



## Expired Abacavir Sulfate Drug as Non-toxic Corrosion Inhibitor for Mild Steel (MS) in 3 M Hydrochloric Acid System

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### Highlights

- The present paper mainly focused on solution for corrosion problem in several sections.
- Tafel plot and impedance study confirms the mixed corrosion inhibition property of expired Abacavir Sulfate drug.
- Mixed MS corrosion inhibition property of expired Abacavir Sulfate drug was confirmed by Tafel plot studies.

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### Abstract

The anti-corrosion property of expired Abacavir Sulfate drug on the mild steel (MS) in the 3 M HCl solution was carried out with the help of weight loss, atomic absorption spectroscopy, Tafel plot, impedance spectroscopy, and scanning electron microscopy studies. The weight loss studies show that, protection property enhances with a rise in the amounts of expired Abacavir Sulfate drug and the maximum of protection efficiency observed at 0.4 g/L of expired Abacavir Sulfate drug. The effect of four different amounts of expired Abacavir Sulfate drug on the MS in the 3 M HCl solution was studied by atomic absorption spectroscopy technique. Mixed MS corrosion inhibition property of expired Abacavir Sulfate drug was confirmed by Tafel plot studies. Nyquist plot studies show that, charge transfer resistance ( $R_{ct}$ ) values are directly proportional to the expired Abacavir Sulfate drug. Scanning electron microscopy results shows that, smooth MS surface in 3 M HCl solution is due to the presence of 0.4 mg/L of expired Abacavir Sulfate drug.

## 1. INTRODUCTION

The study of mild steel (MS) corrosion is very much important due to indirect and direct losses generated by scourge. Hydrochloric acid solutions are generally employed for cleaning, elimination of dust deposits, stimulation of oil wells. Corrosion is an electrochemical process which disintegrates the MS metal. This is a major issue to be addressed by educational and industrial sectors [1-4]. This is because; it causes huge economic losses across the world. Among the numerous corrosion control techniques, use of corrosion inhibitors is the cost effective and most popular approach of MS corrosion control because of high efficiency, facile feasibility and economic synthesis. The inhibitor creates an invisible protective layer on the MS that isolates MS from the aggressive HCl solution and inhibit the disintegration process [5-7]. The inhibition (protection) ability and high adsorption of the organic compound is lying on the fact that, organic species easily transfer electrons to the MS surface. Organic species with N, O, S and P elements are considered to be effective adsorption centers. Even though use of organic species as corrosion inhibitors is one of the economic, effective and easiest methods. But, due to increasing in the awareness of environmental chemistry in the corrosion science field, there is need to discover the green corrosion inhibitors [8-10]. Environmental chemistry is a vital principle which effectively reduces the use of toxic species in design and manufacture application. Hence, the present focus is towards expired drug products. These expired drug products are non toxic and proficient of ensuring robust protection of MS. Hence, in present research, the expired Abacavir Sulfate drug is selected and studied MS corrosion inhibition property

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by weight loss, Tafel plot, atomic absorption and impedance spectroscopy techniques. Surface studies were carried out by scanning electron microscopy (SEM) technique.

## 2. EXPERIMENTAL STUDIES

### 2.1 Preparation of Nontoxic Corrosion Inhibitor and 3 M HCl Solution

Expired Abacavir Sulfate drug collected and different concentrations namely 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L were prepared by using the double distilled water. 3 M HCl solutions was prepared according to the standard procedure.

### 2.2. Mild Steel (MS) Preparation

99 % of MS specimen having the rectangular shapes with 5 cm × 2 cm × 0.3 cm. Before performing the MS corrosion test, MS polished with 1000 and 2000 grades of sand papers. The MS is thoroughly washed with double distilled water and acetone.

### 2.3. Gravimetric Measurement

MS immersed in 100 ml of 3 M HCl solution without and with 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L of expired Abacavir Sulfate drug at 60 °C with an immersion period of 3, 6, 9, 12 and 15 hours. Gravimetric studies repeated and average values are reported. The protection efficiency of expired Abacavir Sulfate drug is calculated from the below relation,

$$\text{Protection efficiency (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100$$

where,  $W_1$  = Weight loss of MS in free 3 M HCl solution and  $W_2$  = Weight loss of MS in protected 3 M HCl solution.

### 2.4. Atomic Absorption Spectroscopy (AAS)

The AAS technique utilized in order to find out the amount of dissolved iron content of mild steel in 3 M HCl solution without and with four different amounts of expired Abacavir Sulfate drug (i.e. 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L).

The corrosion protection efficiency can be find out by following relation,

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

where, B = Dissolved iron content in uninhibited solution and A = Dissolved iron content in inhibited solution.

### 2.5. Electrochemical Studies

Electrochemical studies (both Tafel plot and impedance spectroscopy) studies were carried out with the help of CHI workstation. The MS as working electrode, platinum cell as counter electrode and saturated calomel cell as standard electrode. Open circuit potential obtained by submerging the MS in 3 M HCl solution for about 90 minutes. Nyquist plots obtained by applying the frequency in the range of 100 kHz to 10 MHz with a scan rate of 0.1 mV/s. The Tafel plots are recorded in the frequency range of – 250 mV to + 250 mV with a scan rate of 0.1 mV/s.

