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Investigation the Effect of Neutralizing Amine Corrosion Inhibitor on Corrosion Properties of Pipelines in Light Naphtha

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Abstract

Pipelines handle the majority of crude oil transportation since the oil and gas sector depends on them to move both crude and processed petroleum. Because of this, it is hard to stop the pipeline surfaces from being exposed to corrosion sources on a constant basis. Examples of these sources include pollutants that contain amounts of sulphur and chromate, which can lead to corrosion on the pipeline surfaces. NALCO® EC1005A (neutralising amine) was used as a corrosion inhibitor in three concentrations (0.03%, 0.04%, and 0.05%) on four different types of pipeline materials (Ductile iron, X60 Carbon steel, X80 Carbon steel, and A105 for pipe) and light naphtha solution that was collected from the Al-Diwaniyah Refinery in southern Iraq. All the samples were tested using the immersion method, and PH content analysis. It was determined how temperature (in this work used 45ºC and 55ºC) and light naphtha content affected each other. Because of this, the corrosion resistance of A 105 for pipe samples is largest, ductile iron has the lower value, and X80 steel and X60 steel is moderately valued.

Keywords: *Pipelines; Corrosion inhibitors; Light naphtha; Weight loss; Electrochemical techniques.*

1. Introduction

There is a natural tendency for materials, especially metals, to corrode when they react with their environment. Though the mechanisms by which this phenomenon occurs and the consequences that it causes may differ from one another, it is a phenomenon that affects both metallic and non-metallic materials. Corrosion of metallic materials, or rust, is the most common form of corrosion. Iron, in reaction with oxygen and moisture in the air, forms iron oxide (rust). Polymers, for instance, are affected by degradation, which is a type of corrosion. It is important to note that polymers can also degrade if exposed to UV radiation, heat, moisture, and chemicals, in addition to degradation caused by UV radiation, heat, moisture, and chemicals. Even though ceramics are chemically resistant, they may degrade in aggressive environments because of mechanical wear, thermal shock, and chemical attack, despite the fact that they are chemically resistant. The other type is concrete corrosion, as it is possible for steel reinforcement in reinforced concrete structures to corrode if it is exposed to corrosive chemicals, chloride ions, and carbonation over time. Due to this, the concrete may crack and crumble as a result [1-13]. As mentioned above, the corrosion of metal occurs as a result of chemical reactions between the metal and the environment around it, which causes the metal to slowly disintegrate over time as the environment around it changes [14-18]. As innovative gas fields develop, it is critical that we have the ability to move damp, unprocessed indigenous gases through pipelines and into other inaccessible areas in order to facilitate the advancement of these fields. The importance of understanding corrosion and the methods for preventing it, because of this, cannot be overstated both in terms of safety and economics. Due to the flow of oil inside pipelines, as well as the fact that the pipelines are buried underground, oil pipelines are exposed to internal corrosion as well as external corrosion due to the fact that they are buried underground [18-23].

The use of pipelines for oil and gas delivery is widely recognized as one of the most cost-effective and safest methods. It is still necessary to evaluate corrosion and develop the best mitigation techniques for carbon steel pipelines because they are prone to corrosion. As one of the primary means of transporting oil and gas, pipelines have many advantages, including their low operating costs, quick and convenient operations, and capacity to transport large amounts of material. There are a number of pipelines around the world that are unfortunately subject to both internal and exterior corrosion, which could have a significant negative impact both economically and environmentally in the long run [21-26]. Oil pipelines transfer liquid petroleum products from one location to another. There are four types of oil pipelines, (1) gathering pipelines, which transport oil over short distances with pipe diameters ranging from 10.2 to 30.2 cm, (2) feeder pipelines, which transport oil product from oil storage tanks or processing plants to gearbox pipelines and are typically larger than gathering lines. (3) transmission pipelines, in addition to the smaller diameter pipelines, these are also used for transporting oil and natural gas over longer distances; between provinces or countries, and (4) distribution lines can be up to 122 cm in diameter and deliver crude oil from production to export or consumption points. Corrosion in crude oil pipelines is one of the most serious issues related with the presence of water and contaminants such as chlorides, sulphates, CO_2, and H_2S dissolved gases. One method for preserving interior oil pipes from corrosion is to use corrosion inhibitors [27-28].

Corrosion inhibitors are one of the methods used to reduce corrosion in petroleum industry. To ensure optimum inhibition, the inhibitors must be supplied at concentrations greater than a particular minimum. There are numerous techniques for combating corrosion, such as cathodic protection, organic coatings, and the use of high-quality corrosion-resistant alloys, but film-forming inhibitors are still widely regarded as the unrivalled method of defence for mild steel in an acid environment. Film-forming inhibitors are used in industries to build a molecular layer directly on the steel surface and an aliphatic tail as a second layer of hydrocarbon to prevent water from touching the steel surface and causing corrosion [29-35]. Inhibitor molecules form a barrier between the corrosive water phase and metal surfaces (Fig. 1) [36].

