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# Study of the corrosion inhibition of carbon steel in acidic HCl medium (0.5M) by Aspirin

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**Abstract**:

This study examines the corrosion behavior of mild carbon steel in a 0.5 M hydrochloric acid (HCl) solution and evaluates the inhibitory effectiveness of aspirin (acetylsalicylic acid) as an environmentally friendly corrosion inhibitor. Gravimetric measurements were performed to evaluate the effects of immersion time, acid concentration, and temperature, in the absence and presence of aspirin at a fixed concentration of $10^{-3}$ M. The results show that the corrosion rate significantly increases with temperature, HCl concentration, and immersion time in the non-inhibited solution. However, the addition of aspirin reduced the corrosion rate under all tested conditions, achieved an inhibition efficiency between 8.8% and 16.5%, with the most significant value observed at 50°C after 4 hours. The inhibitory effect is attributed to the adsorption of aspirin molecules on the steel surface, forming a protective barrier against corrosive attack. This work shows the potential of aspirin as a good, cheap, and environmentally friendly inhibitor for mild steel corrosion in acidic environments.

**Keywords:** Mild steel; Corrosion; Hydrochloric acid; Aspirin; Gravimetric method; Green inhibitor.

## I. Introduction

The use of inhibitors is one of the most effective approaches to protecting metals from acid-induced corrosion. In Morocco, hydrochloric acid is produced in large quantities and widely used in various industries, such as the food sector, acid pickling, cleaning, and descaling processes(Benabdellah et al., 2007)(Aouniti et al., 2015). The application of corrosion inhibitors is one of the most effective and practical methods for protecting materials, particularly in acidic environments. A wide variety of inhibitors have been tested and implemented in industrial settings. In our laboratory, numerous studies have been conducted and published on the use of various compounds as corrosion inhibitors in acidic environments( Elmsellem et al, 2011)(Merimi et al., 2022)(Essassi & Aziate, 2017). Whenever exposed to environmental conditions, metals and their alloys inevitably suffer chemical and/or electrochemical reactions, leading to significant corrosion(Zamindar et al., 2024)(Sikine et al., 2017)(Karima et al., 2017)(Sghyar et al., 2025). Carbon steel is an alloy composed primarily of iron and carbon, with a carbon content of up to 2.1% by weight. It may also contain small amounts of other elements such as manganese, silica, and copper, typically at concentrations below 1.7%. Depending on its carbon content, carbon steel is classified into three types: low-carbon steel (< 0.25% carbon), medium-carbon steel (0.25 to 0.60% carbon), and high-carbon steel (0.60 to 1.25% carbon). Each category has distinct mechanical properties, which determine its suitable applications for specific industrial uses(Duy et al., 2024)(Hsissou et al., 2022). Acetylsalicylic acid is a white crystalline compound in the nonsteroidal anti-inflammatory drug class, known for its analgesic, antipyretic, and anti-inflammatory properties. It is soluble in alcoholic solvents and has a planar molecular structure with electron-rich oxygen atoms and delocalized electrons, enabling it to act as an effective corrosion inhibitor for mild steel in acidic environments(Merimi et al., 2023)(Prasanna et al., 2018)(Ikeuba et al., 2022). In this study, the effectiveness of acetylsalicylic acid in inhibiting the corrosion of mild steel in a 0.5 M hydrochloric acid solution was evaluated using gravimetric techniques. The remarkable solubility and chemical reactivity of acetylsalicylic acid can be attributed to the presence of a phenyl group and electronegative heteroatoms, particularly oxygen. These functional groups enhance the molecule's ability to adsorb to the metal surface, promoting the formation of a protective layer and improving its performance as a corrosion inhibitor.

