

## **ELECTROCHEMICAL STUDY OF THE CORROSION INHIBITION OF MILD STEEL IN HYDROCHLORIC ACID BY AMLODIPINE DRUG**

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### **ABSTRACT**

*The inhibition of mild steel corrosion in acidic medium inhibited by amlodipine at room temperature (30°C) was monitored via the linear polarization resistance electrochemical technique using a variable voltage, DC power supply (AC mV metre, 2channel model GVT 427). The concentration of the acid medium was maintained at 0.1M HCl throughout the experiment. The inhibition efficiency was found to increase with increase in the concentration of the drug in the corrosive medium. The highest polarization resistance ( $R_p$ ) ( $1083\Omega\text{cm}^2$ ) was obtained at the highest inhibitor concentration ( $10.0\times 10^{-3}\text{M}$ ) while the lowest  $R_p$  ( $567\Omega\text{cm}^2$ ) was recorded against the lowest inhibitor concentration ( $2.5\times 10^{-3}\text{M}$ ). The adsorption mode of the drug was found to be by monolayer chemisorptions having found the experimental data obeyed the Langmuir adsorption isotherm.*

**Keywords:** Linear polarization resistance (LPR), Corrosion inhibition, Mild steel, Amlodipine, HCl.

### **Contribution/ Originality**

This study documents the investigation of acid corrosion inhibition of mild steel by amlodipine drug, newly screened using a simple and rapid classical electrochemical method based on current/voltage determinations and further treatment of the data from the linear polarization resistance curves.

### **1. INTRODUCTION**

Due to certain chemical and physical processes that take place within the surrounding environment of metals, their dissolution has become inevitable [1]. To reduce this undesirable consequence, some chemical substances have been used to contain corrosion to a considerable extent. Most well known corrosion inhibitors are organic compounds containing nitrogen, sulphur, oxygen and phosphorus in their molecular structures [2]. The efficiency of an organic inhibitor has been related to its ability to be adsorbed on the metal surface replacing water molecules, which are carriers of corrosive species, on the corroding metal surface and this according to Ouali, et al. [3] is depicted in the equation of reaction as shown below:



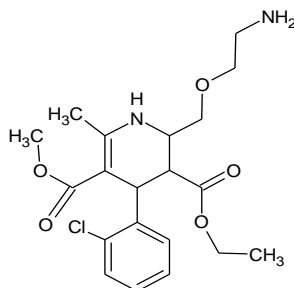
However, a good number of organic inhibitors are expensive and hazardous [4]. This has ignited interests in “green-inhibitors”; corrosion inhibitors which are environmentally friendly and sufficiently available at low cost. Several studies have shown that drugs may provide suitable inhibition against metallic corrosion [5-9]. For example the use of sulfa drugs [10], antifungal drugs [11], and antibacterial drugs [12, 13] as probable corrosion inhibitors have been reported. It is based on this that the authors, in the present work, presents an investigation of the inhibitive effect of amlodipine drug as a corrosion inhibitor for mild steel in acidic medium monitored via an electrochemical method similar to a recently reported work [14].

## 2. EXPERIMENTAL

### 2.1. Inhibitor

The drug employed in this study was amlodipine. It is an antihypertensive drug. It however has other medicinal uses. The systematic (IUPAC) nomenclature of the drug is (R<sub>S</sub>)-3-ethyl-5-methyl-2-[(2-aminoethoxy)methyl]-4-(2-chlorophenyl)-6-methyl-1,4-dihydropyridine-3,5-dicarboxylate and has a molecular formula C<sub>20</sub>H<sub>25</sub>ClN<sub>2</sub>O<sub>5</sub> with molecular weight 408.876g/mol. It has the chemical structure as shown in Figure 1 below:

**Figure-1.** Chemical structure of amlodipine drug



The tablets of amlodipine were obtained from a local drug shop sold under the trade name “Amlovar.” The drug was used without further purification. Different concentrations of the drug were prepared by dissolving appropriate quantities of the tablets. From the mass of the drug sample and its molecular weight relation, appropriate concentrations of the drug were prepared by dilution with doubly distilled water.

### 2.2. Corrosive Medium

The corrosive solution was prepared from reagent grade of HCl by dilution using doubly distilled water without further purification. The concentration of the solution ranged from 0.0025M to 0.010M.

### 2.3. Mild Steel Specimen

Mild steel (98% Fe) used for this investigation was obtained and identified locally. The metal sheets were mechanically press cut into rectangular coupons of about 3cm by 3cm. The thickness of the metal was 0.1cm. In the electrochemical measurements, the working electrode was cut from the mild steel. The coupons were used after polishing with emery papers. They were degreased in acetone, washed with double distilled water and finally dried in an oven.

