International Journal of Chemistry and Materials Research
2018 Vol. 6, No. 1, pp. 1-7
ISSN(e): 2311-763X
ISSN(p): 2312-0991
DOI: 10.18488/journal.64.2018.61.1.7

EXPIRED FLUOXYMESTERONE DRUG AS SUSTAINABLE CORROSION INHIBITOR FOR MILD STEEL (MS) IN 3 M HCL SOLUTION: EXPERIMENTAL INVESTIGATIONS TOWARDS MITIGATION OF METAL DISSOLUTION

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Article History
Received: 18 October 2018
Revised: 21 November 2018
Accepted: 31 December 2018
Published: 24 January 2019

Keywords
Fluoxymesterone drug
Tafel polarization
AC impedance spectroscopy
Scanning electron microscopy
Atomic absorption spectroscopy.

ABSTRACT

The current research presents corrosion inhibition activity of expired Fluoxymesterone drug on the mild steel (MS) in the 3 M HCl solution. The atomic absorption spectroscopy, Tafel polarization and AC impedance spectroscopy studies have been done to verify the corrosion protection efficiency. The surface studies were carried out by scanning electron microscopy (SEM) technique. Atomic absorption spectroscopy results show that, the amount of iron content is low in the presence of corrosion inhibitor when compared with bare system. Tafel plots clearly hint the mixed corrosion inhibition property (inhibition of both anodic and cathodic corrosion process) of expired Fluoxymesterone drug over the MS surface in the acidic environment. From the AC impedance spectroscopy technique, it is observed that, the charge transfer resistance values enhances with a rise in the concentration of the corrosion inhibitor. Surface studies by SEM also support the atomic absorption spectroscopy, potentiodynamic polarization (Tafel plot) and AC impedance spectroscopy results.

1. INTRODUCTION

Mild steel (MS) metal widely used for the making variety of hardware and metallic structures. MS is easily available and cheap in the market. In several industrial sections, MS metal comes in contact with hydrochloric acid solutions during pickling and descaling processes. This contact leads to the corrosion or dissolution process. In recent times, negative consequence might be exposed by many synthetic species which may be pernicious for the atmosphere as well as for the human beings [1-3]. A widespread class of metal corrosion inhibitors is constituted in expired drug products. The non-toxic and easy availability give the expired drug products an important excellency to be employed as prohibition of metal corrosion. The effectiveness of metal corrosion process is inhibited by expired drug products on the MS surface is established due to the presence of heteroatom's such as N, O, P and S atoms in their moieties [4-7]. These elements have feasible corrosion inhibition power. Many corrosion scientists have already studied different expired drug products as a robust corrosion inhibitor, but maximum protection efficiency achieved at higher expired drug concentrations, this specific reason prompted us to carry out the present investigation [8-11].

Expired Fluoxymesterone drug contains O and double bonds in their moieties, which is expected to show good corrosion inhibition property. The chemical structure of Fluoxymesterone is shown in the **Figure 1**.