## II. Materials and Methods

Mild steel test samples measuring 1 × 1 × 0.65 $cm^3$ were prepared for the weight loss tests. The chemical composition of the test samples was as follows: 0.09% P, 0.01% Al, 0.38% Si, 0.05% Mn, 0.21% C, 0.05% S, with the remainder being iron (Fe). Before each measurement, the surface of the samples was mechanically polished using a series of abrasive papers with increasing grit sizes (180, 400, 800, 1000, 1200, and 2000) to obtain a uniform and smooth finish. After polishing, the samples were thoroughly rinsed with distilled water and dried before being immersed in the test solutions.

### a. Gravimetric measurements

The principle of this method is based on measuring the mass loss (Δm) of a metal sample with exposed surface area (S) after immersion in an acidic solution for a specific period of time. The tests are carried out under varying concentrations and temperatures, depending on each experimental condition, both in the presence and absence of the inhibitor(Prasanna et al., 2018). The corrosion rate of the steel is determined by the gravimetric method after a defined immersion period in acidic media, with and without the tested inhibitor, at different concentrations.

$$W = \frac{\Delta m}{S.t}$$

W can be expressed in $mg \cdot cm^{-2} \cdot h^{-1}$.

The inhibition efficiency (E %) of these compounds is calculated using the following equation:

$$\%E = \left(1 - \frac{W(inh)}{W(corr)}\right) \times 100$$

❖ Where $W_{inh}$ and $W_{corr}$ represent the corrosion rate of steel in an acidic environment without and with inhibitor, respectively.

## III. Results and Discussion

### A. Study of corrosion of mild carbon steel in the absence of inhibitor:

#### a. Influence of immersion time on the corrosion rate of mild carbon steel in HCl (0.5M) in the absence of inhibitor:

The effect of immersion time was examined using the gravimetric method in a solution of HCl acid (0.5M) in the absence of the inhibitor at different temperatures (25, 30, 35, 40, 45, 50°C) over immersion time intervals of 1 to 4 hours.

**Table 1 :** Influence of immersion time and temperature on the corrosion rate of carbon steel in HCl (0.5M) in the absence of inhibitor.

| T(°C) | t(h) | $\Delta m_{moy}$(mg) | $W_{corr}$($mg/h.cm^2$) |
|---|---|---|---|
| 25 | 1 | 0,4 | 0,0791 |
| | 2 | 1,3 | 0,0881 |
| | 3 | 1,5 | 0,0952 |
| | 4 | 3,4 | 0,1021 |
| 30 | 1 | 0,4 | 0,0833 |
| | 2 | 1,7 | 0,1057 |
| | 3 | 1,7 | 0,1110 |
| | 4 | 3,8 | 0,1141 |
| 35 | 1 | 0,5 | 0,0998 |

| | | | |
|---|---|---|---|
| | 2 | 1,8 | 0,1081 |
| | 3 | 1,7 | 0,1135 |
| | 4 | 3,8 | 0,1288 |
| 40 | 1 | 0,9 | 0,1119 |
| | 2 | 1,1 | 0,1225 |
| | 3 | 3,2 | 0,1387 |
| | 4 | 5,3 | 0,1648 |
| 45 | 1 | 0,6 | 0,1210 |
| | 2 | 2 | 0,1356 |
| | 3 | 4,3 | 0,1865 |
| | 4 | 5,5 | 0,2237 |
| 50 | 1 | 0,6 | 0,1253 |
| | 2 | 3,3 | 0,1983 |
| | 3 | 3,7 | 0,2641 |
| | 4 | 8,3 | 0,2833 |