### 2.4. Electrochemical Measurements

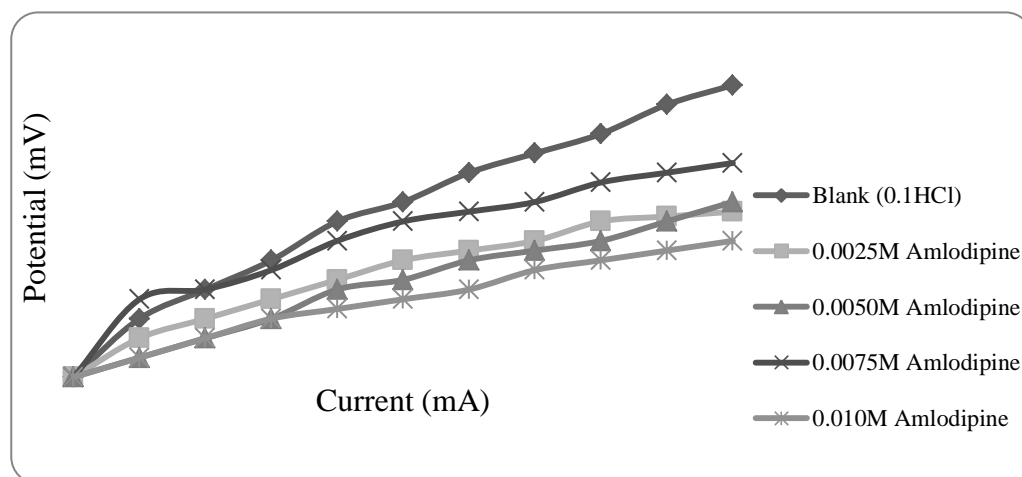
A conventional three-electrode system consisting of mild steel as working electrode, carbon as an auxiliary electrode, and saturated calomel electrode (SCE) as reference electrode were used for the measurements. The corrosion potential of the test mild steel coupons was monitored using a variable voltage, DC power supply (AC mV metre, 2channel model GVT 427). The potential change of the working electrode which occurred as a consequence of the external current was measured by means of the reference electrode (SCE) and a voltmeter. A detailed description of this method has been previously reported by [Wilde and Williams \[15\]](#).

## 3. RESULTS AND DISCUSSIONS

### 3.1. Linear Polarization Resistance

In this technique, the values of change in current as a result of applied potential obtained from electrochemical measurements are used. Useful data are obtained from the slopes extrapolated from the initial linear region of the polarization curves of the potential versus current plots [\[16\]](#). After measuring the currents and potentials, a plot of the parameters measured for mild steel as the working electrode immersed in 0.1M HCl containing different concentrations of the inhibitor is presented in Figure 2.

**Figure-2.** The variation of applied potential and current change for mild steel corrosion in 0.1M HCl in the presence and absence of different concentrations of the inhibitor.



With the help of equation 1, the polarization resistances ( $R_p$ ) were computed from the slopes of the initial regions of the polarization curves [17].

$$R_p = A \times (\text{slope of plot of } E \text{ versus } I) \quad 1$$

where A is the surface area of the electrode, E is the potential and I is the current.

The corrosion current densities ( $I_{corr}$ ) were calculated from equation 2 [18, 19]. This was done to help give an insight into the extent of corrosion.

$$I_{corr} = \frac{B}{R_p} \quad 2$$

where B is a proportionality constant, which equals 0.026V for a particular system [19].

The computation of  $I_{corr}$  gave access to the estimation of the percentage corrosion inhibition efficiency (%IE) via equation 3 [17].

$$\%IE = \frac{I_{corr}^0 - I_{corr}}{I_{corr}^0} \times 100 \quad 3$$

where  $I_{corr}^0$  and  $I_{corr}$  are the corrosion current densities in the absence and presence of the inhibitor.

As seen from Table 1, the values of the corrosion current densities ( $I_{corr}$ ) obtained for mild steel corrosion were higher in the free acid medium –meaning that corrosion rate was higher there– than in the solution containing different concentrations of the inhibitor. Also, it can be seen that the polarization resistance obtained for mild steel in the free acid solution as well as those containing different concentrations of the inhibitor indicate that the drug significantly increased the resistance of the metal against corrosion.

**Table-1.** Corrosion parameters obtained from polarization measurements for mild steel in 0.1M HCl in the presence and absence of different concentrations of the inhibitor at 30°C.

