Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

Abstract
The influence of Domperidone on the inhibition of carbon steel (CS) corrosion in 1M HCl solutions was studied using weight loss (WL), (EIS) electrochemical impedance spectroscopy, electrochemical frequency modulation (EFM) and potentiodynamic polarization (PP) techniques, as well as thermodynamic calculations to explore the adsorption mechanism of Domperidone. The inhibition efficiency (IE %) was found to increase with increasing the dose of the Domperidone and with decreasing temperature. The maximum IE% of 94.9 % was obtained in presence of 1.12x10^-4 M. The inhibition action of Domperidone was explained in terms of adsorption on CS surface. The adsorption process follows Langmuir isotherm and kinetic-thermodynamic model. Thermodynamic and kinetic parameters were calculated and discussed. Polarization tests showed that this drug is of mixed type. Corrosion protection properties of the drug have been inferred from FT-IR spectra and by atomic force microscope (AFM).

Keywords: Corrosion inhibition; Domperidone drug; Carbon steel; WL; EIS; EFM; AFM; FT-IR

Abbreviations: CS: Carbon Steel; EIS: Electrochemical Impedance Spectroscopy; EFM: Electrochemical Frequency Modulation; PP: Potentiodynamic Polarization; IE: Inhibition Efficiency; AFM: Atomic Force Microscope; SCE: Saturated Calomel Electrode

Introduction
Carbon steel is the most worldwide utilized material for industrial and domestic applications, because of its good mechanical properties, availability and relatively reasonable cost. HCl is widely used in various technological processes in industry (e.g. pickling baths, chemical and petrochemical industries). Corrosion of CS is important and expensive and problem in the industries it represents a significant portion of loss as a result of lost production, inefficient operation, and high maintenance. It has been found that one of the best methods of protecting metals against corrosion involves the use of inhibitors which are substances which slow down the corrosion rate [1,2]. The corrosion protection is a surface process, which involves adsorption of the organic compounds on the metal surface. The adsorption depends mainly on the electronic structure of the molecule [3]. There is interesting concern about the toxicity of most organic inhibitors which affect living organisms and also poison the environment [4]. So, there has been increasing search for green inhibitors. Recently, there are several studies carried out on the use of drugs as inhibitors [5-11]. The drugs are biocompatibility in nature, environmentally acceptable, readily available and a renewable source. Due to bio-degradability, eco-friendliness, low cost and easy availability, the pharmaceutical based chemicals have been tried as inhibitors for metals under different environments.

Table 1: A comparison of % IE with different investigated extracts.

| Inhibitor (Drug) | Sample | Medium | IE % | References |
|------------------|--------|--------|------|------------|
| Pencillin G      | Mild steel | H₂SO₄ | 73.7 | [12]       |
| Penicillin V     | Mild steel | H₂SO₄ | 63.3 | [13]       |
| Cefalexin        | Mild steel | HCl   | 67.5 | [14]       |
| Ceftriaxone      | Mild steel | HCl   | 90   | [15]       |
| Cefotaxime       | Mild steel | HCl   | 90   | [16]       |
| Cefixime         | Mild steel | HCl   | 90   | [17]       |
| Cefotibiprole    | Mild steel | HCl   | 91.2 | [18]       |
| Quinoline        | Mild steel | HCl   | 88.7 | [19]       |
| Dapsone          | Mild steel | HCl   | 90.7 | [20]       |
| Domperidone      | Copper   | 3.5% NaCl | 92.6 | [21]       |
| Domperidone      | Carbon steel | HCl | 94.7 | Our results |
Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

Figure 1: Chemical structures of the Domperidone.

(5-chloro-1-[1-[1-oxo-2,3-dihydro-1H-benzimidazol-1-yl)propyl]-4-piperidinyl]-1,3-dihydro-2H benzimidazol-2-one).
Chemical Formula: C₂₃H₂₃ClN₂O₂
Molecular Weight: 425.92.

Experimental

Materials and solutions
Carbon steel with a chemical composition (weight %): C 0.15, Mn 0.680, Si 0.230, Cr 0.077, S 0.016, Ni 0.59, Ti 0.011, Cu 0.160 and Fe balance was used in the corrosion tests. Prior to all measurements, the CS coins were abraded with different grades of emery papers up to 1200 grade, washed with bi-distilled water, degreased with acetone and dried in hot air blower, then kept in a desiccator for use.