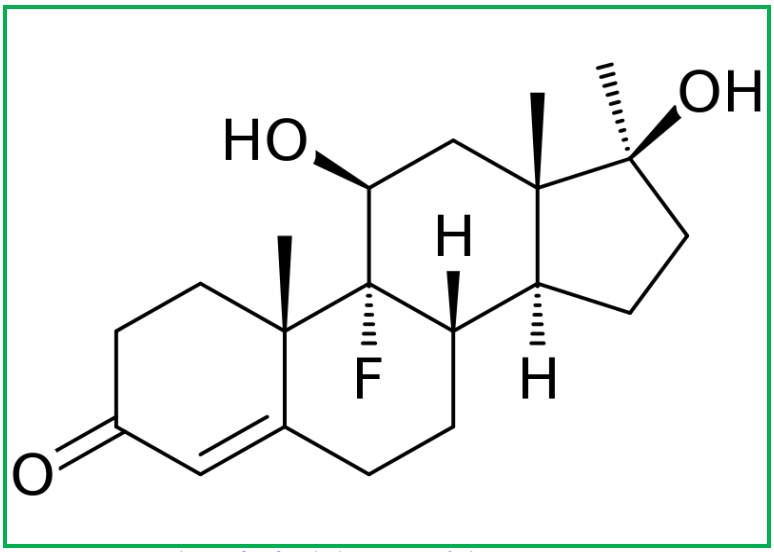

Fig-1. The chemical structure of Fluoxymesterone
Source: Chemdraw and MS-paint

The current research is aimed to investigate the anticorrosion property of expired Fluoxymesterone drug for the MS in 3 M HCl solution based on the atomic absorption spectroscopy, Tafel plots and AC impedance spectroscopy techniques. Surface of MS was screened by scanning electron microscopy (SEM) technique.

2. EXPERIMENTAL SECTION

2.1. Materials Preparation

99 % purity of MS was used in the present investigation. Prior to atomic absorption spectroscopy, Tafel plots, impedance spectroscopy and scanning electron microscopy (SEM) studies, the MS surface was abraded by 100, 500 and 1000 grade sand papers. The expired Fluoxymesterone drug of concentration 0.05 mg, 0.1 mg 0.15 mg and 0.2 mg were prepared. The 3 M HCl solution prepared as per the standard procedure. The atomic absorption spectroscopy (AAS) technique was carried out in order to study the amount of dissolved iron content of MS in 3 M HCl solution in uninhibited and inhibited systems. The atomic absorption spectroscopy (AAS) experiment carried out at 333 K without and with expired Fluoxymesterone drug of concentration of 0.05 mg, 0.1 mg 0.15 mg and 0.2 mg.

The protection efficiency can be calculated from the equation below;

Corrosion protection efficiency = $\frac{B-A}{B} \times 100$,

Where, B= Amount of dissolved iron content in the absence of expired Fluoxymesterone drug and A= Amount of dissolved iron content in the presence of expired Fluoxymesterone drug.

The electrochemical studies were performed with CHI 660C workstation connected with three electrodes (MS= working electrode, Pt= counter electrode and saturated calomel electrode= reference electrode). The electrochemical studies were carried out with potential of ±250 mV with a scan rate of 1 mV s^{-1}.

The protection efficiency can be calculated by following relations;

$$\text{Protection efficiency} = [\,1 - \frac{i'_{corr}}{i_{corr}}\,] \times 100, \quad \text{(Tafel plot studies)}$$

Where, i'_{corr} = Corrosion current density in the presence of expired Fluoxymesterone drug and

i_{corr} = Corrosion current density in the absence of expired Fluoxymesterone drug.

$$\text{Protection efficiency} = \frac{R_{ct\,(inh)} - R_{ct}}{R_{ct(inh)}} \times 100 \quad \text{(Impedance studies)}$$

where, R_{ct} = Charge transfer resistance in in the absence of expired Fluoxymesterone drug and
$R_{ct\,(inh)}$ = Charge transfer resistance in the presence of expired Fluoxymesterone drug.
The surface of MS in 3 M HCl solution without and with expired Fluoxymesterone drug was submitted for SEM analysis.

3. RESULTS AND DISCUSSION

3.1. Atomic Absorption Spectroscopy Studies

The results of atomic absorption spectroscopy (AAS) are shown in the **Table 1.** From this table, it is observed that, the introduction of expired Fluoxymesterone drug to the 3 M HCl solution decreases the amount of dissolved iron content in the 3 M HCl solution. The decrease in the amount of dissolved iron content in the 3 M HCl solution with a rise in the concentration of expired Fluoxymesterone drug is an indication of corrosion inhibition behavior of study inhibitor in the 3 M HCl solution. Maximum corrosion inhibition property observed at 0.2 mg of expired Fluoxymesterone drug on the MS surface in the 3 M HCl solution.

