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# Effect of Henna (Lawsonia inermis) concentration on mild steel corrosion

**Sahib Mohammed Mahdi**

Materials Engineering Department, Al-Mustansiriya University, Baghdad, Iraq.

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**Abstract**
This research was done by using varied concentrations (10, 20 and 30 gm/l) of Henna (H) added to 5%HCl, for different exposure times (1, 24, 168, 336 and 504 hrs), by using electrochemical test. Tafel curves have been recorded of Henna soaking in 5%HCl. The pH values of medium solutions after each test had be record too. The results shows that each concentration of Henna added to 5%HCl has its own behavior, although they are reduce corrosion rate of the mild steel. The concentration with (30gm/l) of Henna was the favorable effect.

**Keywords:** Henna (H); Mild steel; Inhibitor; Corrosion; Potentiostat; Electrochemical test.

## 1. Introduction

Corrosion processes are responsible for numerous losses mainly in the industrial scope [1, 2]. Metallic structures facilities of most industries are exposed corrosion always present. This problem creates significant economic and material losses due to part or whole additional of equipment and assemblies, and plant- reforming stoppages [3]. Corrosion is the decline of metal by chemical occurrence or reaction with its environment. It is a constant and Continuous problem, often hard to remove entirely [4, 5]. Numerous different means can be engaged to slow or avoid metallic corrosion configurations. The most generally protections used are using organic coatings on metals also, plastics, polymers coatings and cathodic and/or anodic protection using organic or inorganic inhibitors [6-8]. Hindrance would be more applied and possible than comprehensive exclusion. Processes of corrosion grow fast after interruption of the protective obstacle and are attended by a number of reactions that variation the properties and composition of both the surface of a metal and the resident environment, for example, oxide films formation, metal cations diffuse into the coating matrix, native pH deviations, and electrochemical potential [9]. The known hazardous effects of most synthetic organic inhibitors and restrictive environmental regulations have now made researchers to focus on the need to develop cheap, non-toxic and environmentally benign natural products as corrosion inhibitors [10]. The increasing anxiety about the toxicity of corrosion inhibitors in the plants has substituted with more eco-friendly plant inhibitors. Thus, plant extracts are becoming vital as an environmentally satisfactory, readily existing and renewable source for widespread range of inhibitors [11, 12]. Most of the natural products are non – toxic, bio – degradable and freely available in plenty. Several parts of plants – seeds, fruits, leaves, flowers etc., have been used as corrosion inhibitors [13]. In various hair dyes and hair-care products. Lawsonia inermis, also called “henna”, comprises many kinds of chemical compounds, such as coumarin, quinones, flavonoids etc. and has sturdier biological activity. Due to its normal and safe characters henna is used as a kind of natural dye, and is used as a raw material for ordinary hair dyes. In addition, henna can be used as colorants for textile and tattoo material. The healing value of Lawsonia inermis is very high and it is used for handlings of headache [14, 15]. In addition, henna has inhibitory action on aluminum and steel in violent solution. Henna has been used as corrosion inhibitor for iron in HCl acid [3, 5]. HCl acid which is widely used for pickling, cleaning, scraping and etching of metals, on the other hand also cause to surface metal corrosion. Lesser inhibitor concentrations can result in reduces of the corrosion rate of the metal [7]. As well as mild steel has been widely used under different situations in chemical and associated industries in handling salt, acid and alkaline solutions. Chloride, nitrate and sulphate ions in aqueous means are mainly violent and accelerate corrosion [4]. In this study the effect of henna concentrations on corrosion rate of mild steel in 5% HCl was investigated. Using the electrochemical tests for varying henna content at different soaking period, recording their pH and microscopy examine the steel samples surface.

## 2. Experimental

Electrochemical Tafel test method, optical microscope examination and pH exam were used in order to detect the effect of Henna powder with different concentrations on mild steel samples corroded in 5%HCl medium at room temperatures.

### *2.1 Materials*

The mild steel samples chemical composition is list in Table 1. Cylindrical samples are used for electrochemical tests. Powder of dry henna of different weights is added to 5%HCl medium at room temperatures.

Table 1. The mild steel samples chemical composition.

| C% | i% | S% | P% | Mn% | Ni% | Cu% | Cr% | Fe% |
|---|---|---|---|---|---|---|---|---|
| 0.17 | 0.02 | 0.01 | 0.01 | 0.43 | 0.04 | 0.05 | 0.02 | Rem. |

### *2.2 Electrochemicel measurements*

The electrochemical tests were carried out using cylindrical specimens of 4.5 $cm^2$ surface area, immersed in 5%HCl solution with adding henna powder as inhibitor at different concentrations (10, 20 and 30 gm/l). The henna was soaked for (1, 24, 168, 336, and 504 hours). A Gamry Serise G300 Potentiostat built in a computer used for electrochemical corrosion measurement (Tafel test). The test was of three electrodes connection (reference electrode, counter electrode and working electrode). Saturated Calomel reference electrode was the reference electrode and graphite rod was the auxiliary electrode. By using Gamry workframe software to record test data, the experiments were carried at room temperature. Saving data in Data Gamry folder and using Gamry Echem Analyst software, for evaluation. Figure 1 shows the setup for all Tafel tests. The inhibitor efficiency percent (η%) has been calculated for each henna concentration at each period of soaking time by using formula (1) [2, 10, 11, 13].