All reagents were obtained from analytical reagent-grade. The aggressive HCl solution was prepared by dilution of HCl grade 37% with bi-distilled water. Domperidone drug was purchased from Cilag –Janssen Pharmaceutics (Belgium, Beerse) and used as received.

Weight loss method

Coins were measured 2×2×0.2 cm dimensions are utilized for weight loss tests, dipped in the corrosive solution (100ml HCl) with and without different concentrations of the drug in the temperature range 25-55°C. Three measurements were made in each case and the average value of the weight loss was taken in order to obtain best reproducibility. The inhibition efficiency (% IE) and (θ) were measured utilizing equation 1 [22]

\[
%\text{IE} = 100 \times \theta = 100 \times \left[1 - \left( \frac{W_{\text{no drug}}}{W_{\text{drug}}} \right) \right]
\]

Where \(W_{\text{no drug}}\) and \(W_{\text{drug}}\) are the mass reduction for CS attendance and lack of the drug in solution of HCl and θ is the degree of coverage surface for drug.

Electrochemical measurements

A conventional cell of capacity 100ml was used. It contains three compartments:

a. C-steel sample as a working electrode;

b. A platinum foil with 1cm² surface area was chosen as a counter electrode;

c. A saturated calomel electrode (SCE) via a Luggin capillary probe was used as a reference electrode. The working electrode was treated as before.

The electrochemical tests were done utilized Potentiostat/ Galvanostat/Zera analyzer (Gamry PCI 300/4). These contain Gamry framework organization created on the ESA400, and a PC with software DC 105 for PP, EIS software 300, and EFM software 140. Echem Specialist software 5.58 was utilized for drawing, graphing, and suitable value.

Tafel polarization was conducted from -600 to -250mV at a sweep rate 1mV s⁻¹ to study the effect of drug on CS corrosion. Corrosion current density \(i_{corr}\) was determined by extrapolating the linear Tafel segments of anodic and cathodic curves to corrosion potential. The %IE and θ were determined using the relationship:

\[
%\text{IE} = \theta \times 100 = \left[1 - \left( \frac{i_{corr}}{i_{corr}^0} \right) \right] \times 100 \quad (2)
\]

Where \(i_{corr}\) and \(i_{corr}^0\) are the corrosion currents in the presence and absence of the drug, respectively.

The EIS tests were conducted using AC signals of 10 mV amplitude for the frequency spectrum from 100kHz to 0.1Hz at OCP. The charge transfer resistance values were obtained from the diameter of the semicircles of the Nyquist plots. The %IE and θ were calculated from the charge transfer resistance values using the following equation:

\[
%\text{IE} = \theta \times 100 = \left[1 - \left( \frac{R_{ct}^0}{R_{ct}} \right) \right] \times 100 \quad (3)
\]

Where \(R_{ct}^0\) and \(R_{ct}\) are the charge-transfer resistances in absence and presence of the drug, respectively.

EFM measurements were conducted using the perturbation signals of frequencies 0.2 and 0.5Hz with 20mV RMS amplitude. All tests have been given in solutions aerated at 25°C. The %IE and θ were calculated using Eq (2).

Results and Discussion

WL measurements

In order to elucidate the influence of immersion time on the corrosion rate of CS, the data as shown in Figure 1 the WL of CS enhances with immersion time and by increasing the dose of Domperidone, the WL of CS samples are decreased indicating that the corrosion rate of Domperidone is decreased [23]. On other hand, Domperidone inhibits the corrosion process by adsorbing at the solution / metal interface. The increased IE and lower corrosion rate might be due to the improved adsorption and rise (9) of drug on surface of CS with dose rise. The maximum IE of Domperidone reached 94.7% and was achieved at 1.12 × 10⁻⁵M

Citation: Fouda AS, El Morsi MA, El-Mogy T (2017) Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug. J Anal Pharm Res 5(5): 00153. DOI: 10.15406/japlr.2017.05.00153
Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

Table 2: Variation of %IE with concentration of Domperidone in 1 M HCl at 25°C after immersion time 30 min.

| Conc, M  | 1 M HCl | 7 x 10⁻⁶ | 1.4 x 10⁻⁵ | 2.8 x 10⁻⁵ | 5.6 x 10⁻⁵ | 8.4 x 10⁻⁵ | 1.12 x 10⁻⁴ |
|----------|---------|----------|------------|------------|------------|------------|-------------|
| %IE      | ----    | 70       | 78.3       | 82.4       | 86.9       | 90.8       | 94.7        |

Temperature effect on IE

Temperature has a strong influence on the phenomenon of corrosion. Figure 3 represents the effect of temperature on the IE of the Domperidone drug at different doses. The results are shown in Table 3. The data revealed that the IE lowered by improving the temperature, because the desorption of drug molecules from the CS surface.