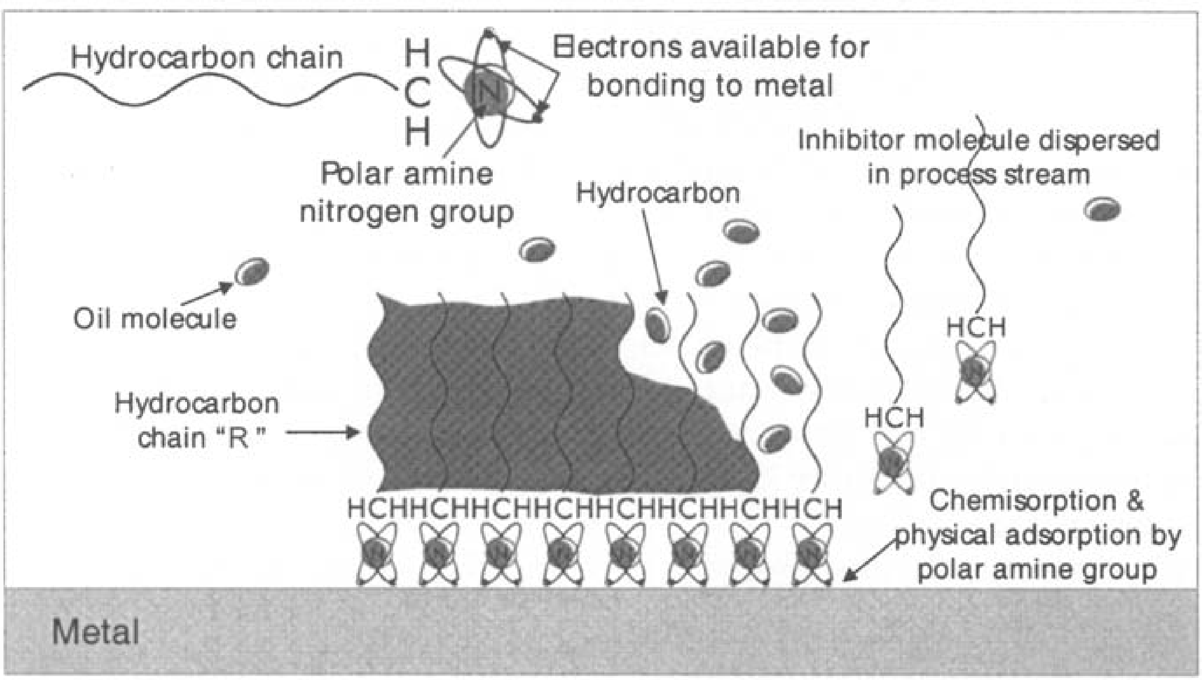

Fig. 1. Schematic illustrating the activity of an oilfield corrosion inhibitor (modified after [36]).

2. Experimental part

2.1. Materials used

All materials were taken from the Diwaniyah/Shinafiyah refiner. Four types of oil pipes in this study as shown in Fig. 2.