$$\eta\% = \frac{W_{corr} - W_H}{W_{corr}} \times 100 \qquad (1)$$

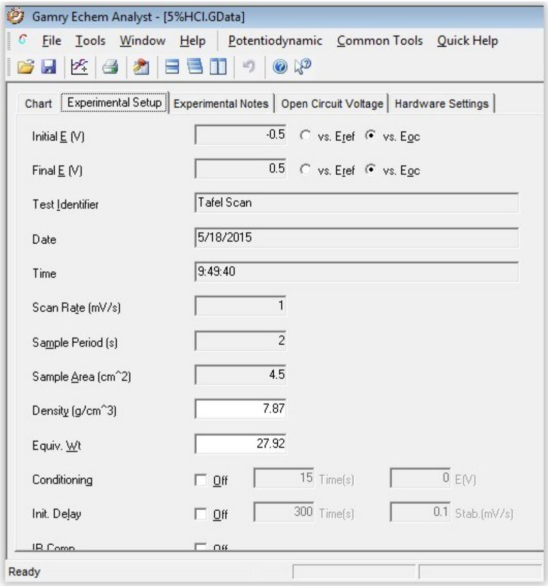
where: η% = inhibitor efficiency percent, $W_{corr}$ = Corrosion rate in mils per year (mpy) of 5% HCl without Henna adding, and $W_H$ = Corrosion rate in (mpy) with Henna added to 5%HCl.

### *2.3 The medium pH measurements*

Using pH-meter type HND-MP1400 for recording pH of Henna of different weight ratio (10, 20, and 30 gm/l) which added to 5%HCl for (1, 24, 168, 336 and 504 hours) interval times.

### *2.4 Microscopic test*

Using optical microscope for examine the specimen surfaces. The images were taken for the specimen after test.



Initial E (V) -0.5 ○ vs. Eref ● vs. Eoc
Final E (V) 0.5 ○ vs. Eref ● vs. Eoc
Test Identifier Tafel Scan
Date 5/18/2015
Time 9:49:40
Scan Rate (mV/s) 1
Sample Period (s) 2
Sample Area (cm^2) 4.5
Density (g/cm^3) 7.87
Equiv. Wt 27.92
Conditioning ☐ Off 15 Time(s) 0 E(V)
Init. Delay ☐ Off 300 Time(s) 0.1 Stab.(mV/s)
IR Comp ☐ Off

Figure 1. The electrochemical experiments setup.

## 3. Results and discussion

The results for each test have been recorded and then discuss to evaluate its effect.

### *3.1 Electrochemical measurements*

A Gamry Serise G300 Potentiostat built in a computer used for electrochemical corrosion measurement (Tafel test), with three electrodes. Figures (2, 3 and 4) are shown the Tafel scan curves of the cylindrical specimens in 5%HCl with and without Henna powder of three electrodes test. This test is done for descriptive effect of solution aging. Figure 2 shows Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L Henna (H) addition for varying exposure times. All curves are about to be close together, low concentration of Henna (10gm/L) gave very close behavior. Figure 3 shows Tafel curves for electrochemical experiments of 5%HCl without and with 20 gm/L Henna (H) addition for varying times. It shows different behavior of curves at varying exposure time; this is because of higher Henna concentration (20gm/L). Figure 4 demonstration Tafel curves for electrochemical experiments of 5%HCl without and with 30 gm/L Henna (H) addition for varying exposure times. This figure shows high decrease in corrosion rate for most interval times compare with 5%HCl acid only. Figures 5-9 shows Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 1 hour, 24 hours, 168 hours, 336 hours and 504 hours of soaking time respectively. Figure 5 of one hour exposure time shows that (30gm/l) of Henna adding is better than others. The same behavior is observed for Figures 6 and 7 of 24hrs and 168 hrs respectively. While Figure 8 shows the henna concentration effect at (336 hrs) of exposure time, here the curves of (20gm/l) henna also decrease corrosion rate as well as (30gm/l). But the Figure 9 which is shows the henna concentrations at 504 hours (3 weeks), it is like the behavior of Figure 2, when the concentration was low (10 gm/l), all curves all about to be close together of concentrations. This is because the effect of Henna is reduced.

Table 2 indicates the values of Tafel curves parameter of both 5%HCl acid without and with Henna addition. These parameters are calculated by the Gamry Echem Analyst software. This table shows that the corrosion rate in mpy of 5%HCl, and Tafel parameter ($E_{corr}$, $\beta_C$, $\beta_A$) without and with adding Henna. Where in Table 3 recording the inhibition efficiency of Henna soaking in 5%HCl using the corrosion rate of Table 2 in mpy. The results are used in Figure 10 which shows the relationship of corrosion rate in mpy with soaking time of henna, the concentrations of (10gm/l) and (20gm/l) show increase in corrosion rate at the first week of soaking and then decrease, which mean that the Henna activity for these concentrations will be effective and inhibitor corrosion after one week of soaking, while the curve of (30gm/l) shows low corrosion rate with the soaking time till two weeks(504hrs),and then corrosion rate increase, this behavior is indicate that Henna inhibition of (30gm/l) is more active for first two weeks period, but will lose its activity for higher exposure time. This is as mention before, at high concentration (30gm/l) there is high content of Henna that diffuse in to 5%HCl acid medium causing to reduce corrosion rate and acidity (pH increase). While for concentrations (10gm/l and 20gm/l) need more soaking time for begin their activity.