Table 3: The temperature effect on the IE of the Domperidone at various doses after 30 min immersion.

| [Inhibitor] M | 25°C | 35°C | 45°C | 55°C |
|--------------|------|------|------|------|
| 7.0 x 10⁻⁶   | 70   | 68.2 | 64.4 | 58.7 |
| 1.4 x 10⁻⁵   | 78.3 | 76.6 | 71.5 | 67.2 |
| 2.8 x 10⁻⁵   | 82.4 | 80   | 76.1 | 71.1 |
| 5.6 x 10⁻⁵   | 86.9 | 85.3 | 80.2 | 75.2 |
| 8.4 x 10⁻⁵   | 90.8 | 88.8 | 84.1 | 78.5 |
| 1.12 x 10⁻⁴  | 94.7 | 92.9 | 88.3 | 83.2 |

Where CR=Rate of Corrosion, R=Constant for Universal Gas, A=Factor Arrhenius Pre Exponential, T=Temperature Absolute, N=Number of Avogadro’s and h=Planck’s Constant. The data of \( E'_a \) were measured from Figure 3 and the data of \( \Delta H'_a \) and \( \Delta S'_a \) were measured from Figure 4. The measured data of \( E'_a \), \( \Delta S'_a \) and \( \Delta H'_a \) are listed in Table 4. These values showed that the presence of Domperidone drug improve the \( E'_a \). The increase values of \( E'_a \) in the presence of Domperidone drug than in its absence is attributed to the physical adsorption [24]. The \( E'_a \) ranging from 37.6 to 60.8 kJ mol⁻¹ can be offer to the physical adsorption [25]. The positive sign of \( \Delta H'_a \) reveals that the dissolution process of CS is endothermic one. Usually, the enthalpy of physical adsorption process is small than 40kJ mol⁻¹ while the enthalpy of chemisorption reach 100kJ mol⁻¹. Hence, the \( \Delta H'_a \) values obtained confirm the physical adsorption of Domperidone molecule on the surface of CS. All \( E'_a \) data are higher than the analogous value of \( \Delta H'_a \) indicate the process of corrosion include a gaseous reaction, simply evolution hydrogen reaction, associated with a break

Kinetic study

Corrosion rate data obtained from the WL tests for CS with and without various doses of Domperidone drug was utilized to measure the, \( E'_a \), entropy, \( \Delta S'_a \) and enthalpy of activation, \( \Delta H'_a \) from the following equations:

\[
\log CR = \frac{E'_a}{RT} + A \tag{4}
\]

and its formulation alternative named transition state equation:

\[
CR = \frac{RT}{N}\exp\left(\frac{-\Delta S'_a}{R}\right)\exp\left(-\frac{\Delta H'_a}{RT}\right) \tag{5}
\]
down in total volume [26]. We remark that $E^*_a$ and $\Delta H^*_a$ data vary in similar way with the drug dose this result permits to verify the known thermodynamic among $E^*_a$ and $\Delta H^*_a$ characterizing unimolecular reaction [27]:

\[ E^*_a - \Delta H^*_a = RT \] (6)

The measured data are too near to RT is 2.62kJ mol$^{-1}$. This result given the inhibitor play equally on $E^*_a$ and $\Delta H^*_a$. The negative sign of $\Delta S^*_a$ lead higher order produced during the activation process. This can be achieved by the formation of activated complex and represents association rather than the dissociation step [28].

**Adsorption isotherms study**

Adsorption isotherm is important to research the mechanism of reaction and also the characteristics of adsorption. Usually information about the kind of adsorption physisorption, chemisorption or comprehensive adsorption of the inhibitor on the CS surface, the tested value have been occurred with many adsorption isotherms to fit surface coverage value to classical isotherms of Frumkin, Temkin, Langmuir, and kinetic-thermodynamic isotherms. The Domperidone drug adsorptions on the CS follow Langmuir adsorption isotherm and kinetic-thermodynamic model.