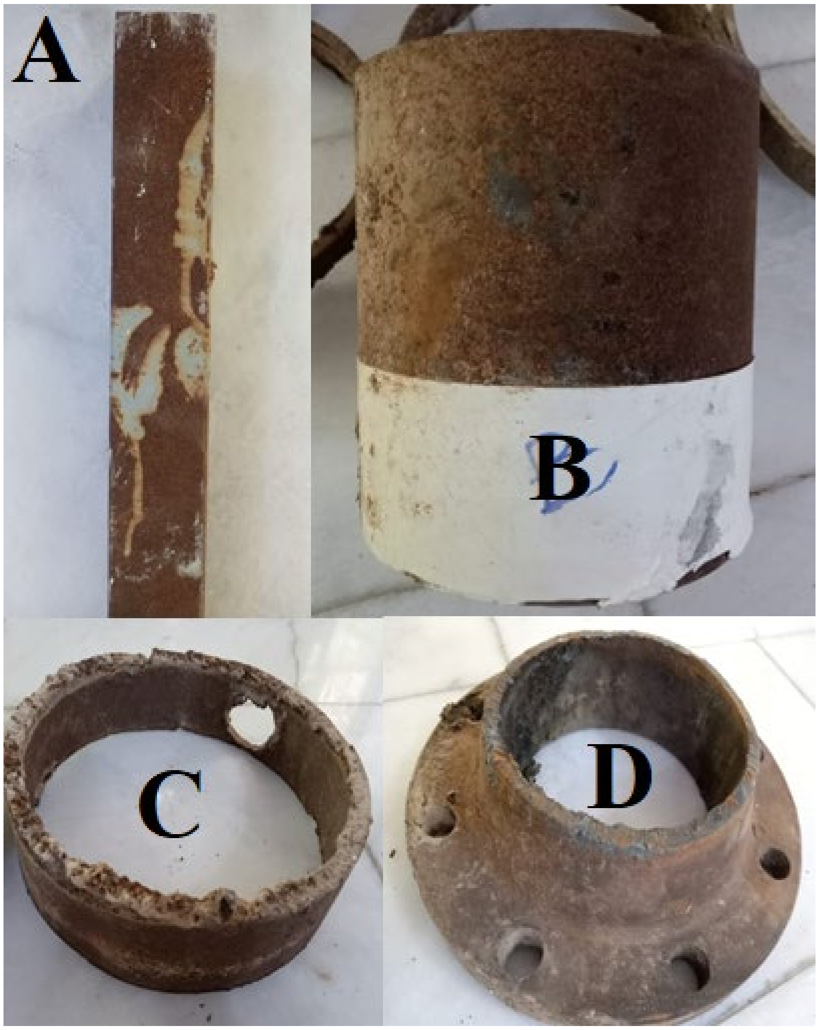

Figure 2. Oil pipelines samples. (A) Ductile Iron, (B) X60 Carbon Steel, (C) X80 Carbon Steel, (D) A 105 for pipe.

The pipes were cleaned and cut into equal-sized samples (5cm * 5cm). Light naphtha used in this work which is obtained after the crude oil enters the refining unit. Finally utilized NALCO® EC1005A as a corrosion inhibitor for this study.

2.2. Samples preparation

The symbols for pipelines samples and inhibitors used in this study was shown in Table 1.

Table 1 The samples prepared for the experiments.

Symbol of sample	% of adding neutralizing amine corrosion inhibitor
A0, B0, C0, D0 Reference	Without inhibitor
A1, B1, C1, D1	0.03%
A2, B2, C2, D2	0.04%
A3, B3, C3, D3	0.05%

2.3. The experimental procedure

The concentration of inhibitor added per litter for testing was approximately 0.03%, 0.04%, and 0.05% in the light naphtha solution.

2.3.1. Immersion test method

Two water baths used for the immersion test and a sensitive four-digit weighing scale used to find the weight variation for every sample before and after the immersion test are shown in Fig. 3. The initial weight of each sample was taken, the samples are suspended inside a glass cup using nylon threads and wooden sticks, the cups are filled with the immersion material produced (light naphtha) which it prepared with specified concentrations for every sample. In this experiment, 80 samples were used between the water baths, with the first basin at 45 degrees and the second basin at 50 degrees. Technically, 20 samples were used for each type of pipeline sample used. After being submerged in light naphtha material for 12 weeks at the specified temperatures, samples are obtained for weighting every 14 days. They are then cleaned with kerosene to remove any remaining light naphtha residue, and they are submerged in the cleaning solution for one minute to remove any oxidation. The cleaning solution contains 200 g of zinc powder and 50 g of sodium hydroxide in one liter of pure water. Then the samples are allowed to air dry at room temperature before the weight is determined. To determine the mass loss caused by corrosion, the weight of the cleaned coupon is subtracted from the initial weight.

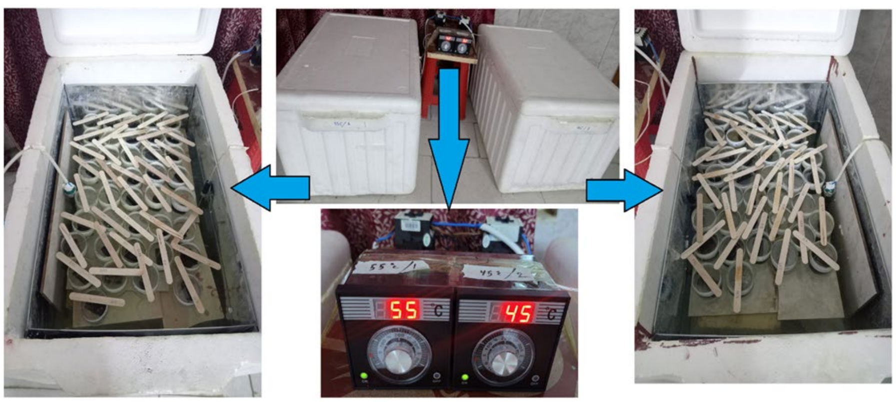

Figure 3. Water baths and samples.