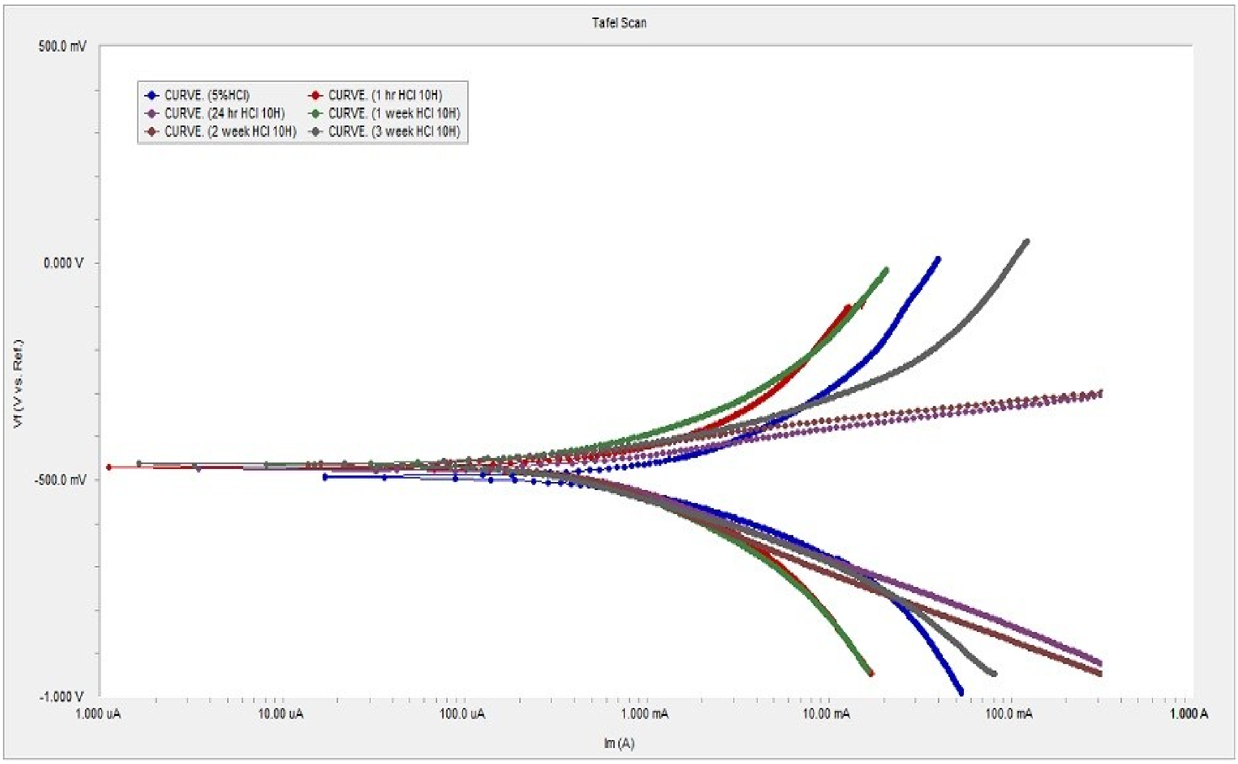


Figure 2. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L Henna (H) addition for varying times.

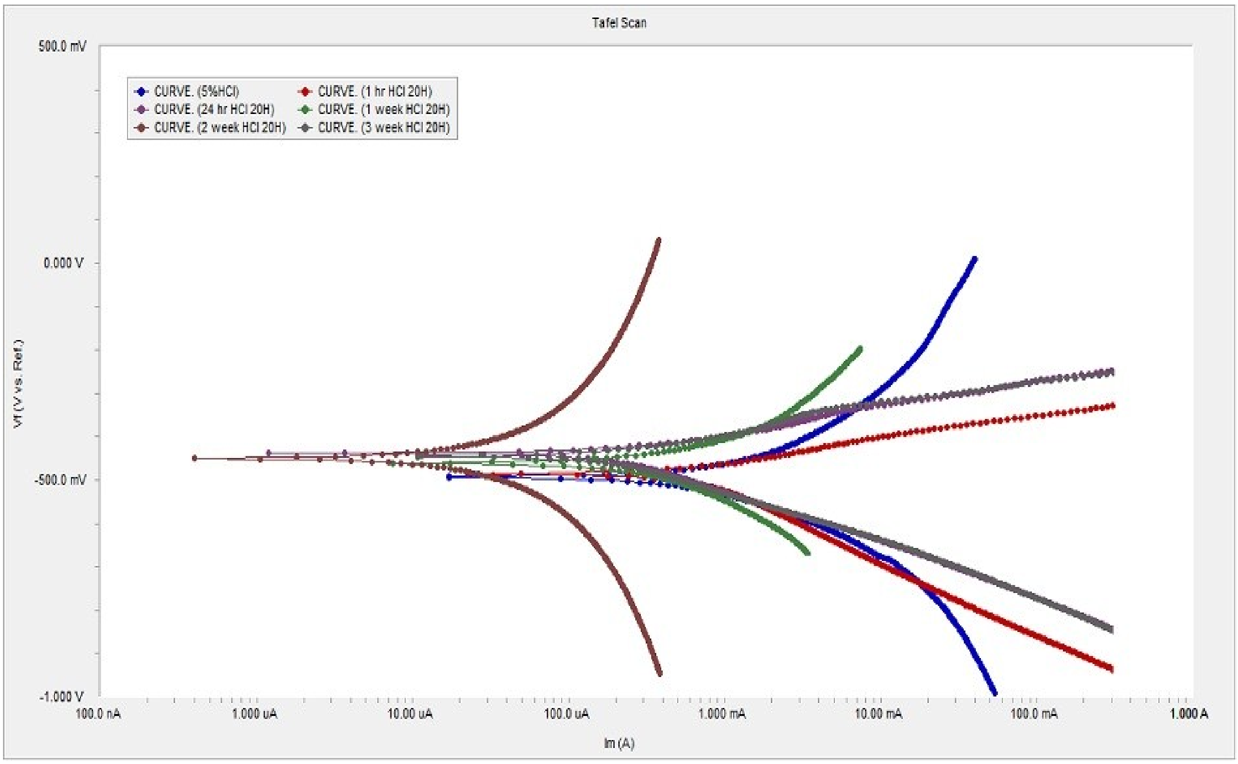


Figure 3. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 20 gm/L Henna (H) addition for varying times.

