inhibitor, this disadvantages using chemical methods.

The sulfate reducers bacteria (SRB), iron bacteria and slime formers constitute the major source of microbiological problems. Large numbers of iron bacteria can precipitate a sufficient quantity of ferric hydroxide, intensifying the plugging problems. Sulphide ion (natural or from bacterial action) oxidises ferrous ions to iron sulphides.

Bacteria are effectively shielded by scale or debris. Biocide is the best chemical to kill bacteria; however, it needs trail to choose suitable biocide. Biocide type must be replaced after time to time as bacteria will gain resistance against biocide. Corrosion can be enhanced by increasing the acidity, temperature, pressure and chloride content while erosion is intensified by increasing the fluid velocity.

Oxygen can only be effectively removed in closed system when the above reactions will continue until all oxygen is consumed. In the absence of oxygen, H₂S will attack low alloy steels. At the response of carbon dioxide and oxygen, corrosion is enhanced and even acid resistant alloys will be attacked. Hydrogen sulphide can only be effectively removed by H₂S scavenger. Corrosion coupons are the best tools for monitoring corrosion compared to another instrument. On strips coupons corrosion rate measured by weight while scale coupons corrosion rate measured depend on closed and open holes. Corrosion coupons reported given accuracy corrosion rate result in vessels and tanks, but it needed skills of the operator while intelligent Pigs became remarkable tools investigating corrosion in pipe line launcher. The scientists related to corrosion science are trying manufacturing alloys are more resistant then carbon steel and stainless steel. Furthermore, they are trying to fabricate transparent plant could be non-corrosive and easy to monitoring.

Acknowledgement

The authors would like to appreciate Mr Najeeb Tantosh and Mr Ahmed Alhamuni from Repsol oil



operation Tripoli, Mr Mustafa Igzera, Mr Samir Alghrari and Mr Abdalstar Farooj from Total oil company Tripoli, with special thanks to all crew at Aljarif offshore oil field from Dietsmann Company for their cooperation to complete this review.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