System/Concentration	$R_p$ ( $\Omega\text{cm}^2$ )	$I_{corr}$ (mA/cm <sup>2</sup> )	Degree of surface coverage ( $\theta$ )	%IE
Blank (0.1M HCl)	567	0.0459	-	-
$2.5 \times 10^{-3}$ M Amlopidine	940	0.0276	0.3972	39.73
$5.0 \times 10^{-3}$ M Amlopidine	944	0.0275	0.3995	39.95
$7.5 \times 10^{-3}$ M Amlopidine	1005	0.0259	0.4360	43.60
$10.0 \times 10^{-3}$ M Amlopidine	1083	0.0240	0.4770	47.70

When the metal specimen stops, it apparently stops corroding, the polarization resistance increases as the inhibition move towards maximum [16]. The experimental data showing the relationship between the polarization resistance ( $R_p$ ) and corrosion current densities ( $I_{corr}$ ) are consistent with the known theoretical basis for the method employed; that. Corrosion current density has an inverse relationship with polarization resistance. The inhibition efficiencies as shown in Table 1 indicate that the polarization resistance increased with as concentration of the inhibitor increased.

### 3.2. Adsorption Isotherm

The inhibitory effect of organic compounds has been attributed to effective adsorption on the metal surfaces. The adsorption may be influenced by the nature and charge of the metallic surface, the type of the corrosive medium and the molecular structure of the inhibitor [20, 21]. The values of the degree of surface coverage ( $\theta$ ) at different concentrations obtained using equation 4 [17] have been used to determine the adsorption process. The adsorption modes are usually confirmed from the fit of experimental data into the various adsorption isotherms.

$$\theta = 1 - \frac{(I_{corr})_{inhibited}}{(I_{corr})_{uninhibited}} \quad 4$$

where  $I_{corr}$  and  $I_{corr}^0$  are the corrosion current densities in the presence and absence of the inhibitor respectively.

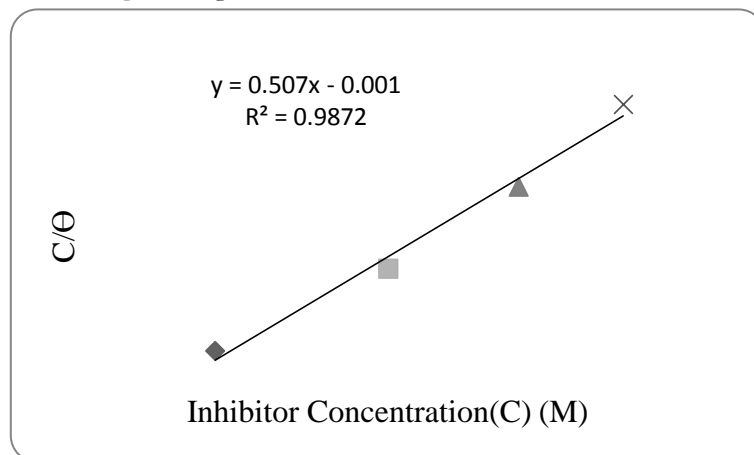
Within the conditions of the investigation, the best correlation between the experimental results and the isotherm functions was obtained using the Langmuir adsorption isotherm. The Langmuir adsorption isotherm for monolayer chemisorptions is given by equation 5 [22]

$$\frac{C}{\theta} = 1/k + C \quad 5$$

where  $C$  is the concentration of the corrosion inhibitor,  $\theta$  is the degree of surface coverage and  $k$  is the adsorption equilibrium constant.

The plot of  $C/\theta$  against  $C$  gave a straight line as shown in Figure 3. It was found that the linear correlation coefficient is close to 1.00. The isotherm confirms Langmuir adsorption isotherm, suggesting monolayer chemisorptions of amlodipine [22].

**Figure-3.** Langmuir adsorption isotherm for mild steel in 0.1M HCl containing various concentrations of amlodipine drug as inhibitor.



### 4. CONCLUSIONS

From the results of the study the following may be concluded:

1. Amlodipine drug significantly increased the resistance of the mild steel against corrosion in 0.1M solution and therefore can be employed as an environmentally safe, cost effective and easily accessible corrosion inhibitor for the metal.
2. The inhibition efficiency increased with increase in the concentration of the inhibitor.
3. The adsorption process of amlodipine on mild steel in HCl solution was found to obey the Langmuir adsorption isotherm.
4. The inhibitory action of the compound signifies the action of its molecular structure.

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