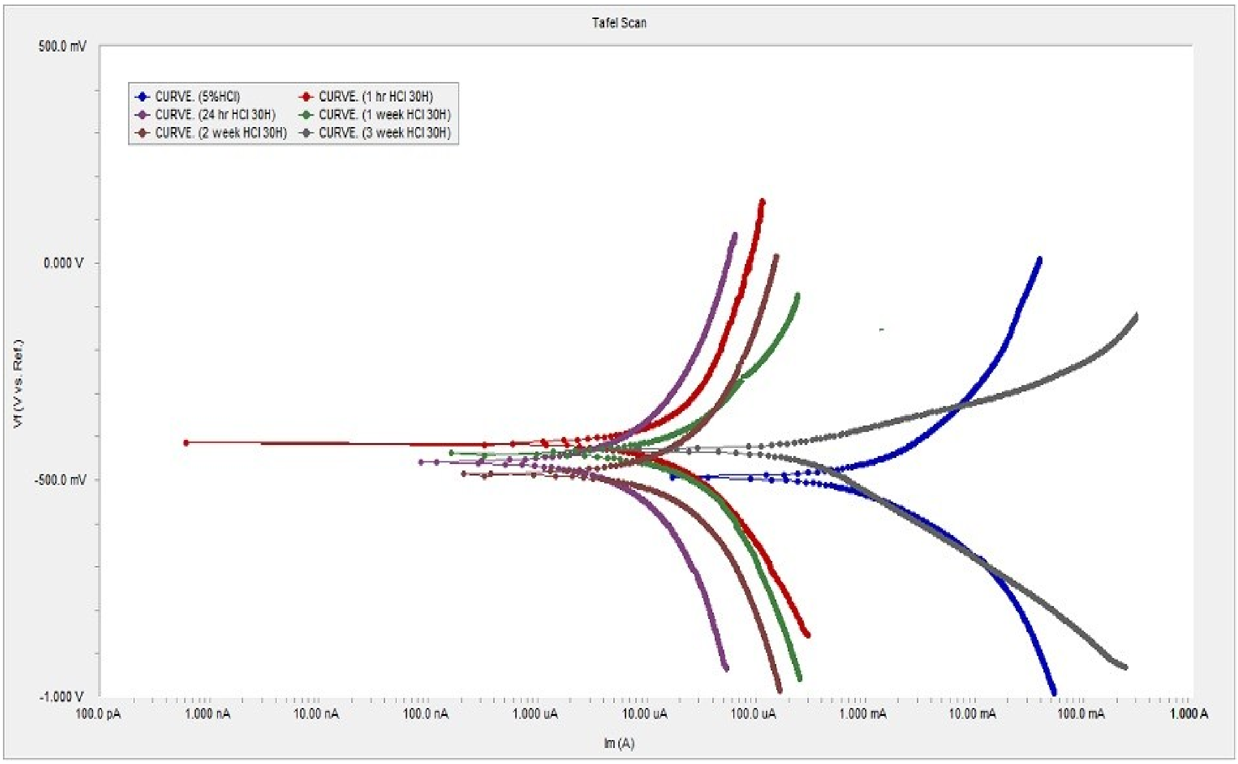


Figure 4. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 30 gm/L Henna (H) addition for varying times.