- [1] Vanaei, H. R., Eslami, A., & Egbewande, A. (2017). A review on pipeline corrosion, in-line inspection (ILI), and corrosion growth rate models. *International Journal of Pressure Vessels and Piping*, 149, 43-54.
- [2] Faes, W., Lecompte, S., Ahmed, Z. Y., Van Bael, J., Salenbien, R., Verbeken, K., & De Paepe, M. (2019). Corrosion and corrosion prevention in heat exchangers. *Corrosion Reviews*, 37(2), 131-155.
- [3] Shekari, E., Khan, F., & Ahmed, S. (2017). Economic risk analysis of pitting corrosion in process facilities. *International Journal of Pressure Vessels and Piping*, 157, 51-62.
- [4] Kroon, D. H., Bowman, E., & Jacobson, G. (2019). Corrosion Management Can Save Water and Wastewater Utilities Billions of Dollars Annually. *Journal: American Water Works Association*, 111(1).
- [5] Demirbas, A., Alidrisi, H., & Balubaid, M. A. (2015). API gravity, sulfur content, and desulfurization of crude oil. *Petroleum Science and Technology*, 33(1), 93-101.
- [6] Sk, M. H., & Abdullah, A. M. (2017). Corrosion of General Oil-field Grade Steel in CO₂ Environment—an Update in the Light of Current Understanding. *Int. J. Electrochem. Sci*, 12, 4277-4290.
- [7] Wang, Z., Liu, M., Lu, M., Zhang, L., Sun, J., Zhang, Z., & Tang, X. (2018). The effect of temperature on the hydrogen permeation of pipeline steel in wet hydrogen sulfide environments. *Int. J. Electrochem. Sci*, 13, 915-924.
- [8] Yan, W., Brown, B., & Nescic, S. (2018, July). Investigation of the Threshold Level of H₂S for Pitting of Mild Steel in CO₂ Aqueous Solutions. In *the NACE International Annual Conference and Exposition* (p. 11472).
- [9] Eslamimanesh, A., Anderko, A., & Lencka, M. M. (2019, May). Prediction of General and Localized Corrosion of Corrosion-Resistant Alloys in Aggressive Environments. In *CORROSION 2019*. NACE International.
- [10] Bhandari, J., Khan, F., Abbassi, R., Garaniya, V., & Ojeda, R. (2015). Modelling of pitting corrosion in marine and offshore steel structures—A technical review. *Journal of Loss Prevention in the Process Industries*, 37, 39-62.
- [11] Shrestha, B. R., Hu, Q., Baimpos, T., Kristiansen, K., Israelachvili, J. N., & Valtiner, M. (2015). Real-time monitoring of aluminum crevice corrosion and its inhibition by vanadates with multiple beam interferometry in a surface forces apparatus. *Journal of the Electrochemical Society*, 162(7), C327-C332.
- [12] Liu, Z. Y., Wang, X. Z., Du, C. W., Li, J. K., & Li, X. G. (2016). Effect of hydrogen-induced plasticity on the stress corrosion cracking of X70 pipeline steel in simulated soil environments. *Materials Science and Engineering: A*, 658, 348-354.
- [13] Xiao, K., Dong, C., Wei, D., Wu, J., & Li, X. (2016). Galvanic corrosion of magnesium alloy and aluminum alloy by kelvin probe. *Journal of Wuhan University of Technology-Mater. Sci. Ed.*, 31(1), 204-210.
- [14] Islam, M. A., & Farhat, Z. (2017). Erosion-corrosion mechanism and comparison of erosion-corrosion performance of API steels. *Wear*, 376, 533-541.
- [15] Li, J., Tang, M., Ye, Z., Chen, L., & Zhou, Y. (2017). Scale formation and control in oil and gas fields: A review. *Journal of Dispersion Science and Technology*, 38(5), 661-670.
- [16] Kakooei, S., Ismail, M. C., & Ariwahjoedi, B. (2012). Mechanisms of microbiologically influenced corrosion: a review. *World Appl. Sci. J*, 17(4), 524.
- [17] Liu, H., Fu, C., Gu, T., Zhang, G., Lv, Y., Wang, H., & Liu, H. (2015). Corrosion behavior of carbon steel in the presence of sulfate reducing bacteria and iron oxidizing bacteria cultured in oilfield produced water. *Corrosion Science*, 100, 484-495.
- [18] Loto, C. A. (2017). Microbiological corrosion: Mechanism, control and impact—A review. *The International Journal of Advanced Manufacturing Technology*, 92(9-12), 4241-4252.
- [19] Telegdi, J., Shaban, A., & Trif, L. (2017). Microbiologically influenced corrosion (MIC). In *Trends in oil and gas corrosion research and technologies* (pp. 191-214). Woodhead Publishing.
- [20] Popov, B. N. (2015). *Corrosion engineering: principles and solved problems*. Elsevier.
- [21] Rees, A., Gallagher, A., Comber, S., & Wright, L. (2017). Are zinc sacrificial anodes a major source of zinc to the estuarine environment: A case study of the Hamble, UK..
- [22] Baxter, R., & Britton, J. (2011). Offshore Cathodic Protection 101 what it is, and how it works. *WWW page*.
- [23] Ates, M. (2016). A review on conducting polymer coatings for corrosion protection. *Journal of adhesion science and Technology*, 30(14), 1510-1536.
- [24] Ashworth, V. (2010). 4.18. Principles of cathodic protection. *Shreir's Corros; Elsevier: New York, NY, USA*, 2747-2762.
- [25] Talbot, D. E., & Talbot, J. D. (2018). *Corrosion science and technology*. CRC press.; 2018.
- [26] Course, A. U. C. S. (2011). Advanced Course. *West Virginia University, Morgantown, West Virginia*.
- [27] Verma, C., Ebenso, E. E., & Quraishi, M. A. (2017). Ionic liquids as green and sustainable corrosion inhibitors for metals and alloys: an overview. *Journal of Molecular Liquids*, 233, 403-414.
- [28] Wysocka, J., Krakowiak, S., & Ryl, J. (2017). Evaluation of citric acid corrosion inhibition efficiency and passivation kinetics for aluminium