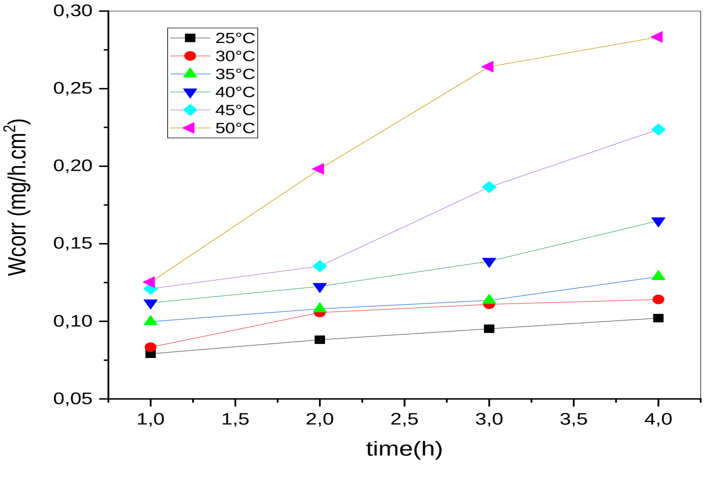


**Figure 1:** The corrosion rate curves of HCl acid (0.5M) in the absence of inhibitor as a function of immersion times of 1, 2, 3, and 4 hours for temperatures ranging from 25°C to 50°C.

Table 1 shows the effect of immersion time on the corrosion rates of mild carbon steel in HCl (0.5M) alone. It can be seen that there is an increase in mass loss with immersion time and that the corrosion rate increases significantly at the same time when the temperature rises from 25°C to 50°C. The corrosion rate reaches a maximum value (0.2833 g/cm$^2$.h) at 50 °C for an immersion time of 4 hours. The effect of immersion time on the corrosion rate is shown in Figure 1.

### b. Influence of HCl concentration on corrosion rate:

To better understand the aggressiveness of hydrochloric acid on mild steel, a series of experiments were conducted to evaluate the effect of HCl concentration on the corrosion rate in the absence of any inhibitor. The tests were carried out at a constant temperature of 30°C and an immersion time of 1 hour, while varying the molar concentration of HCl from 0.5 M to 1 M.

**Table 2 :** The effect of the concentration of an HCl solution in the absence of the inhibitor with an immersion time of 1 hour and at a temperature of 30°C.

| Concentration(M) | $\Delta m_{moy}$(mg) | $w_{corr}$moy (mg/h.cm$^2$) |
|---|---|---|
| 0 ,5 | 0,4 | 0,08 |
| 0 ,6 | 1,16 | 0,16 |
| 0,7 | 1,5 | 0,18 |
| 0,8 | 1,96 | 0,28 |
| 0,9 | 2,5 | 0,4 |
| 1 | 5,76 | 0,82 |

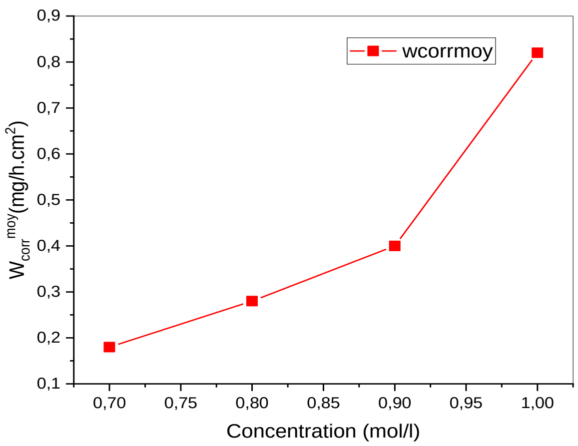


**Figure 2 :** The corrosion rate in (mg/h.cm$^2$) as a function of concentration in mol/l after immersion time t=1h and temperature T=30°C.

From the results in Table 2, we can see that when the concentration increases, the corrosion rate of HCl acid in the absence of the inhibitor also increases, at a temperature of 30°C and an immersion time of 1 hour. We also observe a clear increase in the corrosion rate starting at an HCl concentration of 0.9 mol/l, where the corrosion rate doubles (from 0.4 mg/h.cm$^2$ to 0.8 mg/h.cm$^2$). We believe this result is important because it clearly shows the HCl concentration range that has a significant corrosive effect.