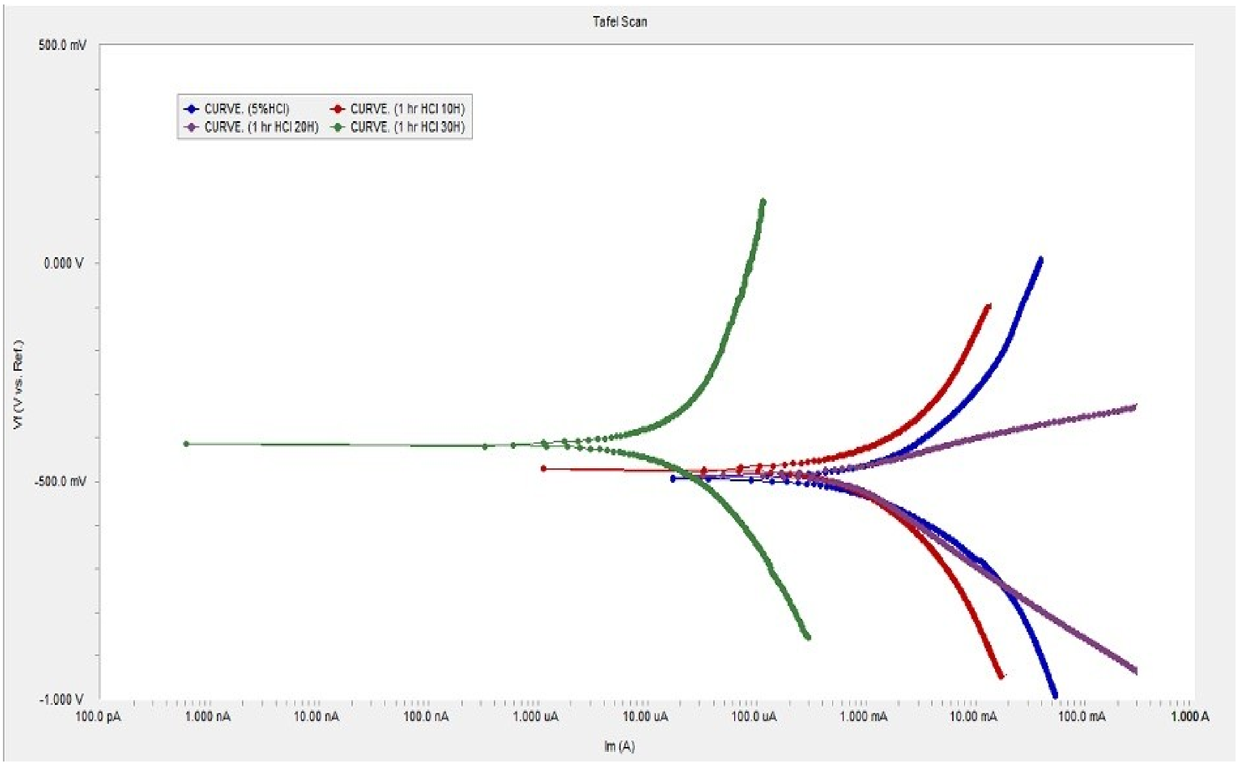


Figure 5. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 1 hour soaking time.

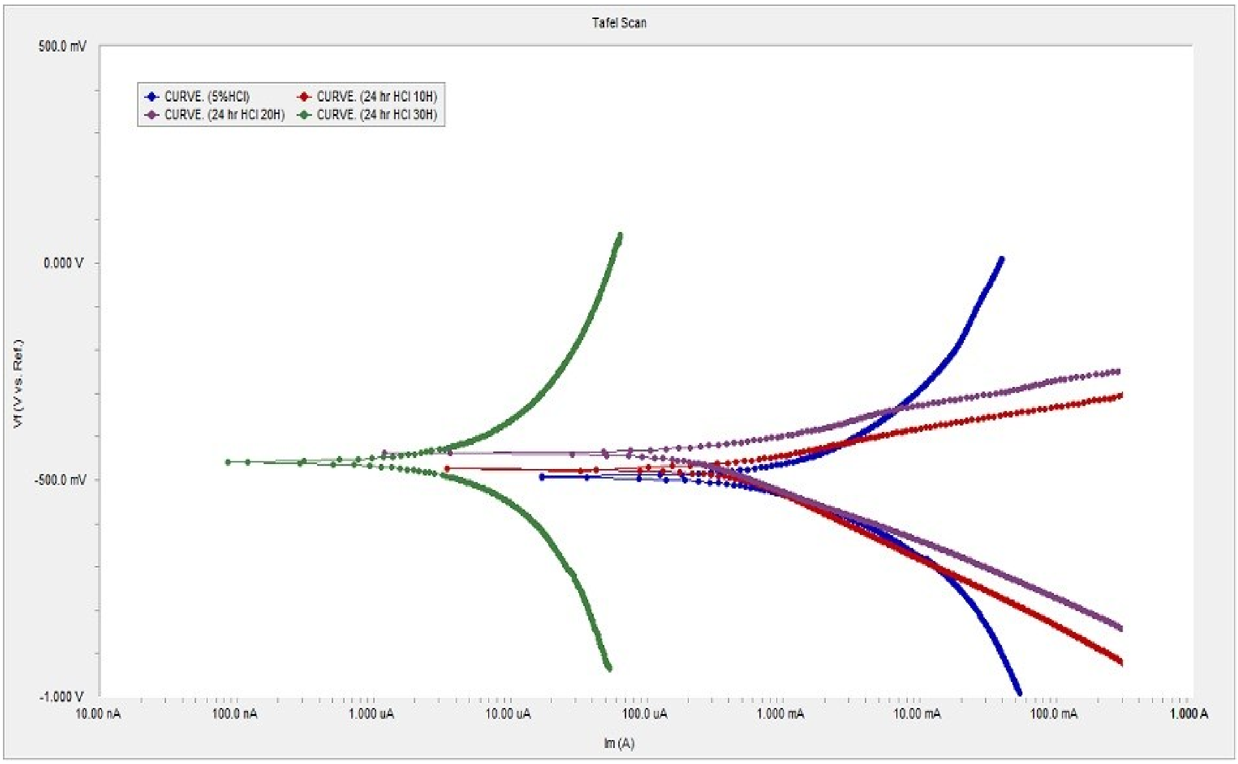


Figure 6. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 24 hours soaking time.