**Langmuir adsorption isotherm:** Figure 5 & 6 give the relation among $C/\theta$ and $C$ of the Domperidone drug in HCl on the CS surface (isotherm Langmuir). Langmuir adsorption model postulates [29] that:

i) There is no reaction among the molecules adsorbed,

ii) The energy of adsorption not depends on $(\theta)$ and

iii) Maximum adsorption corresponds to the saturated monolayer.

The Langmuir equation can be described by equation (7) indicating that only one molecule could be adsorbed on one adsorption site.

\[ \frac{C}{\theta} = \frac{1}{K_{\text{ad}}} + C \] (7)

### Table 4: Activation parameters for CS dissolution with and without various doses of Domperidone drug in 1M HCl.

| Conc, M  | $\Delta S^*_a$, J mol$^{-1}$ K$^{-1}$ | $\Delta H^*_a$, J mol$^{-1}$ K$^{-1}$ | $E^*_a$, J mol$^{-1}$ K$^{-1}$ | $E^*_a - \Delta H^*_a$ |
|----------|----------------------------------|----------------------------------|--------------------------------|--------------------------|
| 1M HCl   | 186                              | 26.26                            | 28.87                          | 2.61                     |
| $7 \times 10^{-4}$ | 167                              | 34.97                            | 37.58                          | 2.62                     |
| $1.4 \times 10^{-3}$ | 159                              | 37.96                            | 40.58                          | 2.62                     |
| $2.8 \times 10^{-3}$ | 155                              | 39.78                            | 42.4                           | 2.62                     |
| $5.6 \times 10^{-3}$ | 143                              | 44.19                            | 46.81                          | 2.62                     |
| $8.4 \times 10^{-3}$ | 127                              | 49.84                            | 52.46                          | 2.62                     |
| $1.12 \times 10^{-4}$ | 10                               | 58.16                            | 60.79                          | 2.63                     |

The measured data are too near to RT is 2.62kJ mol$^{-1}$. This result given the inhibitor play equally on $E^*_a$ and $\Delta H^*_a$. The negative sign of $\Delta S^*_a$ lead higher order produced during the activation process. This can be achieved by the formation of activated complex and represents association rather than the dissociation step [28].

### Figure 4 : (log CR/T Vs.1000/T) for CS in 1M HCl with and without different doses of Domperidone drug.

### Figure 5 : Langmuir isotherm plotted as $C/\theta$ vs. Conc. of Domperidone drug for the corrosion of CS in 1 M HCl at 25°C.

### Figure 6 : Kinetic model plotted as log ($\theta/1- \theta$) vs. log $C$ of Domperidone drug for the CS corrosion in 1M HCl at 25°C.
Where Θ=Degree of Coverage, C=Drug Dose in the Bulk of Solution and \( K_{ads} \)=Constant Equilibrium for the Adsorption Process, which given from the intercept of the lines and its data is illustrated in Table 5 and it is due to the \( \Delta G^o_{ads} \) by follow:

\[
K_{ads} = \frac{1}{55.5 \exp \left( -\Delta G^o_{ads} / RT \right)} \quad (8)
\]

| Table 5: \( K_{ads} \), \( \Delta G^o_{ads} \) and of active center number \( (1/y) \) and \( y \) number of inhibitor molecules occupying one active site for drug adsorbed of on CS at unlike temperatures. |
|---|---|---|---|---|---|
| Temp °C | \( K_{ads} \times 10^4 \text{M}^{-1} \) | \( -\Delta G^o_{ads} \text{kJ mol}^{-1} \) | \( R_L \) | \( 1/Y \) | \( -\Delta G^o_{ads} \text{kJ mol}^{-1} \) | \( K_{ads} \times 10^4 \text{M}^{-1} \) |
| 25 | 24.21 | 40.7 | 0.99 | 1.54 | 0.65 | 49 | 68.15 |
| 35 | 22.86 | 41 | 0.99 | 1.53 | 0.65 | 44.7 | 63.24 |
| 45 | 20.65 | 43 | 0.99 | 1.52 | 0.66 | 44.5 | 59.01 |
| 55 | 18.36 | 44 | 0.99 | 1.51 | 0.66 | 44.3 | 53.56 |

Where 55.5=water molar dose in the solution. Besides, the fundamental characteristic isotherm Langmuir can be communicated in term of a dimensionless separation partition factor, \( R_L \) [30], which describes the kind of isotherm and given by:

\[
R_L = 1 / \left( 1 + K C \right) \quad (9)
\]

The lower \( R_L \) data led to maximum adsorption favorable. If \( RL>1 \) unfavorable, \( 0<R_L<1 \) favorable \( R_L=1 \) linear, and if \( R_L=0 \) irreversible [31]. Table 5 shows the estimated data of \( R_L \) for Domperidone drug at various dose and unlike temperatures. It was found that all \( R_L \) data are less than unity confirming that the adsorption processes is favorable i.e. its fixation capacity grows rapidly with dose in equilibrium in liquid phase.