#### c. Influence of temperature on the corrosion rate of mild carbon steel in HCl (0.5M) in the absence of inhibitor:

The effect of temperature was examined using the gravimetric method in a solution of HCl acid (0.5M) in the absence of the inhibitor at different temperatures (25, 30, 35, 40, 45, 50°C) over immersion time intervals of 1 to 4 hours. The results are presented in Table 1.

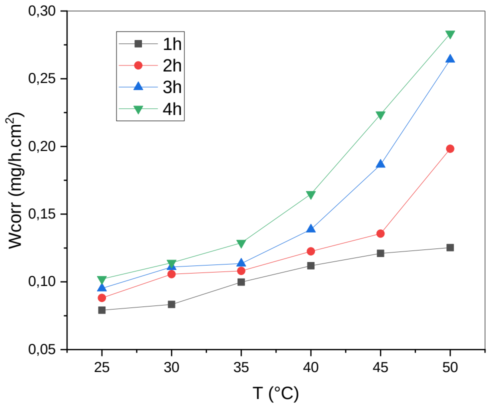


**Figure 3:** The corrosion rate curves of HCl acid (0.5M) in the absence of the inhibitor as a function of temperature from 25°C to 50°C for immersion times of 1, 2, 3, and 4 hours.

Table 1 shows the effect of temperature on the corrosion rates of mild carbon steel in HCl (0.5M) alone. It can be seen that there is an increase in mass loss with immersion time and that the corrosion rate increases significantly at the same time when the temperature rises from 25°C to 50°C. The corrosion rate reaches a maximum value (0.2833 g/cm$^{2}$·h) at 50 °C for an immersion time of 4 hours. The effect of immersion time on the corrosion rate is shown in Figure 3.

### B. Study of the corrosion of mild carbon steel in the presence of aspirin:

#### a. Influence of immersion time on the corrosion rate of mild carbon steel in HCl (0.5M) in the presence of aspirin at ($10^{-3}$M):

The effect of immersion time was examined using the gravimetric method in a solution of HCl acid (0.5M) in the presence of aspirin ($10^{-3}$M) at different temperatures (25, 30, 35, 40, 45, 50°C) in immersion time intervals ranging from 1 to 4 hours.

**Table 3:** Influence of immersion time and temperature on the corrosion rate of mild carbon steel in HCl (0.5M) in the presence of aspirin inhibitor ($10^{-3}$M).

| T(°C) | t(h) | $\Delta m_{moy}$(mg) | $W_{inhib}$(mg/h.cm$^2$) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 25 | 1 | 0,34 | 0,0721 |
| | 2 | 1,18 | 0,0799 |
| | 3 | 1,15 | 0,0858 |
| | 4 | 3 | 0,0902 |
| 30 | 1 | 0,33 | 0,0752 |
| | 2 | 1,53 | 0,0949 |
| | 3 | 1,41 | 0,0990 |
| | 4 | 3,32 | 0,0999 |
| 35 | 1 | 0,42 | 0,0895 |
| | 2 | 1,6 | 0,0961 |
| | 3 | 1,53 | 0,0993 |
| | 4 | 3,31 | 0,1123 |
| 40 | 1 | 0,8 | 0,0999 |
| | 2 | 0,96 | 0,1079 |
| | 3 | 2,78 | 0,1205 |
| | 4 | 4,58 | 0,1425 |
| 45 | 1 | 0,55 | 0,1075 |
| | 2 | 1,72 | 0,1185 |
| | 3 | 3,72 | 0,1615 |
| | 4 | 5,59 | 0,1897 |
| 50 | 1 | 0,49 | 0,1094 |
| | 2 | 2,83 | 0,1703 |
| | 3 | 3,18 | 0,2226 |
| | 4 | 6,97 | 0,2365 |