Table-1. Atomic absorption spectroscopy results

Concentration (mg)	Amount of dissolved iron content in 3 M HCl solution	Protection efficiency in percentage
Bare	0.050	
0.05	0.021	58.000
0.10	0.011	78.000
0.15	0.0051	89.800
0.20	0.0029	94.200

Source: Msword Table Draw

3.2. Potentiodynamic Polarization Technique

The polarization character of MS in 3 M HCl solution without and with expired Fluoxymesterone drug of four different concentrations was analyzed and obtained plots are shown in the **Figure 2**. The results of Tafel plots are shown in the **Table 2.** The addition of 0.05 mg, 0.1 mg, 0.15 mg and 0.2 mg of expired Fluoxymesterone drug concentration reduces the corrosion current density values. The MS corrosion current density values are inversely proportional to expired drug inhibitor concentration. The decrease in the corrosion current density values with an increase in the expired Fluoxymesterone drug is a clear hint of corrosion inhibition property of expired Fluoxymesterone drug on the MS surface in 3 M HCl solution. Further, the corrosion potential (E_{corr}) values are within 85 mV compared to the blank solution, which indicates that, expired Fluoxymesterone drug act as mixed corrosion inhibitors. It is also observed that, the cathodic and anodic Tafel slope values are not directed towards any direction, which also supports the mixed corrosion inhibition property of expired Fluoxymesterone drug.

The adsorptive expired drug inhibitor blocks the release of hydrogen gas on the MS in 3 M HCl solution by blocking the active sites of MS and therefore protects the MS metal from the HCl solution.

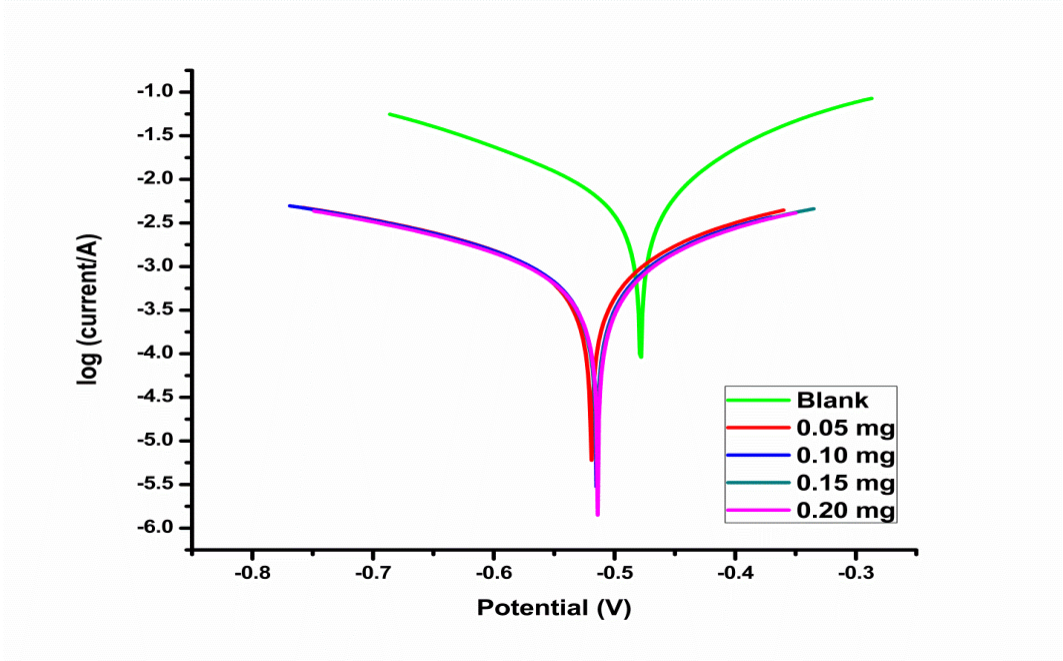

Fig-2. Tafel plots without and with inhibitor

Source: OriginPro8

Table-2. Tafel plot results

Concentration (mg)	Corrosion potential (mV)	Cathoidc Tafel slope (V/dec)	Anodic Tafel slope (V/dec)	Corrosion current (A)	Protection efficiency
Bare	-478	5.792	7.183	0.006398	
0.05	-519	4.653	5.596	0.0009265	85.518
0.10	-515	4.717	5.597	0.0008568	86.608
0.15	-515	4.737	5.630	0.0008131	87.291
0.20	-514	4.759	5.636	0.0007986	87.517