**Kinetic thermodynamic model**

According to the kinetic thermodynamic model the adsorption isotherm relationship is represented by the equation (10):

\[
\log \left( \frac{\Theta}{1 - \Theta} \right) = y \log C + \log K^\dagger \quad (10)
\]

Where \( y \)= number of molecules drug presence on active center of the metal surface and \( 1/y = \) number of active center made by one drug molecule. Values of \( y>1 \) implies the formation of multilayers of drug on the surface of CS. Data of \( y<1 \) mean a drug molecules obtain will occupy more than one active center.

Table 5 reveals that the data of \( K_{ads} \) lower by temperature rise, this lead to the binding power of the drug to the metal surface lower with raising temperature. Such habit can be interpreted on the basis that improve temperature results in desorption of some molecules of the Domperidone from the metal surface [32]. Maximum data of \( K_{ads} \) mean excellent protection efficiency of the inhibitor, i.e., higher electrical interaction among the adsorbing molecules and presence of double-layer at the boundary phase.

The data of the \( \Delta G^o_{ads} \) in most samples are negative. The \(-ve\) data signify a spontaneous adsorption of the drug molecules and stability of the adsorption layer. Usually, data of \( \Delta G^o_{ads} \) up to -20kJ mol\(^{-1}\) are consistent with electrostatic reaction among a charged metal and molecules[which given physical adsorption] while those more negative than -40kJ mol\(^{-1}\) contain charge sharing or change from the inhibitor molecules to the surface of metal to form a co-ordinate kind bond, which given chemisorption [33]. Outcome attendance in Table 5 led to that the data of \( \Delta G^o_{ads} \) for all models studied lie between -40.7 and -45.9kJ mol\(^{-1}\), given the mechanism of adsorption by Domperidone tested may be mixed one (chemisorption and physisorption). The values of \( \Delta H^o_{ads} \) obtained by plot of \( \ln K_{ads} \) against 1000/T the slope of the straight line is \( -\Delta H^o_{ads}/R \). In the present case; the values of \( \Delta H^o_{ads} \) obtained in this study was -7.5kJ mol\(^{-1}\) and lower than (40kJ mol\(^{-1}\)), this indicative of physisorption [34]. Moreover, physisorption was judging from the lower of %IE with temperature improves [35]. From represent obtained results indicate that the process of inhibition used in this reaction is mixed physisorption and chemisorptions process.

But, values of other thermodynamic parameter as \( \Delta H^o_{ads} \) can supplementary knowledge about the corrosion protection mechanism. Generally \( +ve \) data of \( \Delta H^o_{ads} \) led to that the adsorption of drug is an exothermic while a positive value of \( \Delta H^o_{ads} \) is endothermic. Generally, an exothermic process signifies either physisorption or chemisorption while process endothermic is unequivocally attributable to chemisorption [36]. In an exothermic process, physisorption is characteristic from chemisorption by considering the absolute data of \( \Delta H^o_{ads} \) for the physisorption process which is break down than 40kJ mol\(^{-1}\) while that for chemisorption process arrive to 100kJ mol\(^{-1}\) [37]. Van’t Hoff equation was utilized to get more \( \Delta H^o_{ads} \) adsorption enthalpy.

\[
\ln K_{ads} = -\frac{\Delta H^o_{ads}}{RT} + \text{constant} \quad (12)
\]

