

Antibiotic Derivative as Corrosion Inhibitor for Mild Steel in Aqueous Environment

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Abstract: The inhibition efficiency of antibiotic derivative toward the corrosion behavior of mild steel using aqueous environment was studied using weight loss method and potentiodynamic polarization techniques. The obtained result revealed that the drug performed well as corrosion inhibitor in aqueous environment. The inhibition efficiency increased with increasing inhibitor concentration. The highest inhibition occurs through adsorption of the Inhibitor molecule on the metal surface without modifying the mechanism of corrosion process. The adsorption of these compound on mild steel follows Langmuir adsorption isotherm. Polarisation curves indicate that investigated antibiotic are mixed type inhibitor.

Key words: Mild steel, corrosion, antibiotic agent, neomycin tri sulphate, potentiodynamic polarization, inhibition

INTRODUCTION

Several methods used currently to reduce corrosion of mild steel. One of such methods is the use of pharmaceutical drugs. Chemical inhibitors play an important role in the protection and mitigation strategies for retarding corrosion. The most effective and efficient inhibitors are the organic compounds that have pi bonds, heteroatom (P, S, N and O) and inorganic compounds, such as chromate, dichromate, nitrite and so on (Shukla *et al.*, 2009). However, the use of these compounds has been questioned lately, due to the several negative effects they have caused in the environment (Shukla and Quraishi, 2009). Thus, the development of the novel corrosion inhibitors of natural source and non-toxic type has been considered to be more important and desirable (Naggar, 2007). Because of their natural origin, as well as their non-toxic characteristics (Fouda *et al.*, 2010) and negligible negative impacts on the aquatic environment (Ahamad and Quraishi, 2010), drugs (chemical medicines) seem to be ideal candidates to replace traditional toxic corrosion inhibitors. These molecules depend mainly on the certain physical properties of the inhibitor molecule such as functional group, steric factors, electron density at the donor atoms and electronic structure of the molecules. Regarding the adsorption of the inhibitor two types of interaction are responsible. One is physical adsorption which involves electrostatic charge between ionic charge and metal solution interface (Singh and Quraishi, 2011). Other which involves charge transfer from inhibitor molecule to the metal surface. The inclination towards eco-friendly

corrosion inhibitors development intersects across several goals of pharmaceutical research, one of which is to discover or develop molecules with desired biological activity. The present study is aimed at investigating the inhibitory effect of neomycin tri sulphate for mild steel corrosion of in aqueous environment.

MATERIALS AND METHODS

Specimen preparation: According to ASTM method as reported already (Dubey and Potdar, 2009), cold rolled mild steel strips were cut into pieces of 5×1 cm having the following composition (in percentage) % C = 0.017; Si = 0.007; Mn = 0.196; S = 0.014; P = 0.009; Ni = 0.013; Mo = 0.015; Cr = 0.043 and Fe = 99.686 was used. The samples were polished, drilled a hole at one end and numbered by punching. During the study the samples were polished with various grades of SiC abrasive papers (from grits 120-1200) and degreased using Acetone.

Preparation of solutions: All the solutions were prepared using NICE brand analar grade chemicals in double distilled water and bubbling purified by nitrogen gas for 30 min to carry out de-aeration of the electrolytes.

Preparation of inhibitor: Various concentration of inhibitor was prepared on the basis Le Chatlier's principle.

Weight loss measurement: Mild steel specimens were immersed 1 M KCl for 2 h at room temperature (28±2°C) for each inhibitor concentration. Then the specimens were

Table 1: Data of weight loss measurement for mild steel in 1 M KCl in the absence and presence of different concentration of investigate compounds at 2 h

Inhibitor	Concentration of inhibitor M	Corrosion rate	Inhibition efficiency (%)
Neomycin	Blank	17.0	-
Tri sulphate	1×10^{-4}	13.5	20.7
	2×10^{-4}	11.7	31.2
	3×10^{-4}	9.3	45.3
	4×10^{-4}	6.8	60.2
	5×10^{-4}	6.0	64.7

removed, rinsed in double distilled water, acetone and the loss in weight of the specimen was determined. From this, the Inhibition Efficiency (IE %) was calculated using the equation:

$$IE\% = \frac{W_o - W_i}{W_o} \times 100$$

where, W_o and W_i (in g) are the values of the weight loss observed of mild steel in the absence and presence of inhibitor respectively.