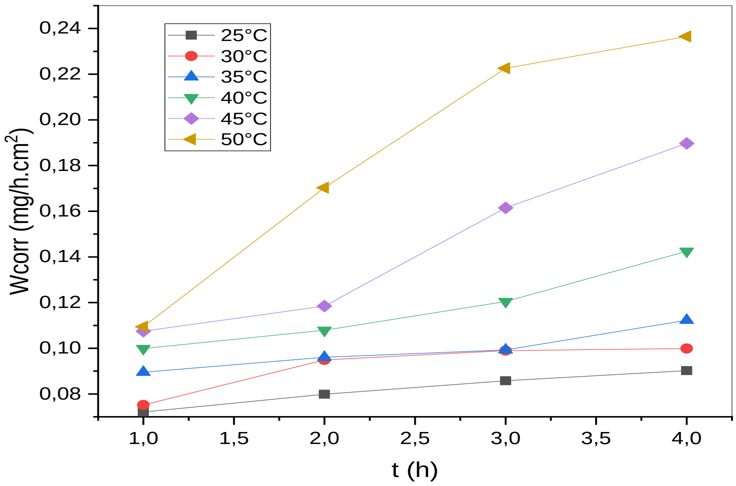


**Figure 4:** The corrosion rate curves of HCl acid (0.5M) in the presence of aspirin at $10^{-3}$M as a function of immersion times of 1, 2, 3, and 4 hours for temperatures ranging from 25°C to 50°C.

Table 3 shows the effect of immersion time on the corrosion rates of mild carbon steel in HCl (0.5M) in the presence of aspirin at $10^{-3}$M. It can be seen that there is an increase in mass loss with immersion time and that the corrosion rate increases significantly at the same time when the temperature rises from 25°C to 50°C. The corrosion rate reaches a maximum value (0.2365 $mg/cm^2.h$) at 50°C for an immersion time of 4 hours. The effect of immersion time on the corrosion rate is shown in Figure 4.

### b. Influence of HCl concentration in the presence of aspirin:

In order to better understand the aggressiveness of hydrochloric acid on mild steel, a series of experiments was performed to evaluate the effect of HCl concentration on the corrosion rate in the absence of any inhibitors. The tests were performed at a constant temperature of 30°C and for an immersion time of one hour, varying the molar concentration of HCl from 0.5 M to 1 M.

**Table 4:** The effect of the concentration of an HCl solution in the presence of aspirin with an immersion time of 1 hour and at a temperature of 30°C.

| C HCl(M) | Δm(mg) | Wcorr($mg/h.cm^2$) |
|---|---|---|
| 0,5 | 1,7 | 0,2043 |
| 0,8 | 1,9 | 0,2283 |
| 1 | 1,3 | 0,2462 |

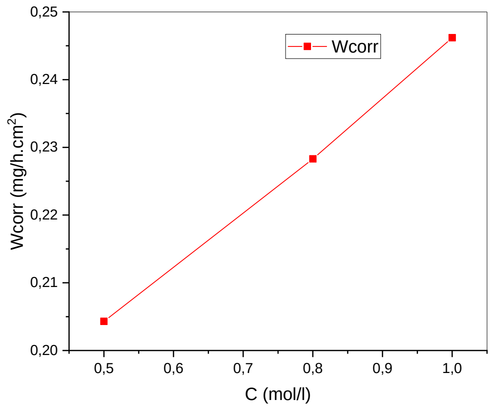


**Figure 5 :** The corrosion rate of HCl acid in the presence of aspirin as a function of concentration.

From the results in Table 4, we can see that when the concentration increases, the corrosion rate of HCl acid in the presence of aspirin also increases, at a temperature of 30°C and an immersion time of 1 hour.

### c. Influence of temperature on the corrosion rate of mild carbon steel in HCl (0.5M) in the presence of aspirin at ($10^{-3}$M):

The effect of temperature was examined using the gravimetric method in a solution of HCl acid (0.5M) in the presence of aspirin ($10^{-3}$M) at different temperatures (25, 30, 35, 40, 45, 50°C) for immersion times ranging from 1 to 4 hours. The results are presented in Table 3.