2.3.2. Measurement of pH value

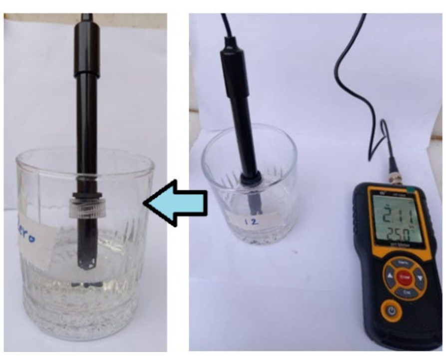

Figure 4. Digital pH meter during the test.

A professional digital device was utilised to measure the pH value of each sample's solution every two weeks during the 12-week immersion period. The initial value was also measured prior to the immersion process. Fig.4 details the procedure.

3. Results and discussions

3.1. Chemical composition analysis of pipelines samples

The chemical composition of samples is shown in Table 2.

Table 2. Chemical composition of steel.

Element	Weight of element [%]			
	Ductile iron (A)	X60 Carbon steel (B)	X80 Carbon steel (C)	A 105 for pipe (D)
C	3.61	0.21	0.063	0.35
Si	2.83	0.38	0.28	0.1
Mn	0.38	1.35	1.83	0.7
P	0.025	0.015	0.011	0.035
S	0.015	0.015	0.0006	0.04
Ni	0.05	0.02	0.03	0.4
Cu	0.56	-	-	0.4
Cr	0.04	0.025	0.03	0.3
Mg	0.06	-	-	-
Mo	-	0.013	0.22	0.12
Nb	-	0.08	0.061	0.02
Fe (calcu-lated)	92.43	97.892	97.474	97.535

3.2. Immersion test

Corrosion rate (mm/y) vs temperature from the immersion corrosion test of the four pipeline materials—ductile irons, X60, X80 carbon steel, and A 105 for pipe—in the ten light naphtha solutions over the course of a 12-week period are displayed in Figs. 5 to 8. The test temperature range for the corrosion test is 45°C to 55°C.

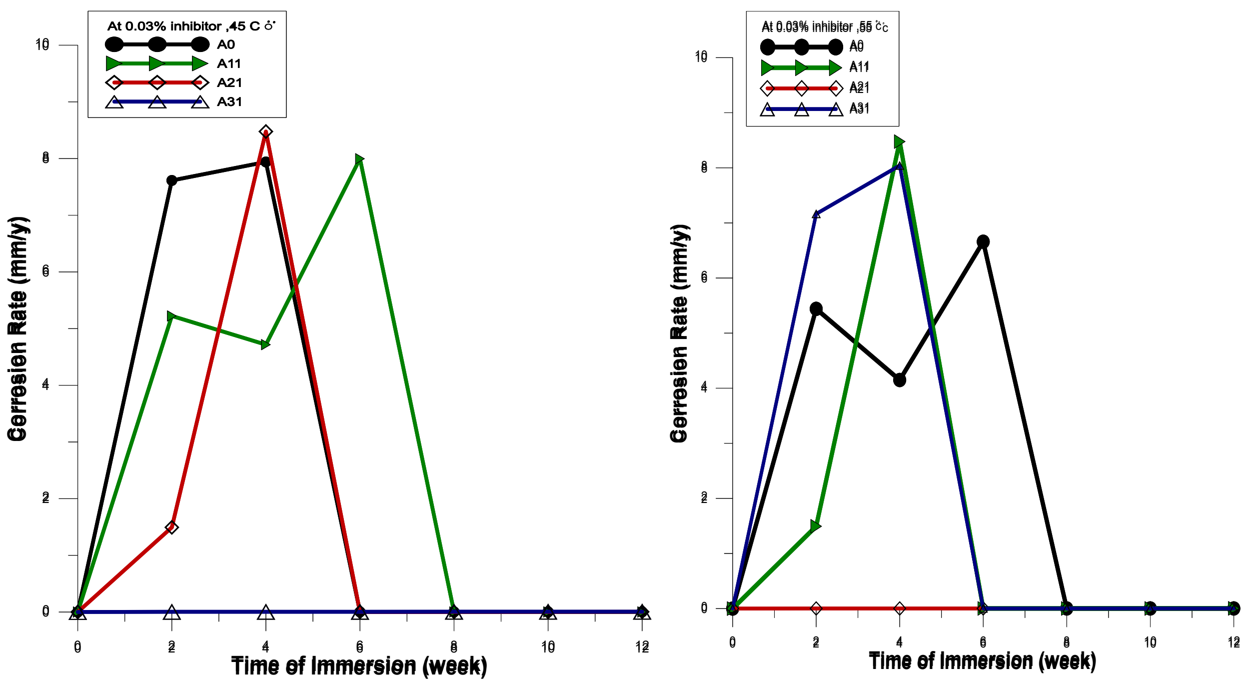

Figure 5 Corrosion rate vs. temperature (45^{o}C and 55^{o}C) of the sample A in light naphtha during 12 weeks of immersion..