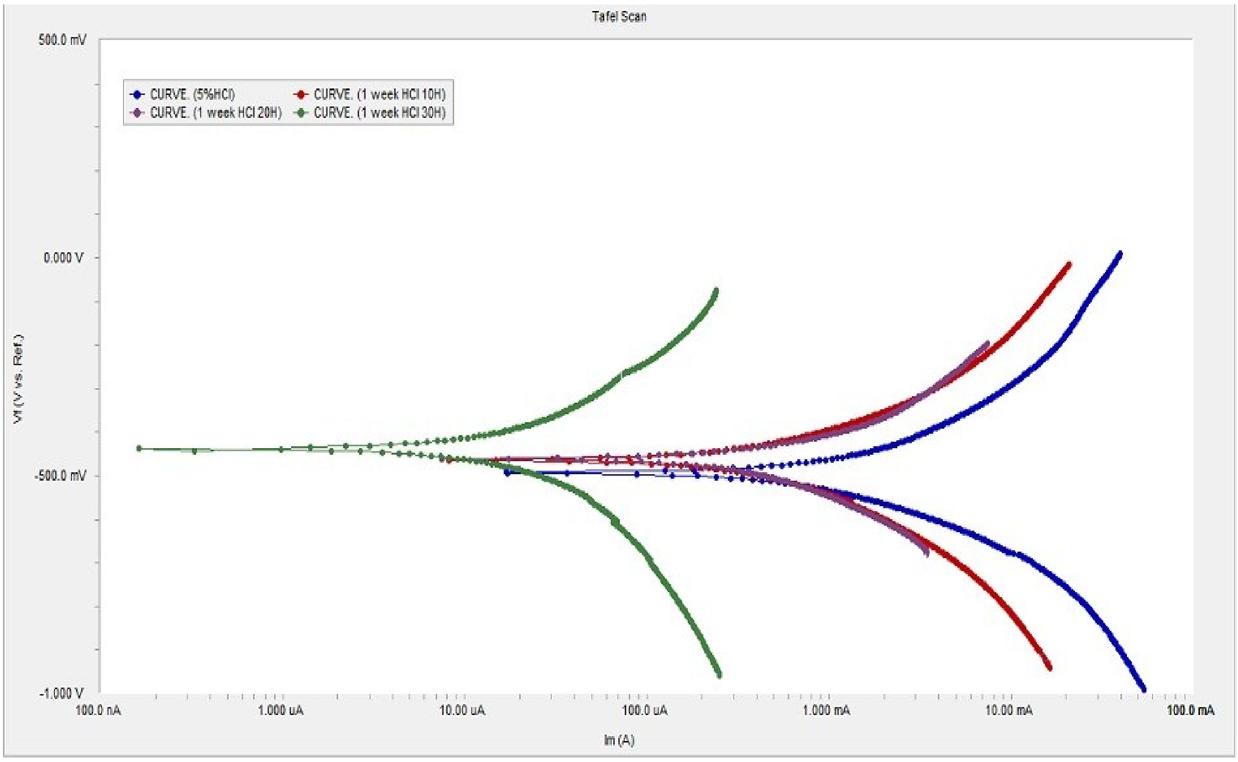


Figure 7. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 168 hours (1 week)soaking time.

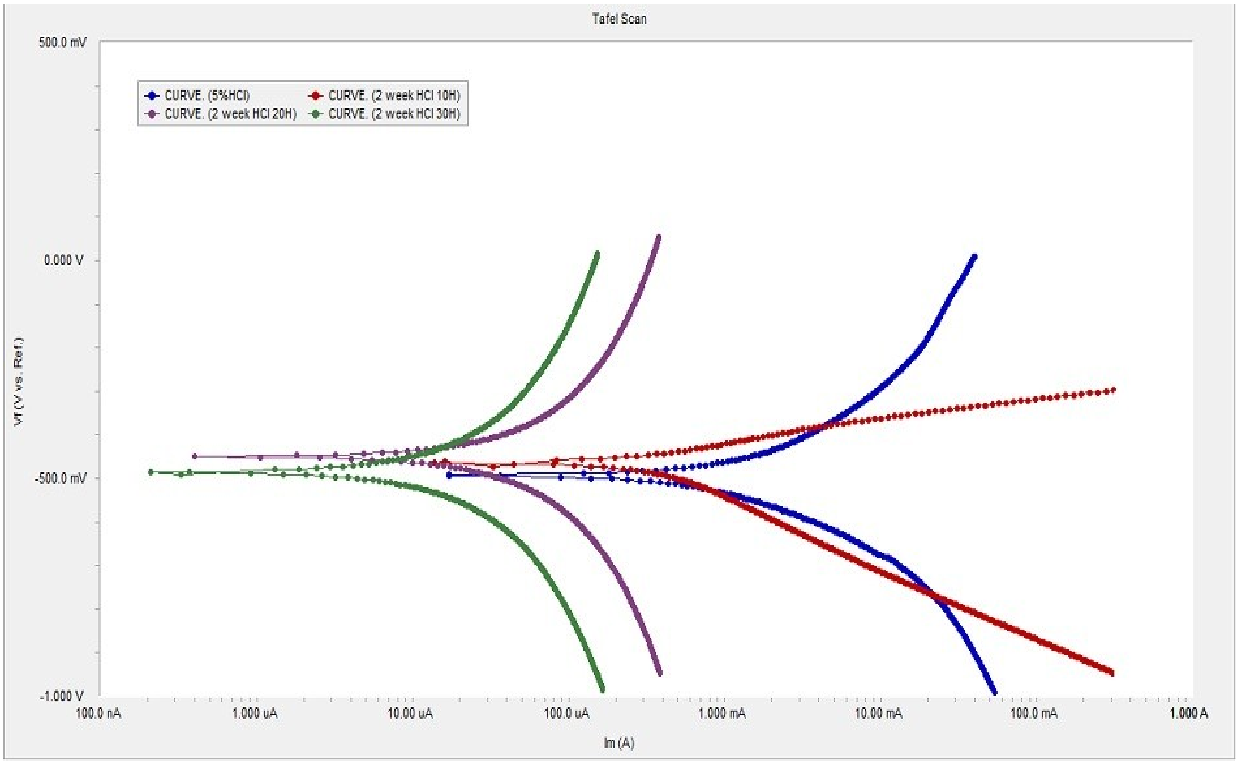


Figure 8. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 336 hours (2 weeks) soaking time.