Source: MS word Table draw

3.3. AC Impedance Spectroscopy Studies

The results obtained from the impedance studies are shown in the **Figure 3 and Table 3.** As evident from the **Table 3** that, the charge transfer resistance values are enhanced with a rise in the concentration of the corrosion inhibitor. This is due to decrease in the local dielectric constant when inhibitor is added to the 3 M HCl solution. The charge transfer resistance values are directly proportional to the inhibitor concentration. This nature confirms the corrosion inhibition property of expired Fluoxymesterone drug on MS in 3 M HCl solution. The shape of Nyquist plots in the absence and presence of expired Fluoxymesterone drug is same which confirms the charge transfer process plays a vital role in the MS dissolution process in studied acidic environment.

Table-3. AC Impedance studies

Concentration (mg)	Charge transfer resistance (Ω)	Protection efficiency (%)
Bare	37.8	
0.05	233.3	83.797
0.10	246.2	84.646
0.15	328.3	88.486
0.20	337.9	88.813

Source: MS word Table draw

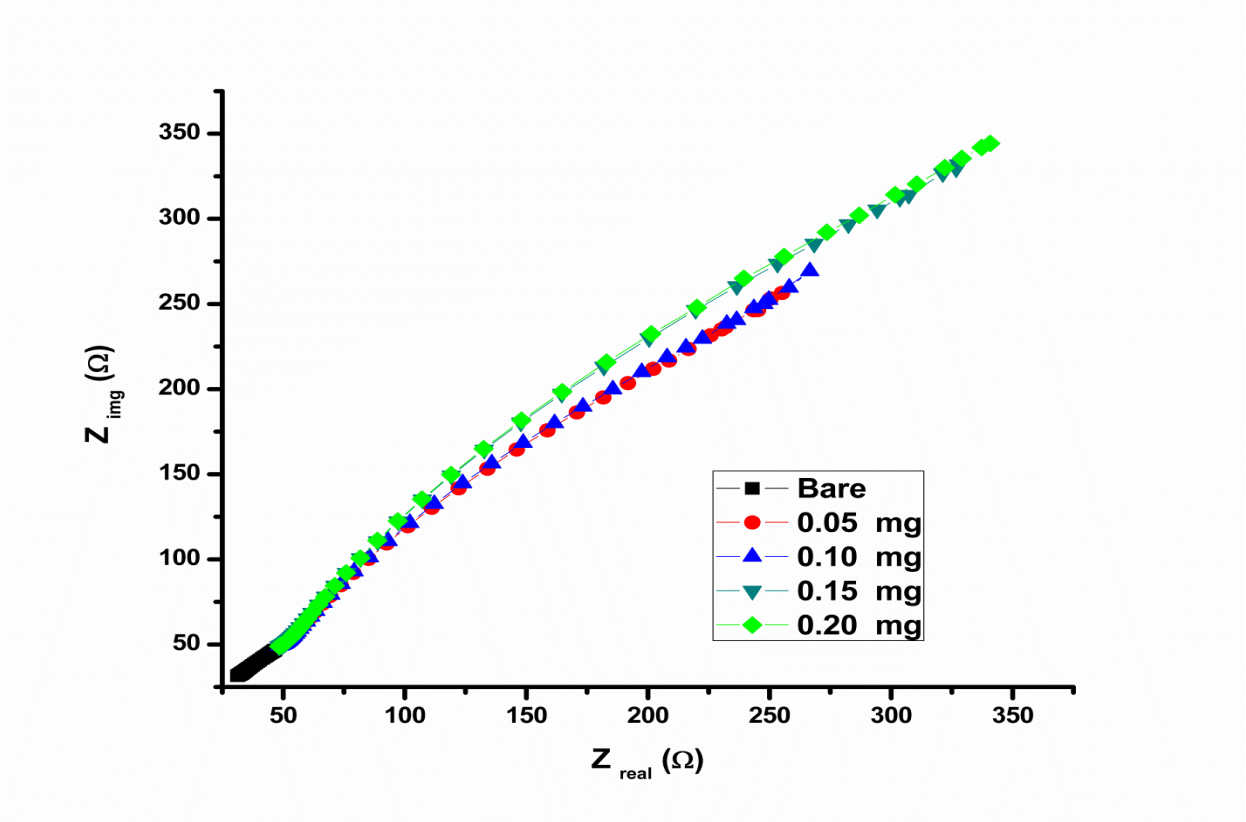

Fig-3. Nyquist plots without and with inhibitor

Source: OriginPr8

3.4. Scanning Electron Microscopy Technique