**PP measurements**

The anodic and cathodic PP curves of the CS in 1M HCl with
Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

and without various doses of Domperidone drug are shown in Figure 7. Electrochemical corrosion kinetic parameters obtained by PP method such as current corrosion densities (\(i_{corr}\)), corrosion potentials (\(E_{corr}\)), Tafel slopes cathodic and anodic (\(b_a\), \(b_c\)) and protection efficiency [%IE] are illustrated in Table 6. The corrosion current and corrosion rate decreased with increasing Domperidone, consequently, the inhibition efficiency increases, reaching a maximum value of 94.9% at 1.12x10^{-5} M of Domperidone. This is due to the blocked fraction of the metal surface by adsorption, this can be attributed to the presence of electron-donating groups (\(\pi\)-electrons on aromatic ring, O, N) in Domperidone that can react with the metal surface and protect it from the attack [38]. The obtained data revealed that addition of Domperidone in 1M HCl solution lower the anodic dissolution of CS and also prevent the cathodic hydrogen evolution reaction. Also, the shift in \(E_{corr}\) from the blank solution was about 13mV less than 85mV, indicating that Domperidone plays as a mixed-type inhibitor [39], in addition to the values of \(b_a\) and \(b_c\) are approximately constant. Thus protection of corrosion in 1M HCl solution is merely due to the blocking of surface active sites by adsorption.

Table 6: Electrochemical parameters given from polarization curves for CS in 1M HCl with and without various doses of Domperidone at 25°C.

| [Inh.], M | \(-E_{corr}\), mV SCE | \(i_{corr}\), mA cm\(^{-2}\) | [%IE] | CR mmy\(^{-1}\) | \(b_a\), mV dec\(^{-1}\) | \(-b_c\), mV dec\(^{-1}\) |
|-----------|----------------------|----------------------|-------|----------------|-----------------|----------------|
| 1 M HCl   | 11.4415              | 70                   | 40.1  | 60             | 69              |
| 7.0x10^{-5} | 244                 | 3.4291              |       |               |                 |
| 1.4x10^{-5} | 247                 | 2.4975              | 78.2  | 29.21          | 51              | 120          |
| 2.0x10^{-5} | 239                 | 1.9517              | 82.9  | 22.82          | 30              | 117          |
| 5.6x10^{-5} | 240                 | 1.5116              | 86.8  | 17.67          | 33              | 111          |
| 8.4x10^{-5} | 265                 | 1.0803              | 90.6  | 12.63          | 69              | 111          |
| 1.12x10^{-4} | 263                | 0.5894              | 94.9  | 6.89           | 47              | 67           |

**EIS tests:** The results obtained can be illustrated in terms of the equivalent circuit (Figure 8) which was utilized with preceding model the C/acid interface [40]. Figure 9a & b displays the Nyquist (a) and Bode (b) digrams for CS in solution of HCl with and without various doses of Domperidone drug. Figure 9a shows; the semicircle with drug is higher than that in the Blank. Figure 9b shows the Bode plots which gave only one capacitive time constant and one well resolved peak. The electrochemical parameters were calculated and are listed in Table 7 which indicates that the charge transfer resistance (\(R_{ct}\)) % IE increased while double layer capacitance (\(C_d\)) is decreased by increasing Domperidone dose. This is due to the lower in local dielectric constant and/or an increase in the electrical double layer thickness, suggesting that Domperidone molecules function by solution/interfac adsorption [41]. It could be assumed that the lowering of \(C_d\) data is caused by the replacement gradual of water molecules by adsorption of Domperidone molecules on the surface of electrode, which lower the extent of dissolution.

**AFM analysis**

The advantage of this method is that the roughness of the surface can be determined. Figure 10a shows 3d AFM image of CS coins before immersion in the corrosive medium with roughness 14.1nm. Figure 10b is an image obtained for CS coins after immersion in 1M HCl solution with roughness 392.6nm. Figure 10c is the image of CS after immersion in 1M HCl + 300ppm of drug with roughness 289.0nm. The lower value of roughness in the presence of drug as compared to its absence indicates the adsorption of drug molecules on CS surface, and hence inhibit the corrosion process.

**Citation:** Fouda AS, El Morsi MA, El-Mogy T (2017) Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug. J Anal Pharm Res 5(5): 00153. DOI: 10.15406/japhr.2017.05.00153
Mechanism of inhibition

Generally, Corrosion inhibition mechanism in acid medium is the adsorption of inhibitor onto the metal surface. As far as the inhibition process is concerned, it is generally assumed that adsorption of the inhibitor at the metal/solution interface is the first step in the action mechanism of the inhibitors in aggressive acid media. Four types of adsorption may take place during inhibition involving organic molecules at the metal/solution inter-face: [44] electrostatic attraction between charged molecules and the charged metal, [45] interaction of unshared electron pairs in the molecule with the metal, [46] interaction of π-electrons with the metal, and a combination of the above [47]. The extent of adsorption of an inhibitors depended on the number of adsorption sites and their charge density, molecular size, heat of hydrogenation, mode of interaction with the metal surface, and the formation metallic complexes [48].