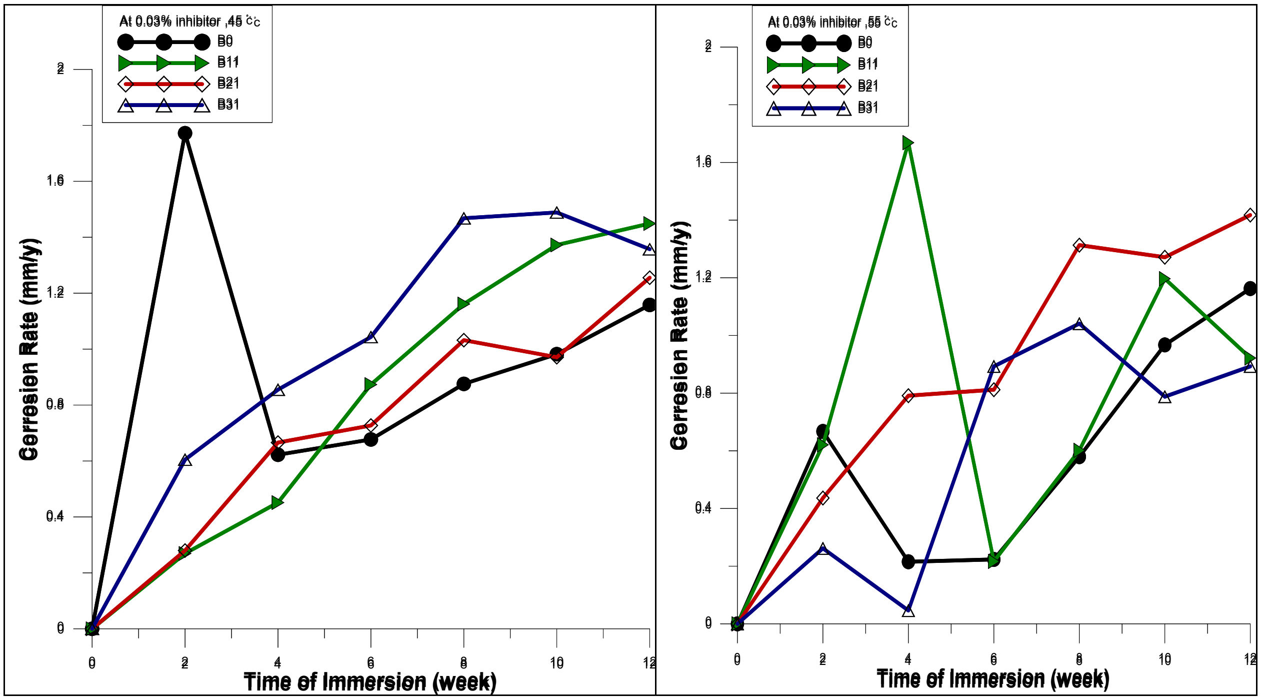

Figure 6. Corrosion rate vs. temperature (45ºC and 55ºC) of the sample B in light naphtha during 12 weeks of immersion.