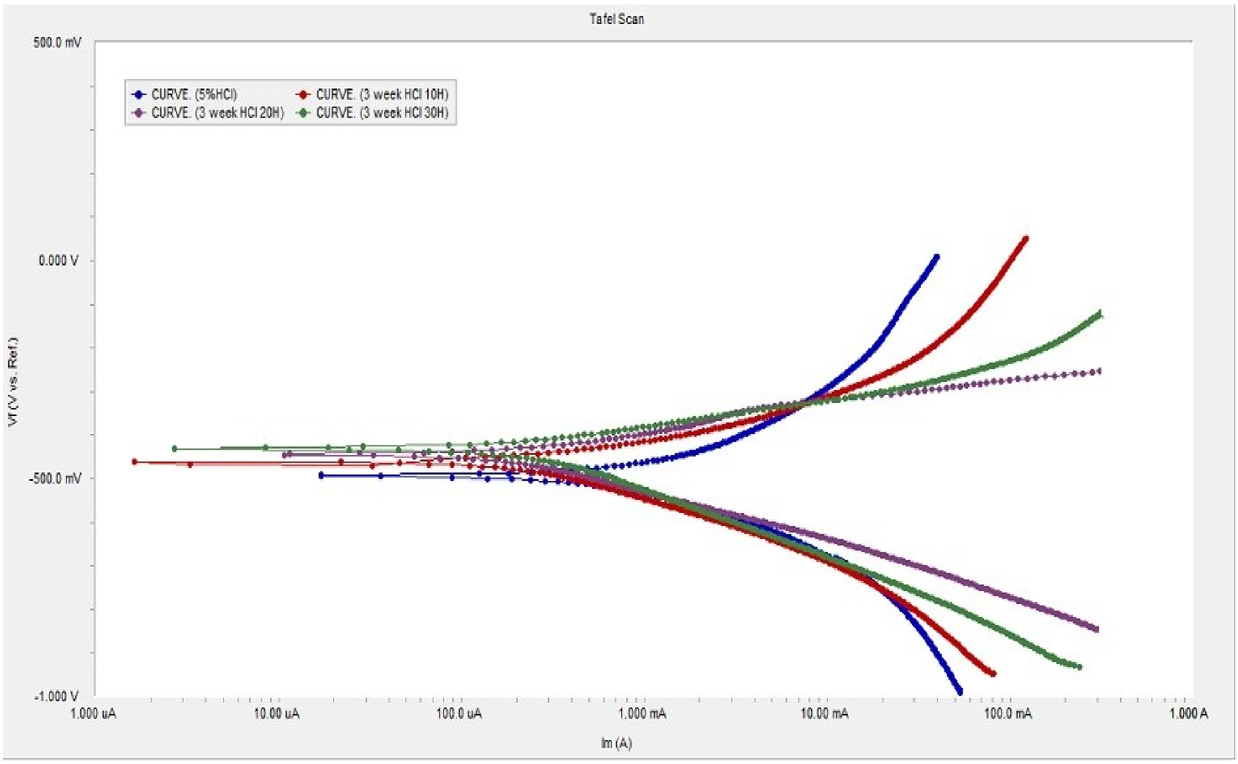


Figure 9. Demonstrate Tafel curves for electrochemical experiments of 5%HCl without and with 10 gm/L, 20 gm/L and 30 gm/L Henna (H) addition for 504 hours (3 weeks) soaking time.

Table 2. Indicates the parameters value of Tafel test for 5%HCl without and with 10gm/l, 20gm/l and 30gm/l of Henna (H) at different time of soak.

| Environment | $E_{corr}$ V | $I_{corr}$ A | $\beta_C$ | $\beta_A$ | Corrosion rate mpy |
|---|---|---|---|---|---|
| 5%HCl | -0.493 | 0.001060 | 0.1888 | 0.1905 | 107.3 |
| 1hr +10gm/l H | -0.471 | 0.0000934 | 0.0559 | 0.0435 | 9.487 |
| 24hrs +10gm/l H | -0.475 | 0.000126 | 0.0601 | 0.0328 | 12.76 |
| 168hr +10gm/l H | -0.464 | 0.000440 | 0.1901 | 0.1589 | 44.7 |
| 336hr +10gm/l H | -0.463 | 0.00000797 | 0.0374 | 0.0379 | 9.299 |
| 504hr +10gm/l H | -0.481 | 0.000208 | 0.1141 | 0.0217 | 0.8091 |
| 1hr +20gm/l H | -0.586 | 0.000081 | 0.339 | 0.0213 | 8.222 |
| 24hrs +20gm/l H | -0.437 | 0.0000693 | 0.722 | 0.32 | 7.033 |
| 168hr +20gm/l H | -0.461 | 0.000427 | 0.2163 | 0.1173 | 43.4 |
| 336hr +20gm/l H | -0.450 | 0.000239 | 1.501 | 1.464 | 24.25 |
| 504hr +20gm/l H | -0.444 | 0.000212 | 0.131 | 0.0636 | 21.52 |
| 1hr +30gm/l H | -0.414 | 0.00000252 | 0.3485 | 0.719 | 2.557 |
| 24hrs +30gm/l H | -0.230 | 0.00000116 | 0.3727 | 1.000e15 | 1.175 |
| 168hr +30gm/l H | -0.439 | 0.00000854 | 0.1603 | 0.1613 | 0.867 |
| 336hr +30gm/l H | -0.486 | 0.0000132 | 0.2543 | 0.2755 | 1.342 |
| 504hr +30gm/l H | -0.367 | 0.00000228 | 0.3147 | 0.648 | 0.2313 |

### *3.2 The medium pH measurements*

From Table 3 the solution pH of the 5%HCl with (10, 20 and 30gm/l) of Henna had been recorded for soaking time of (1, 24, 168, 336 and 504 hours). Figure 11 shows the relationship between the corrosion potential and pH of the corrosion medium (5%HCl with Henna) for the period of exposure time. It is clear that the effect of (10gm/l ) and (20gm/l) Henna concentration in 5%HCl are in small area, for that it is difficult to control them, While the curve of (30gm/l) Henna concentration in 5%HCl give large area of ($E_{corr}$ – pH), giving good control on corrosion medium. The variation of pH solutions of Hennna soaked in 5%HCl means that there are varied reaction and different products.