The inhibitory action of Domperidone drug may be due to any or combination of the above mechanisms. The higher IE may be due to the large molecular weight of the compound which covered wider surface of the CS. Corrosion inhibition of CS in 1M HCl by Domperidone can be explained on the basis that the CS surface acquires positive charge in the acid medium [49]. It is believed that the Cl⁻ ions could be specifically adsorbed on the metal surface and creates an excess of negative charge on the surface, then the protonated Domperidone can be in the acid medium.

Table 7: Impedance parameters for CS corrosion with and without various doses of Domperidone drug at 25ºC.

| Conc, M | $R_p$, ohm cm² | $C_{dl}$, x10⁻⁵ μF cm⁻² | $\Theta$ | %IE |
|---------|----------------|--------------------------|--------|-----|
| 1 M HCl | 36.81          | 167.6                    | ----  | ----|
| 7.0 x 10⁻⁶ | 129.3          | 161                      | 0.715 | 71.5 |
| 1.4 x 10⁻⁵ | 173.8          | 129.6                    | 0.788 | 78.8 |
| 2.8 x 10⁻⁵ | 216.6          | 89.4                     | 0.83  | 83   |
| 5.6 x 10⁻⁵ | 291            | 84.9                     | 0.874 | 87.4 |
| 8.4 x 10⁻⁵ | 409.5          | 80.7                     | 0.91  | 91   |
| 1.12 x 10⁻⁴ | 696.8          | 63                       | 0.947 | 94.7 |

Table 8: EFM spectra of CS corrosion with and without various doses of Domperidone drug at 25ºC.

| Conc, M | $i_{corr}$, mA cm⁻² | $\beta_1$, mV Dec⁻¹ | $-\beta_2$, mV Dec⁻¹ | CR mpy | CF-2 | CF-3 | %IE |
|---------|---------------------|---------------------|---------------------|--------|------|------|-----|
| Blank   | 470.1               | 91                  | 106                 | 214.8  | 2.02 | 3.5  | ----|
| 7 X 10⁻⁶ | 133.5              | 86                  | 125                 | 61     | 1.94 | 3.43 | 71.6 |
| 1.4 X 10⁻⁵ | 100.4              | 91                  | 120                 | 45.89  | 2.19 | 2.39 | 78.6 |
| 2.8 x 10⁻⁵ | 83.98              | 81                  | 121                 | 38.37  | 2.02 | 5.74 | 82.2 |
| 5.6 X 10⁻⁵ | 57.56              | 107                 | 115                 | 26.3   | 1.92 | 1.74 | 87.8 |
Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug

| Concentration | Inhibition Efficiency |
|---------------|----------------------|
| 8.4 X 10^-5   | 38.7                 |
| 1.12 X 10^-4  | 23.71                |
| 1.76          | 79                   |
| 1.91          | 86                   |
| 2.41          | 10.83                |
| 91.8          | 1.94                 |
| 2.46          | 72                   |
| 95            |                      |

Conclusion

The outcome given from various tests such as WL, PP, EIS, EFM, measurements and FT-IR showed that Domperidone drug protect corrosion of CS in molar HCl and results obtained from this study are reproducible. It exhibited a maximum inhibition efficiency mean value obtained from our different measurements of 94.8 % at 1.12x10^-4 concentration. Tafel curves give that Domperidone is a mixed kind. The inhibition of CS corrosion by Domperidone can be attributed to the adsorption ability of drug molecules onto the reactive sites of the metal surface. The process of inhibition used in this reaction is mixed physiosorption and chemisortions process. The Domperidone improve the time needed for CS to consume half of its original amount.