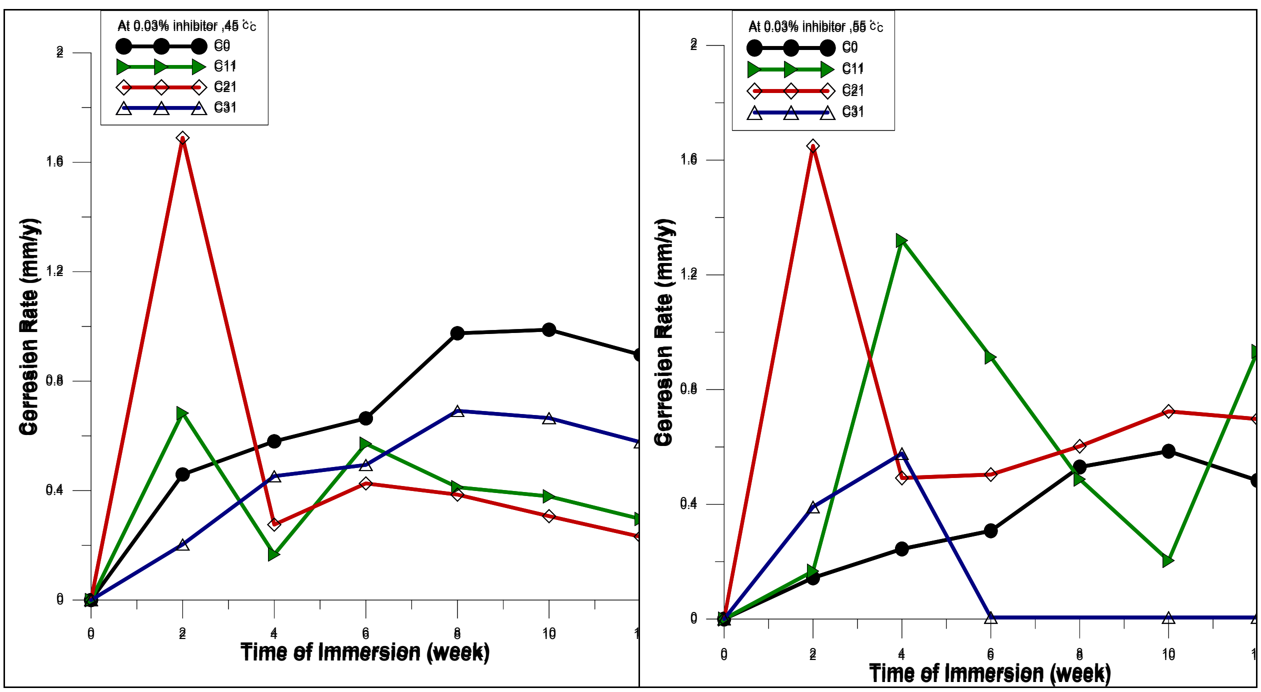

Figure 7 Corrosion rate vs. temperature (45ºC and 55oC) of the sample C in light naphtha during 12 weeks of immersion.

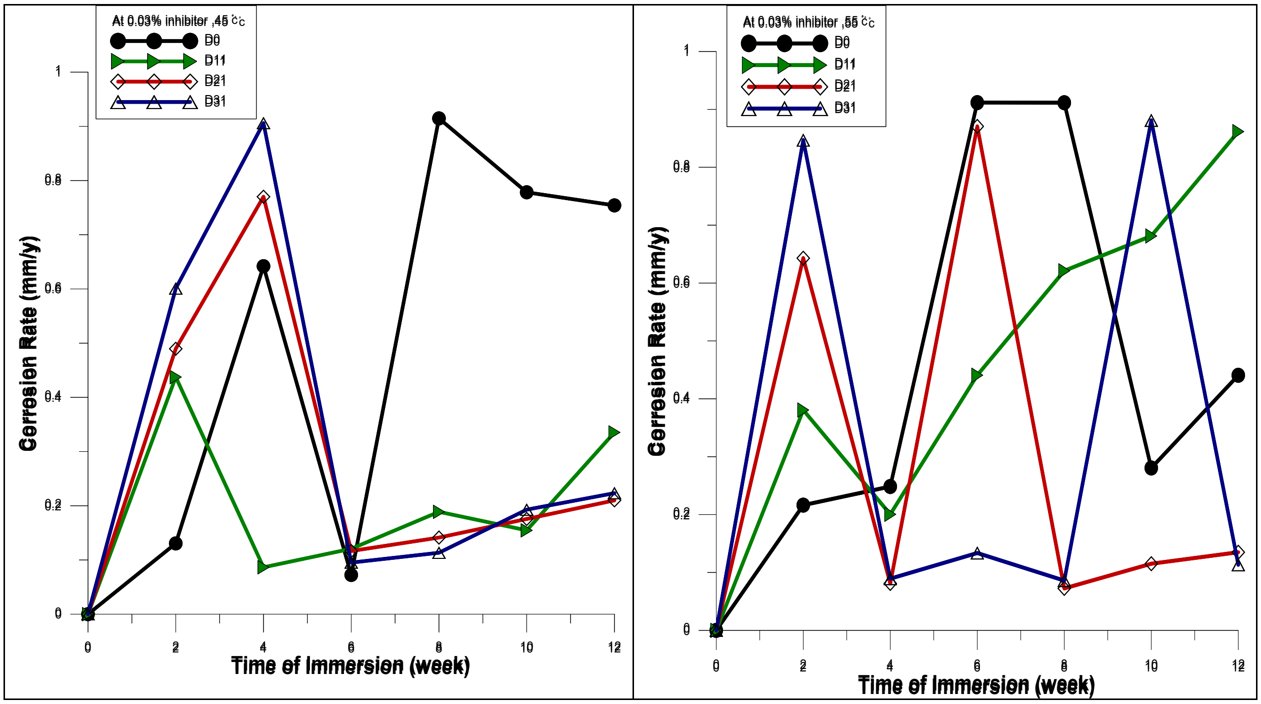

Figure 8 Corrosion rate vs. temperature (45°C and 55°C) of the sample D in light naphtha during 12 weeks of immersion.