Figure 4 (a, b) shows the SEM images of MS in the absence and presence of the expired Fluoxymesterone drug in 3 M HCl solution. Rough surface of MS was observed in the absence of expired Fluoxymesterone drug in 3 M HCl solution, which is due to direct contact of hydrochloric acid ions on the MS surface. Smooth surface observed in the presence of 0.2 mg of expired Fluoxymesterone drug is due to the formation of protective film on the MS surface in 3 M HCl solution.

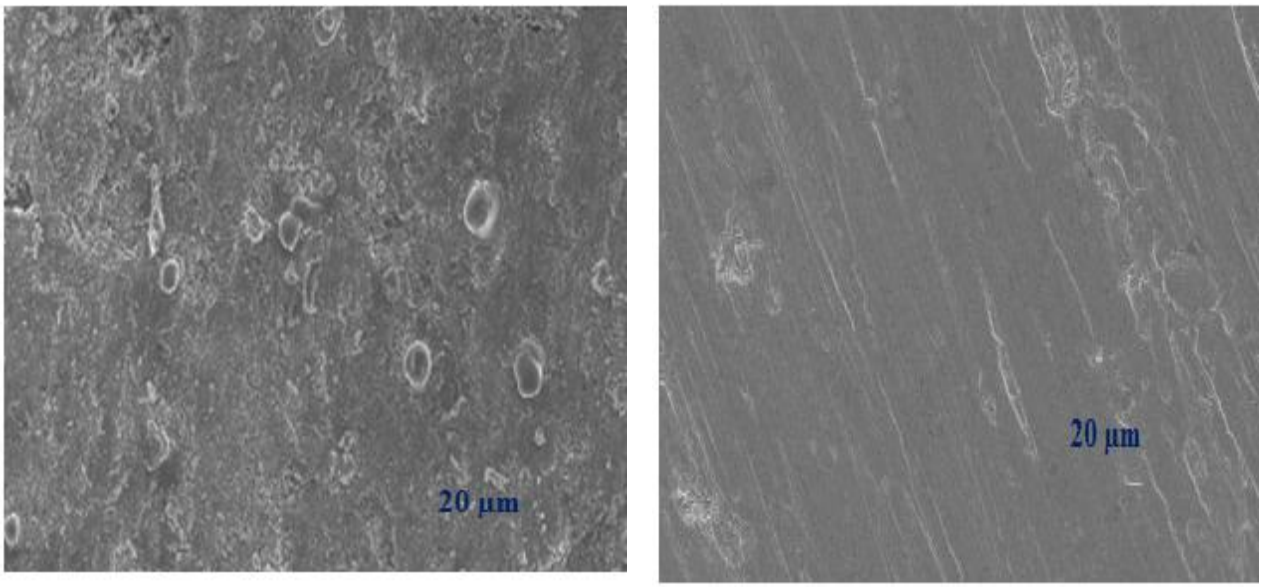

Fig-4(a, b). SEM images without inhibitor and with inhibitor

Source: MS paint

4. CONCLUSION

The corrosion inhibition property of expired Fluoxymesterone drug on MS in 3 M HCl was scrutinized by atomic absorption spectroscopy, potentiodynamic polarization, impedance and SEM techniques. Atomic absorption spectroscopy and impedance results confirm the corrosion inhibition property of expired Fluoxymesterone drug on the MS in 3 M HCl solution with concentration dependent mode. The electrochemical Tafel studies show the mixed corrosion inhibition property of expired Fluoxymesterone drug on the MS in 3 M HCl solution. The adsorption of expired Fluoxymesterone drug on the MS in 3 M HCl solution was thoroughly verified by SEM technique.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

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