References

1. Grandsis JR, Yu VL (2016) Malignant (necrotizing) external otitis. In: Post TW (Eds.), Waltham, USA.
2. Johnson AK, Batra PS (2014) Central skull base osteomyelitis: an emerging clinical entity. Laryngoscope 124(5): 1083-1087.
3. Lee S, Hooper R, Fuller A, Turlakow A, Cousins V, et al. (2008) Otogenic cranial base osteomyelitis: a proposed prognosis-based system for disease classification. Otology & neurotology: official publication of the American Otological Society. American Neurotology Society [and] European Academy of Otology and Neurotology 29(5): 666-672.
4. Sneepada GS, Kwartler JA (2003) Skull base osteomyelitis secondary to malignant otitis externa. Curr Opin Otolaryngol Head Neck Surg 11(5): 316-323.
5. Chen CN, Chen YS, Yeh TH, Hsu CJ, Tseng FY (2010) Outcomes of malignant external otitis: survival vs mortality. Acta oto-laryngol 130(1): 89-94.
6. Leventhal D, Wilcox TO, Evans J, Finden SG (2011) Bilateral skull base osteomyelitis in an immunocompetent patient. Ear Nose Throat J 90(12): E23-E26.
7. Prasad KC, Prasad SC, Mouli N, Agarwal S (2007) Osteomyelitis in the head and neck. Acta oto-laryngol 127(2): 194-205.
8. Gruver A, Hudson I, Sampowski G (2007) Immunosenescence of ageing. J Pathol 211(2): 144-156.
9. Geiger H, Rudolph KL (2009) Aging in the lympho-hematopoietic stem cell compartment. Trends in immunology 30(7): 360-365.
10. Ogawa T, Kitagawa M, Himokawa K (2000) Age-related changes of human bone marrow: a histometric estimation of proliferative cells, apoptotic cells, T cells, B cells and macrophages. Mech Ageing Dev 117(1-3): 57-68.
11. Blyth CC, Gomes L, Sorrell TC, da Cruz M, Sud A, et al. (2011) Skull-base osteomyelitis: fungal vs. bacterial infection. Clin Microbiol Infect 17(2): 306-311.
12. Patmore H, Jebruel A, Uppal S, Raine CH, McWhinnie P (2010) Skull base infection presenting with multiple lower cranial nerve palsies. Am J Otolaryngol 31(5): 376-380.
13. Ridder GJ, Breunig C, Kaminsky J, Pfeiffer J (2015) Central skull base osteomyelitis: new insights and implications for diagnosis and treatment. European archives of oto-rhino-laryngology 272(5): 1269-1276.
14. Kraus DH, Rehm SJ, Kinney SE (1988) The evolving treatment of necrotizing external otitis. The Laryngoscope 98(9): 934-939.
15. Stokkel MP, Boot CN, van Eck-Smit BL (1996) SPECT gallium scintigraphy in malignant external otitis: initial staging and follow-up. Case reports. Laryngoscope 106(3 Pt 1): 338-340.
16. Clark MR, Pretorius PM, Byren I, Milford CA (2009) Central or atypical skull base osteomyelitis: diagnosis and treatment. Skull Base 19(4): 247-254.
17. Okpala NC, Siraj QH, Nilsson E, Pringle M (2005) Radiological and radionuclide investigation of malignant otitis externa. J Laryngol Otol 119(1): 71-75.
18. Chalub G, Van Fleet R, Guinto FC, CwnwWN, Martinez L, et al. (1992) MR imaging of chalazal and paracanal lesions. AJR Am J Roentgenol 159(5): 1069-1074.
19. Sharma P, Agarwal KK, Kumar S, Singh H, Bal C, et al. (2013) Utility of (99m)Tc-MDP hybrid SPECT-CT for diagnosis of skull base osteomyelitis: comparison with planar bone scintigraphy, SPECT, and CT. Jpn J Radiol 31(2): 81-88.
20. Adams A, Offiah C (2012) Central skull base osteomyelitis as a complication of necrotizing otitis externa: Imaging findings, complications, and challenges of diagnosis. Clin Radiol 67(10): e7-e16.
21. Levin WJ, Shary JH, Nichols LE, Lucente FE (1986) Bone scanning in severe external otitis. Laryngoscope 96(11): 1193-1195.
22. Sorsdahl OA, Goodhart GL, Williams HT, Hanna LJ, Rodriguez J (1993) Quantitative bone gallium scintigraphy in osteomyelitis. Skeletal Radiol 22(4): 239-242.

Citation: Fouda AS, El Morsi MA, El-Mogy T (2017) Investigation of the Inhibition of Carbon Steel Corrosion in Hydrochloric Acid Solutions by Domperidone Drug. J Anal Pharm Res 5(5): 00153. DOI: 10.15406/japlr.2017.05.00153