Potential dynamic polarisation: The behavior of mild steel coupons with and without the extracts was investigated by potentiodynamic polarization plots. Analysis was performed in the standard solution containing varied concentrations of the inhibitor by changing the potential from -250 to +250 mV at a scan rate of 1 mV s^{-1} (Pang *et al.*, 2008). Corrosion current densities were obtained from the linear Tafel plots and the inhibition efficiency evaluated from the measured I_{corr} values obtained using below equation:

$$IE\% = \frac{I_{o_{\text{corr}}} - I_{i_{\text{corr}}}}{I_{o_{\text{corr}}}} \times 100$$

where, $I_{o_{\text{corr}}}$ and $I_{i_{\text{corr}}}$ represent the corrosion current density with and without the inhibitor concentrations.

RESULTS AND DISCUSSION

Weight loss method: From Table 1, it is clear that the corrosion rate was decreased with increasing concentration of inhibitor and inhibition efficiency increased with increasing the concentration of the inhibitor (Naggar, 2007). In addition, the maximum corrosion inhibition efficiency of neomycin tri sulphate for mild steel in 1 M KCl 64.7%, respectively at 5×10^{-4} of the inhibitor solution for 2 h at room temperature (Fig. 1).

Adsorption isotherm: In aqueous solution, the metal surface was always covered with absorbed molecule. Therefore, the adsorption of inhibitor molecule from an

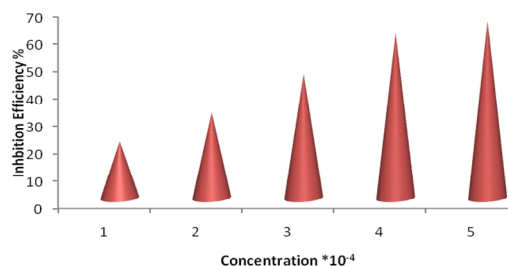


Fig. 1: Weight loss curve for Mild steel in 1 M KCl in the presence and the absence of different concentration Neomycin trisulphate at 2 h

aqueous solution is a quasi substituted process and the inhibitor that have the ability to adsorb strongly on the metal surface will hinder the dissolution reaction of such metal in the corrosive medium. The degree of surface coverage is considered as the determining factor which plays the main role in inhibition efficiency. The extend of adsorption depends on many factors such as the nature of metal, condition of metal surface, the chemical structure of inhibitor molecule, the nature of its functional groups, pH and type of corrosion medium (Samide *et al.*, 2011). Basic information on the interaction between the inhibitor and the Mild steel metal surface can be proved by the adsorption isotherm and in general, inhibitor can function either by physical (electrostatic) adsorption or chemisorption with the metal surface. Actually, the adsorbed molecule may cause some difficulty for the surface to adsorb further molecule from neighboring sites. To acquire more information about the interaction between the inhibitor molecules and the metal surface, a number of mathematical adsorption expressions have been developed to fit the degree of surface coverage through different adsorption isotherms in order to provide some knowledge on the nature of interaction of the adsorbed molecule (Gece and Bilgic, 2009). The fractional surface coverage θ at different concentrations of inhibitors in 1 M KCl solutions were determined from the weight loss measurements data using the equation:

$$(\theta) = \frac{W_o - W_i}{W_o} \quad (1)$$

where, W_o and W_i are the values of weight loss of uninhibited and inhibited specimens, respectively.

$$Kc = \frac{\theta}{1 - \theta} \quad (2)$$

Where:

c = The concentration of the inhibitor

θ = The fractional surface coverage

The Langmuir isotherm, Eq. 4 which is based on the assumption that all adsorption sites are equivalent and that molecular binding, occurs independently from the fact whether the nearby sites are occupied or not was verified for all the studied inhibitors. The adsorption equilibrium constant K is related to the free energy of adsorption ΔG_{ads} as:

$$K = \frac{1}{C_{solvent}} \exp\left(\frac{-\Delta G_{ads}}{RT}\right) \quad (3)$$

Where:

$C_{solvent}$ = Represents the molar concentration of the solvent which in the case of water is 55.5 mol dm^{-3}

R = The gas constant

T = The thermodynamic temperature in K

The Langmuir isotherm, Eq. 5 can be rearranged to obtain the following expression:

$$\frac{c}{\theta} = \frac{1}{K} + c \quad (4)$$

so that, a linear-relationship can be obtained on plotting c/θ as a function of c with a slope of unity. The thermodynamic parameters K and ΔG_{ads} for the adsorption of the studied inhibitors on Mild steel is obtained by Langmuir's adsorption isotherm are plotted in Fig. 2 and the obtained values are given in Table 2. It was found that the linear correlation coefficients clearly prove that the adsorption of Neomycin from 1 M KCl solutions on the Mild steel corrosion obeys the Langmuir adsorption isotherm. The negative values of ΔG_{ads}^0 for the addition of inhibitors indicate that the process of adsorption of studied inhibitors is spontaneous in nature (Solmaz *et al.*, 2007). The free energy of adsorption of (ΔG_{ads}) for mild steel in 1 M KCl it was found to be $-8.056 \text{ kJmol}^{-1}$, respectively.