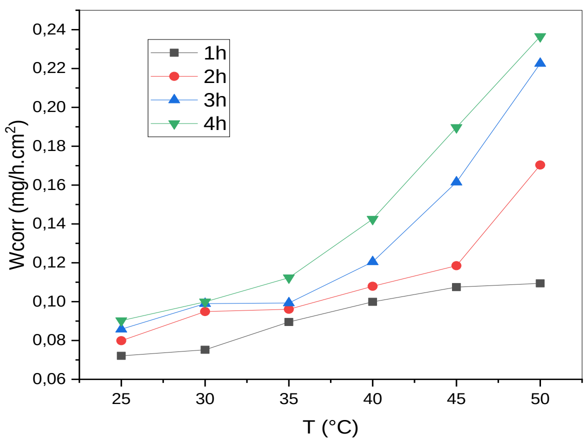


**Figure 6:** The corrosion rate curves of HCl acid (0.5M) in the presence of aspirin at $10^{-3}$M as a function of temperature (25°C to 50°C) for immersion times ranging from 1 to 4 hours.

Table 3 shows the effect of temperature on the corrosion rates of mild carbon steel in HCl (0.5M) in the presence of aspirin at $10^{-3}$M. It can be seen that there is an increase in mass loss with immersion time and that the corrosion rate increases significantly at the same time when the temperature rises from 25°C to 50°C. The corrosion rate reaches a maximum value (0.2365 $mg/cm^2.h$) at 50°C for an immersion time of 4 hours. The effect of immersion time on the corrosion rate is shown in Figure 6.

### d. Influence of time and temperature on the corrosion efficiency of mild carbon steel in HCl (0.5M) in the presence of aspirin at ($10^{-3}$M):

The effect of time and temperature was examined using the gravimetric method in a solution of HCl acid (0.5M) in the presence of aspirin ($10^{-3}$M) at different temperatures of 25, 30, 35, 40, 45, 50°C for immersion times ranging from 1 to 4 hours.

**Table 5 :** Influence of immersion time and temperature on the effectiveness of mild carbon steel in HCl (0.5M) in the presence of aspirin ($10^{-3}$M).

| T(°C) | t(h) | $W_{corr}$(mg/h.cm$^2$) | $W_{inhib}$(mg/h.cm$^2$) | E % |
|---|---|---|---|---|
| 25 | 1 | 0,0791 | 0,0721 | 8,8 |
| | 2 | 0,0881 | 0,0799 | 9,3 |
| | 3 | 0,0952 | 0,0858 | 9,9 |
| | 4 | 0,1021 | 0,0902 | 11,6 |
| 30 | 1 | 0,0833 | 0,0752 | 9,7 |
| | 2 | 0,1057 | 0,0949 | 10,2 |
| | 3 | 0,111 | 0,099 | 10,8 |
| | 4 | 0,1141 | 0,0999 | 12,4 |
| 35 | 1 | 0,0998 | 0,0895 | 10,3 |
| | 2 | 0,1081 | 0,0961 | 11,1 |
| | 3 | 0,1135 | 0,0993 | 12,5 |
| | 4 | 0,1288 | 0,1123 | 12,8 |
| 40 | 1 | 0,1119 | 0,0999 | 10,7 |
| | 2 | 0,1225 | 0,1079 | 11,9 |
| | 3 | 0,1387 | 0,1205 | 13,1 |
| | 4 | 0,1648 | 0,1425 | 13,5 |
| 45 | 1 | 0,121 | 0,1075 | 11,1 |
| | 2 | 0,1356 | 0,1185 | 12,6 |
| | 3 | 0,1865 | 0,1615 | 13,4 |
| | 4 | 0,2237 | 0,1897 | 15,2 |
| 50 | 1 | 0,1253 | 0,1094 | 12,7 |

| | | | | |
|---|---|---|---|---|
| | 2 | 0,1983 | 0,1703 | 14,1 |
| | 3 | 0,2641 | 0,2226 | 15,7 |
| | 4 | 0,2833 | 0,2365 | 16,5 |