- alloys in alkaline media by means of dynamic impedance monitoring. *Electrochimica Acta*, 258, 1463-1475.
- [29] Bharatiya, U., Gal, P., Agrawal, A., Shah, M., & Sircar, A. (2019). Effect of Corrosion on Crude Oil and Natural Gas Pipeline with Emphasis on Prevention by Ecofriendly Corrosion Inhibitors: A Comprehensive Review. *Journal of Bio-and Tribo-Corrosion*, 5(2), 35.
- [30] Ansari, F. A., Verma, C., Siddiqui, Y. S., Ebenso, E. E., & Quraishi, M. A. (2018). Volatile corrosion inhibitors for ferrous and non-ferrous metals and alloys: A review. *Int. J. Corros. Scale Inhib*, 7(2), 126-150.
- [31] Jafar, S. A., & Fathi, M. I. (2015). Reducing of Corrosion Rate in Boiler Tubes by Using Oxygen Scavengers. *Iraqi Journal of Chemical and Petroleum Engineering*, 16(4), 21-29.
- [32] Mohammed, N. J., Mahmood, N. N., Kareem, A. K., & Alwan, H. A. (2016). Removing all Forms of Soluble Sulphides From Drilling Fluid. *Journal of Petroleum Research & Studies*, 115(11th), 32-44.
- [33] Martinez, A. D., Mukkamala, R., Otero, E. J. A., & Bailey, J. P. (2017). *U.S. Patent No. 9,638,018*. Washington, DC: U.S. Patent and Trademark Office.
- [34] Méndez Ramírez, J. R. (2011). *Diseño y Construcción del Reactor de Mezcla Completa para la Evaluación de Inhibidores de Corrosión en Crudo, Agua de Formación y Petróleo de Petroproducción-Lago Agrio* (Bachelor's thesis).
- [35] Abdel-Karim, R., Farag, M. A., Ahmed, H. A. A., & El-Raghy, S. (2016). Corrosion Resistance of API5L X52 Carbon Steel in Sulfide Polluted Environments. *Materials Sciences and Applications*, 7(01), 39.
- [36] Moslehifard, E., Moslehifard, M., Ghasemzadeh, S., & Nasirpour, F. (2019). Corrosion Behavior of a Nickel-base Dental Casting Alloy in Artificial Saliva Studied by Weight Loss and Polarization Techniques. *Journal of Dentistry of Tehran University of Medical Sciences*.
- [37] Shukla, P. K., DeWitt, J., Krissa, L. J., & Whited, T. (2019, May). Monitoring Effectiveness of Vapor Corrosion Inhibitors for Tank Bottom Corrosion Using Electrical Resistance Probes and Coupons. In *CORROSION 2019*. NACE International.
- [38] Espinoza, A. J., & Field, T. C. (2017). Comparison of Intrusive and Non-Intrusive Methods for Corrosion Monitoring of Fuel Processing Systems.
- [39] Wu, J. W., Bai, D., Baker, A. P., Li, Z. H., & Liu, X. B. (2015). Electrochemical techniques correlation study of on-line corrosion monitoring probes. *Materials and Corrosion*, 66(2), 143-151.
- [40] Ramella, C., Canavese, G., Corbellini, S., Pirola, M., Cocuzza, M., Scaltrito, L., ... & Tasso, A. (2015). A novel smart caliper foam pig for low-cost pipeline inspection—Part B: Field test and data processing. *Journal of Petroleum Science and Engineering*, 133, 771-775.
- [41] Ameh, E. S., Ikpeseni, S. C., & Lawal, L. S. (2017). A review of field corrosion control and monitoring techniques of the upstream oil and gas pipelines. *Nigerian Journal of Technological Development*, 14(2), 67-73.
- [42] Nazarov, A., Vucko, F., & Thierry, D. (2016). Scanning Kelvin Probe for detection of the hydrogen induced by atmospheric corrosion of ultra-high strength steel. *Electrochimica Acta*, 216, 130-139.
- [43] Yin, L., Jin, Y., Leygraf, C., & Pan, J. (2016). A FEM model for investigation of micro-galvanic corrosion of Al alloys and effects of deposition of corrosion products. *Electrochimica Acta*, 192, 310-318.
- [44] Samson, G., Deby, F., Garcia, J. L., & Perrin, J. L. (2018). Monitoring DIAMOND device for corrosion state evaluation of reinforced concrete structures. In *MATEC Web of Conferences* (Vol. 199, p. 04007). EDP Sciences.
- [45] Barshinger, J., Lynch, S., Solutions, P. E., & Nugent, M. (2017). Deployment of Cellular-Based Ultrasonic Corrosion Measurement System for Refining & Petro-Chemical Plant Applications. *American Petroleum Institute*.
- [46] Birketveit, Ø., & Stipanicev, M. (2016). Insight in Sidestream Corrosion Field-testing from the North Sea: Experiences, Benefits and Pitfalls. In *NACE International Corrosion Conference Proceedings* (p. 1). NACE International.
- [47] Sophian, A., Tian, G., & Fan, M. (2017). Pulsed eddy current non-destructive testing and evaluation: A review. *Chinese Journal of Mechanical Engineering*, 30(3), 500-514.
- [48] Zaki, A., Chai, H. K., Behnia, A., Aggelis, D. G., Tan, J. Y., & Ibrahim, Z. (2017). Monitoring fracture of steel corroded reinforced concrete members under flexure by acoustic emission technique. *Construction and building materials*, 136, 609-618.
- [49] Wang, H., Hu, C., Han, L., & Yang, M. (2015). Effects of microbial cycling of Fe (II)/Fe (III) and Fe/N on cast iron corrosion in simulated drinking water distribution systems. *Corrosion Science*, 100, 599-606.
- [50] Tang, X., Wang, S., Qian, L., Li, Y., Lin, Z., & Xu, D. (2015). Corrosion behavior of nickel base alloys, stainless steel and titanium alloy in supercritical water containing chloride, phosphate and oxygen. *Chemical Engineering Research and Design*, 100, 530-541.

How to cite this manuscript: Ihssin A. Abdalsamed, Ibrahim A. Amar, Fatima A. Altohami, Fatma A. Salih, Mazek S. Mazek, Masood A. Ali, Abubaker A. Sharif, Corrosion Strategy in Oil Field System. *Journal of Chemical Reviews*, 2020, 2(1), 28-39.