As seen in Figs. 5 to 8, there is a slight rise in weight loss difference at low temperatures (less than 45°C), but after 55°C, there is a significant increase in weight loss difference. Contributing to the rapid difference in weight loss was the fact that as the temperature of the light naphtha increased, the light naphtha started to degrade and release more ions. These ions moved more easily through the light naphtha and increased oxidation and reduction processes.

Changes in temperature can have an impact on the impurities found in light naphtha, which include materials, dissolved gases, salts, and more. The reaction of CO_2, H_2S, and other components in light naphtha with the metal surface causes an increase in the production of corrosion products such as $FeCO_3$, FeS, Fe_3C, and other films as the temperature rises. Pits and cracks in the metal surface may be caused by the chloride ion's easy entry through the oxide coating.

The solubility of oxygen gas in light naphtha solution is affected by temperature, on the other hand. When the temperature rises, oxygen becomes less soluble yet diffuses more quickly. The oxygen molecules travel more quickly at higher temperatures, and the light naphtha's surface tension decreases correspondingly. The corrosion process tends to accelerate as a result of the oxygen molecules moving more quickly, which increases the oxygen diffusion rate.

3.3. Evaluation of pH value

After the samples were immersed in a corrosion test for a duration of 12 weeks, the PH value against temperature obtained from the light naphtha solution is displayed in Figs. 9 to 12.

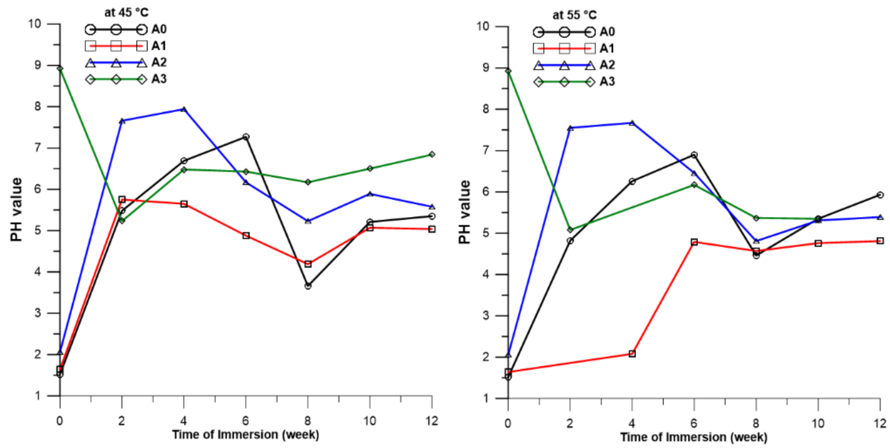

Figure 9. pH value vs. temperature (45°C and 55°C) of the sample A in light naphtha during 12 weeks of immersion.

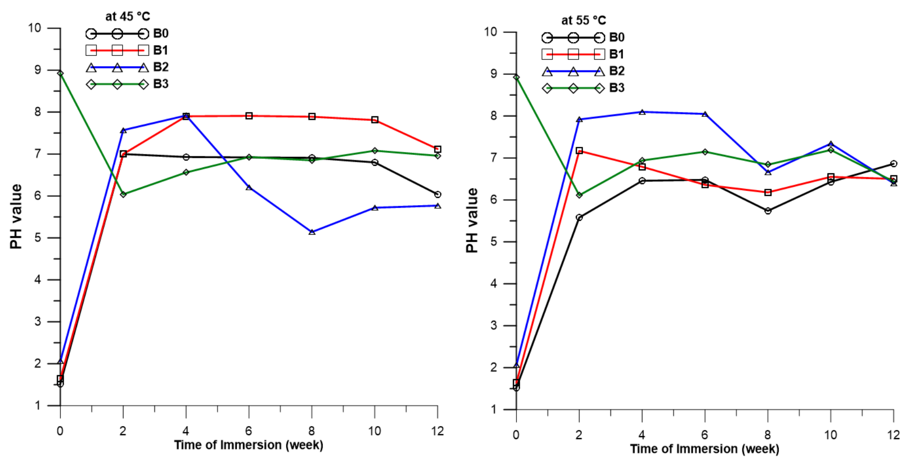

Figure 10. pH value vs. temperature (45°C and 55°C) of the sample B in light naphtha during 12 weeks of immersion.