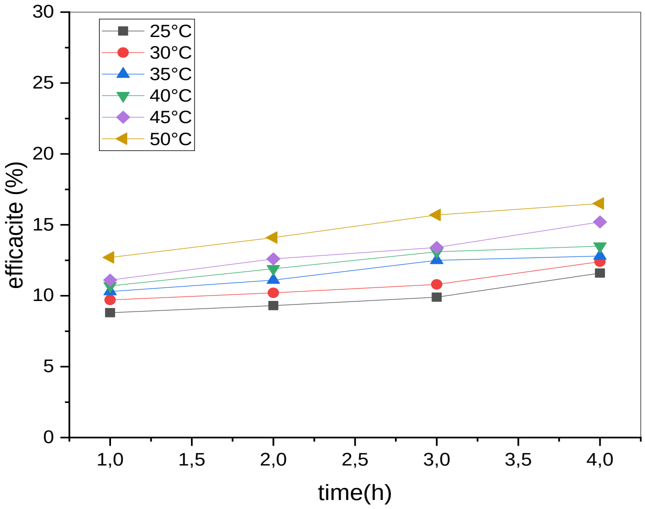


**Figure 7:** The efficiency curves of mild carbon steel in HCl acid (0.5M) in the presence of aspirin at $10^{-3}$M as a function of immersion times of 1, 2, 3, and 4 hours for temperatures ranging from 25°C to 50°C.

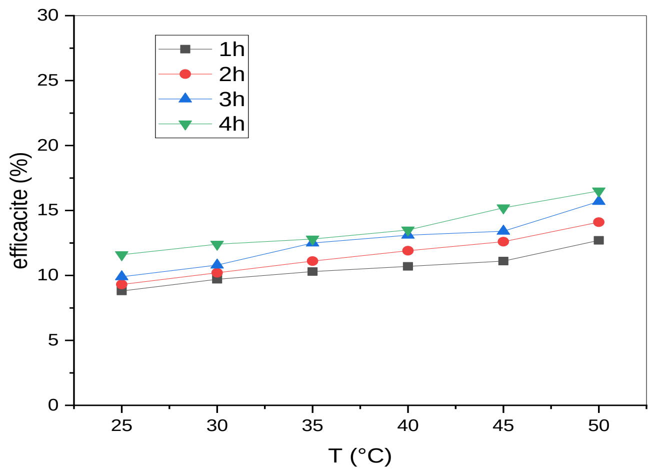


**Figure 8:** The efficiency curves of mild carbon steel in HCl acid (0.5M) in the presence of aspirin at $10^{-3}$M as a function of temperature (25°C to 50°C) for immersion times ranging from 1 to 4 hours.

Table 5 shows the effect of time and temperature on the effectiveness of mild carbon steel in an HCl (0.5M) environment in the presence of $10^{-3}$M aspirin. It can be seen that there is an increase in mass loss with immersion time and that the corrosion rate increases significantly at the same time when the temperature rises from 25°C to 50°C. The efficiency reaches a maximum value (16.5%) at 50°C for an immersion time of 4 hours. The effect of immersion time on the corrosion rate is shown in Figures 7 and 8.