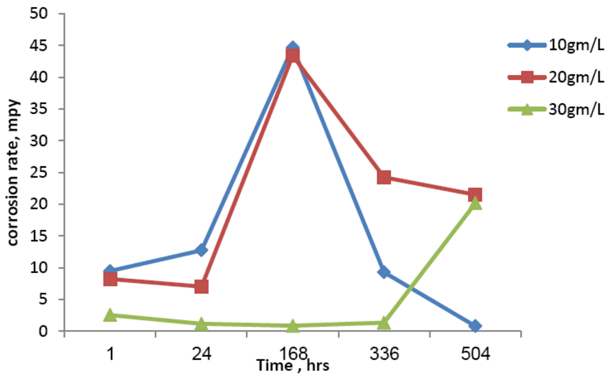


Figure 10. Shows the corrosion rate of 5%HCl with 10, 20 and 30gm/l of Henna at varying soaking time.

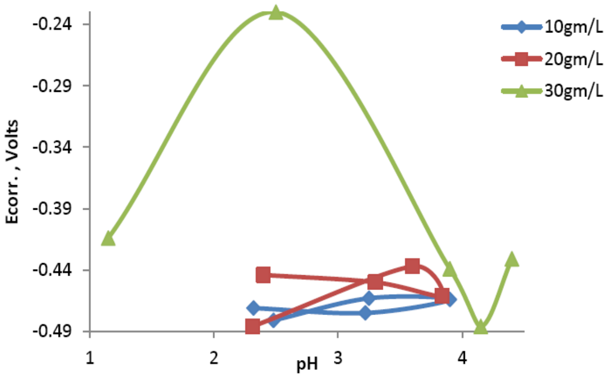


Figure 11. Shows corrosion potential with respect to medium pH of 5%HCl with 10, 20 and 30gm/l of Henna at varying soaking time.

### *3.3 Microscopic inspections*

Figures 12-14 clarify the structure of the specimens of one week (168 hrs) of exposure time in 5%HCl with 10gm/l, 20gm/l and 30gm/l respectively in optical microscope at magnification (X100). For Figures 12 and 13 it is obvious that there is a film layer on the surface of the specimen immersed in acid with Henna solution, and observes corrosion impress. Whereas Figure 14 shows Henna precipitate on surface specimen immersed in 5%HCl with 30gm/l. That is cause good inhibition of the specimen as shown before in Figure 10.

Table 3. The inhibitor efficiency of Henna soaking in 5% HCl acid using electrochemical test, and the pH value of the solution.

| Efficiency of Henna added to HCl by electrochemical test | | | |
|---|---|---|---|
| Henna concentration gm/l | Soaking time, hours | Efficiency η% | pH value |
| 10 | 1 | 91 | 2.32 |
| 10 | 24 | 88 | 3.22 |
| 10 | 168 | 58.3 | 3.9 |
| 10 | 336 | 91 | 3.25 |
| 10 | 504 | 99.2 | 2.48 |
| 20 | 1 | 92 | 2.31 |
| 20 | 24 | 93 | 3.6 |
| 20 | 168 | 59.55 | 3.84 |
| 20 | 336 | 77 | 3.3 |
| 20 | 504 | 79.9 | 2.4 |
| 30 | 1 | 97.6 | 1.15 |
| 30 | 24 | 98.9 | 2.5 |
| 30 | 168 | 99.1 | 3.9 |
| 30 | 336 | 98.7 | 4.15 |
| 30 | 504 | 81.1 | 4.4 |

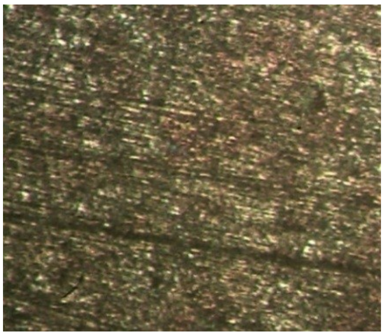


Figure 12. Shows the structure of specimen immersed in 5%HCl with 10gm/l of Henna X100.

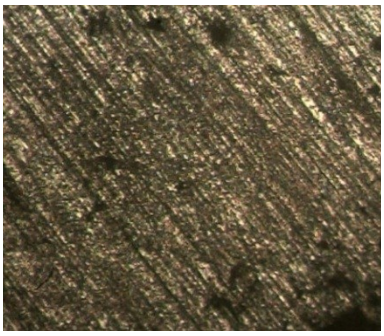


Figure 13. Shows the structure of specimen immersed in 5%HCl with 20gm/l of Henna X100.

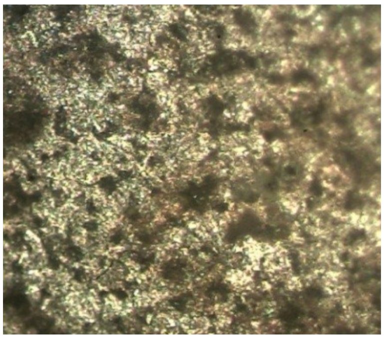


Figure 14. Shows the structure of specimen immersed in 5%HCl with 30gm/l of Henna X100.

## 4. Conclusion

1. Henna powder can be used as inhibitor when added to dilute strong acids.
2. Henna powder inhibition is active for limited period, not more three weeks (504 hours) for this study circumstances.
3. High concentration of Henna (30gm/l) is more active than lower concentrations, specially for the first week of exposure.
4. The reactant products of Henna forms a film layer on metal surface, can help in metal surface protection.
5. pH solutions of 5%HCl with variable content of Henna give different values of pH, because of different reactions and product.

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