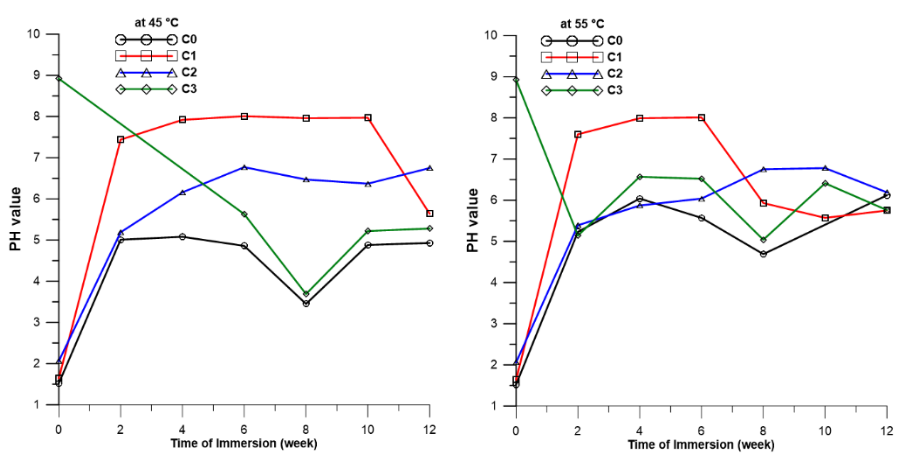

Figure 11. pH value vs. temperature (45°C and 55°C) of the sample C in light naphtha during 12 weeks of immersion.

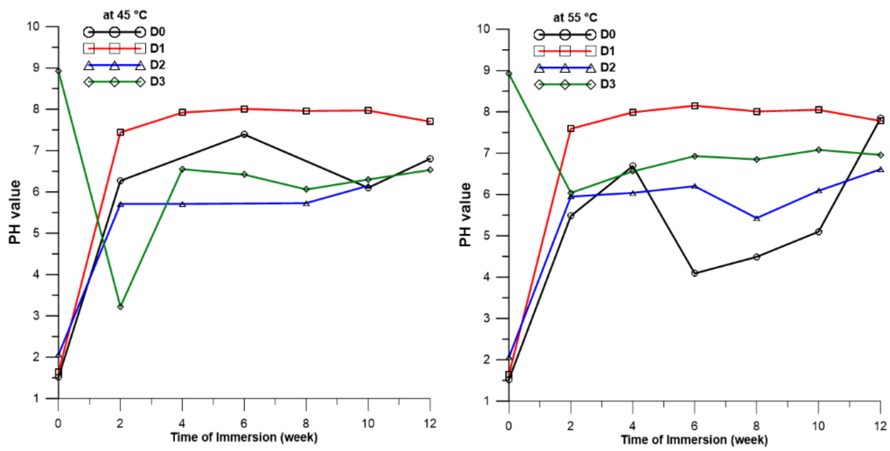

Figure 12. pH value vs. temperature (45℃ and 55℃) of the sample D in light naphtha during 12 weeks of immersion.

The ductile iron has the lowest PH value, as shown by Figs. 9 to 12; the pipe A 105 has the lowest value, and the samples of X60 and X80 carbon steel have moderate values. This is ascribed to a number of factors that affect corrosion resistance values, particularly the percentage of carbon contained. In comparison to A 105 for pipe, X80, and X60 carbon steel, which have substantially lower carbon contents and all of the carbon is present in a combined form, the ductile iron material has higher carbon percent values, 3% min., as shown in Table 2. Elevated carbon content causes ductile iron to become more brittle or softer in comparison to other alloys. This means that, in comparison to the two other alloys, ductile iron is more susceptible to the corrosion component in light naphtha.

The capacity of trace elements to react with metal surfaces or other components in light naphtha is affected by temperature. A range of sulfur-metal salts, including Cu_2S, can be formed by the interaction of these trace elements with sulphur compounds. As shown in Table 2, the percentage of items in each sample test is minimal. At low temperatures, these components have little effect on corrosion issues, but at higher temperatures, they cause serious issues.

4. Conclusion

After testing the pipelines samples with or without of corrosion inhibitors we can conclude the following points:

1. The corrosion resistance of the pipe A105 is higher than that of ductile iron, and the values of carbon steel X60 and X80 are moderate.
2. The effectiveness of the corrosion inhibitor is influenced by temperature, sample type, and composition.
3. A drop in inhibitor concentration accompanied by an increase in the quantity of oxides (iron oxide and chlorides) produced as a result of corrosion.

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Declarations

-Ethical approval: The authors certify that the ethics approval and consent to participate.
-The authors certify that they NO Funding received for this work.
-Data and code availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.
- Conflict of Interest: not applicable.

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