## *IV. Discussion*

The results of this study provide a comprehensive understanding of the corrosion behavior of mild carbon steel in a hydrochloric acid environment, both in the absence and presence of aspirin as an inhibitor. Gravimetric analysis identified three factors influencing the corrosion rate: immersion time, acid concentration, and temperature. In the absence of an inhibitor, the corrosion rate increased significantly with longer immersion times and lower temperatures (Table 1, Figure 1). This observation is consistent with the general understanding that more thermal energy accelerates electrochemical reactions at the metal-solution interface, which increases corrosion rates(Zamindar et al., 2024)(Sikine et al., 2017). Similarly, increasing the HCl concentration resulted in an increase in the corrosion rate (Table 2, Figure 2), particularly noticeable above 0.9 M. This behavior can be attributed to the availability of hydrogen ions, which supports the cathodic reduction reaction, leading to more metal dissolving. These results are consistent with previous studies on acid-induced corrosion of carbon steel(Duy et al., 2024)(Hsissou et al., 2022). When aspirin was introduced to the system at a fixed concentration of $10^{-3}$ M, a marked decrease in the corrosion rate was observed in all experimental conditions (Tables 3 and 4; Figures 4 and 5). The inhibition efficiency ranged from 8.8% to 16.5%, with the strongest effect at 50°C after 4 hours of immersion (Table 5; Figures 7 and 8). This shows that aspirin acts as an effective corrosion inhibitor, however with moderate efficiency. The performance improvement at longer immersion times could suggest that the adsorption of aspirin on the steel surface follows a chemisorption mechanism, as is often the case with organic inhibitors containing electronegative atoms such as oxygen(Merimi et al., 2023)(Prasanna et al., 2018)(Ikeuba et al., 2022). The inhibitory capacity of aspirin can be attributed to its molecular structure, which includes a carboxylic acid group and an ester functional group capable of forming bonds with the metal surface. The plane structure and electron-rich sites probably promote adsorption on the steel surface, creating a protective barrier that protects the metal from corrosive elements(Merimi et al., 2023). Compared to other studies using pharmaceutical inhibitors, the inhibitory efficacy of aspirin in this study is reasonable. For example, similar values were reported by Prasanna et al. and Ikeuba et al., who demonstrated that aspirin exhibits environmentally friendly and non-toxic inhibitory properties for mild steel in acidic environments(Prasanna et al., 2018)(Ikeuba et al., 2022). However, other inhibitors, such as Schiff bases or heterocyclic compounds, can achieve greater efficacy depending on the nature and position of the donor atoms( Elmsellem et al, 2011)(Merimi et al., 2022). In general, the experimental results confirm the initial hypothesis that aspirin can inhibit the corrosion of mild steel in acidic environments. Although its effectiveness remains modest, aspirin's low toxicity, availability, and cost make it an interesting candidate for further optimization and potential synergistic use with other environmentally friendly additives or inhibitors.

## V. Conclusion

In this study, the corrosion behavior of mild carbon steel in hydrochloric acid (HCl 0.5 M) was thoroughly investigated using gravimetric techniques, both in the absence and presence of aspirin as a corrosion inhibitor. The results showed that the corrosion rate increases significantly with immersion time, acid concentration, and temperature. Without an inhibitor, mild steel demonstrated high sensitivity to corrosion, particularly at elevated acid concentrations and high temperatures. The introduction of aspirin at a concentration of $10^{-3}$ M effectively reduced the corrosion rate in all tested conditions, with inhibition rates ranging from 8.8% to 16.5%. The most significant inhibition was observed at 50°C after 4 hours of immersion. This performance is attributed to the ability of aspirin molecules, which contain electronegative functional groups, to adsorb to the metal surface and form a protective barrier that reduces acid attack. Although aspirin has moderate inhibitory efficacy compared to some conventional organic inhibitors, its advantages, including low cost, environmental friendliness, and pharmaceutical availability, make it a promising candidate for environmentally friendly corrosion inhibition. Furthermore, additional studies are encouraged to explore the synergistic effects of aspirin with other ecological additives and to understand the adsorption mechanism in greater detail using electrochemical and surface analysis techniques.

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**Conflicts of Interest:** The authors declare that there are no conflicts of interest.

**Compliance with Ethical Standards:** This article does not contain any studies involving human or animal subjects.

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