It is well known that the values of ΔG_{ads} in the order of -20 kJ mol^{-1} or lower indicate a physisorption while those about -40 kJ mol^{-1} or higher involve charge sharing or transfer from the inhibitor molecules to the metal surface to form a co-ordinate type of bond (Fouda *et al.*, 2010).

The calculated adsorption values for the studied inhibitor show that the adsorption is of physical in nature and there is no chemisorption between the inhibitor molecule and the metal surface (Abdallah *et al.*, 2012). This indicates that the adsorption of neomycin at 2 h takes place through electrostatic interaction between the inhibitor molecule and the metal surface. Hence, it indicates that the interaction between the inhibitor molecule and metal surface is physisorption.

Potential dynamic polarization: Table 3 effect of concentration of investigate compounds for the corrosion of mild steel in 1 M KCl at room temperature.

The potentiodynamic polarization for mild steel in 1 M KCl in the presence and absence of drug is shown in the Fig. 3. Electrochemical parameters such as corrosion

Table 2: Thermodynamic parameters for the adsorption of Neomycin on the Mild Steel surface in 1 M KCl

Medium	Concentration (M)	Surface coverage (θ)	ΔG_{ads} KJ mol^{-1}	$K \times (10^{-2} \text{ M}^{-1})$
1 M KCl	5×10^{-4}	0.647	-7.056	1.81

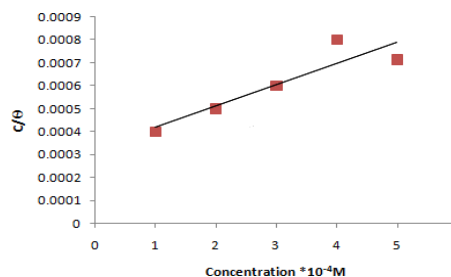


Fig. 2: Langmuir isotherm for adsorption of Neomycin on the Mild Steel surface studied at 1 M KCl

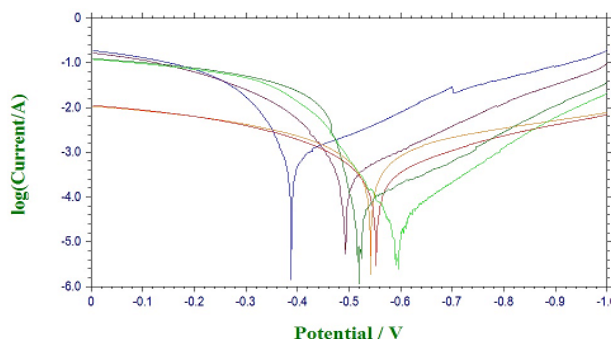


Fig. 3: Potentiodynamic polarization curves for the corrosion of mild steel in 1 M KCl in the presence and the absence of various concentration of neomycin at room temperature

Table 3: Effect of concentration of investigate compounds for the corrosion of mild steel in 1 M KCl at room temperature

Inhibitor concentration	β_c (V dec ⁻¹)	β_a (V dec ⁻¹)	E_{corr}	$I_{corr} \times 10^{-4}$ (A)	Corrosion rate (mmpy)	IE %
Blank	4.015	10.06	-0.356	6.682	33.03	----
0.0001 M	4.917	5.326	-0.542	6.245	29.14	11.7772
0.0002 M	5.026	10.632	-0.493	3.913	22.86	30.7902
0.0003 M	4.809	6.088	-0.553	3.332	19.38	41.3261
0.0004 M	7.61	16.314	-0.594	3.218	13.43	59.34
0.0005 M	4.558	10.2	-0.477	2.358	10.915	66.9543

current density (I_{corr}), corrosion potential (E_{corr}), Tafel constant, degree of surface coverage and the inhibition efficiency were calculated from Tafel plot are given in Table 3. It shows that the investigated antibiotic drug do not shift the E_{corr} values significantly, suggesting that they behave as mixed type inhibitor (Zhang *et al.*, 2009).

CONCLUSION

The antibiotic neomycin tri sulphate was found to be modest inhibitor in the aqueous medium giving up to 64.7% in 1 M KCl. The inhibition efficiency increased with increase in concentration of inhibitors at two hour at room temperature. The inhibition is due to the inhibitor molecule on the mild steel because of the presence of π -electrons and hetero atoms that cause blocking active sites. The adsorption of the drug is exothermic spontaneous as suggested by the negative values of ΔG_{ads} and obeys Langmuir's adsorption isotherm. The adherence of the data to Langmuir's adsorption isotherm support physical adsorption process. Polarisation data showed that the used inhibitor act as mixed type inhibitor in 1 M KCl.

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