With the help of Tafel plots, the corrosion protection efficiency can be calculated from the equation below,

$$\text{Protection efficiency} = \left[ 1 - \frac{i'_{\text{corr}}}{i_{\text{corr}}} \right] \times 100$$

where,  $i'_{\text{corr}}$  = Protected MS corrosion current density and  $i_{\text{corr}}$  = Unprotected corrosion current density.

The charge transfer resistance ( $R_{\text{ct}}$ ) values are used in the calculation of protection efficiency of the expired Abacavir Sulfate drug as per the following equation,

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

where,  $R_{\text{ct}}$  = Unprotected charge transfer resistance value and  $R_{\text{ct}(\text{inh})}$  = Protected charge transfer resistance value.

## 2.6. Scanning Electron Microscopy Technique

MS surface morphology without and with expired Abacavir Sulfate drug was examined by scanning electron microscopy with an immersion period of 2 hours.

## 3. RESULTS AND DISCUSSION

### 3.1. Weight Loss Studies

The effect of contact time on the corrosion inhibition efficiency of the MS in 3 M HCl solution was studied by weight loss technique at 60<sup>o</sup> C with four different amounts of expired Abacavir Sulfate drug. Table 1 shows the corrosion protection efficiency of the expired Abacavir Sulfate drug for MS in 3 M HCl solution without and with 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L of expired Abacavir Sulfate drug. The protection efficiency of the expired Abacavir Sulfate drug enhances with a rise in the expired Abacavir Sulfate drug amounts. This can be explained by adsorption of expired Abacavir Sulfate drug molecules on the MS in 3 M HCl solution. The physical/chemical attraction between the expired Abacavir Sulfate drug and MS in 3 M HCl solution reduces the corrosion rate of the MS in 3 M HCl solution. The attraction between the expired Abacavir Sulfate drug and MS in 3 M HCl solution increases with a rise in the expired Abacavir Sulfate drug concentration. It is also observed that, the increase in the immersion period from 3 hours to 15 hours reduces the MS corrosion protection property of expired Abacavir Sulfate drug in the 3 M HCl solution. The increase in the contact time from 3 hours to 15 hours facilitates the desorption phenomena of chemically/physically adsorbed expired Abacavir Sulfate drug species in the 3 M HCl solution. At higher immersion period, the protection rate is slightly lower; this is because of increase in the acceleration of the mild steel corrosion process which is due to the formation of unstable protective layer of expired Abacavir Sulfate drug on the MS surface in the 3 M HCl solution at higher immersion period.

**Table 1.** Weight loss results for mild steel in 3 M HCl solution without and with corrosion inhibitor

Concentration (g/L)	Immersion period	Protection efficiency (in percentage)
Blank	3	
0.1		70.000
0.2		80.000
0.3		85.000
0.4		95.000
Blank	6	
0.1		74.285
0.2		82.857
0.3		88.571
0.4		94.285
Blank	9	
0.1		78.688

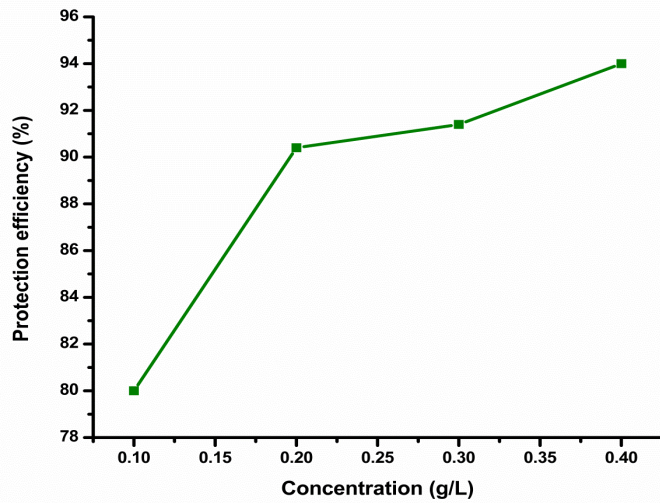
0.2		85.245
0.3		86.885
0.4		88.524
Blank	12	
0.1		74.444
0.2		76.666
0.3		78.888
0.4		83.333
Blank	15	
0.1		73.636
0.2		77.272
0.3		80.909
0.4		85.454

### 3.2. Atomic Absorption Spectroscopy (AAS) Technique

The AAS technique used in order to examine the weight of dissolved iron content of the MS in the 3 M HCl solution without and with 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L of expired Abacavir Sulfate drug. The results of AAS are shown in the Table 2 and Figure 1. The atomic absorption spectroscopy studies show that, the weight of dissolved iron content is low in the presence of four different amounts of expired Abacavir Sulfate drug on the MS in 3 M HCl solution, whereas, in the absence of expired Abacavir Sulfate drug, the weight of dissolved iron content is high in the free 3 M HCl solution. These differences are a clear hint of corrosion protection property of expired Abacavir Sulfate drug on the MS in 3 M HCl solution. Presence of expired Abacavir Sulfate drug on the surface of MS in 3 M HCl solution prevents the loss of iron content of MS in 3 M HCl solution.

**Table 2.** Atomic absorption spectroscopy results for mild steel metal in 3 M HCl solution

Concentration (g/L)	Amount of MS dissolved in 3 M HCl solution	Protection efficiency (in percentage)
Blank	0.050	
0.1	0.010	
0.2	0.0048	80.000
0.3	0.0043	90.400
0.4	0.0030	91.400
		94.000



**Figure 1.** Atomic absorption spectroscopy results

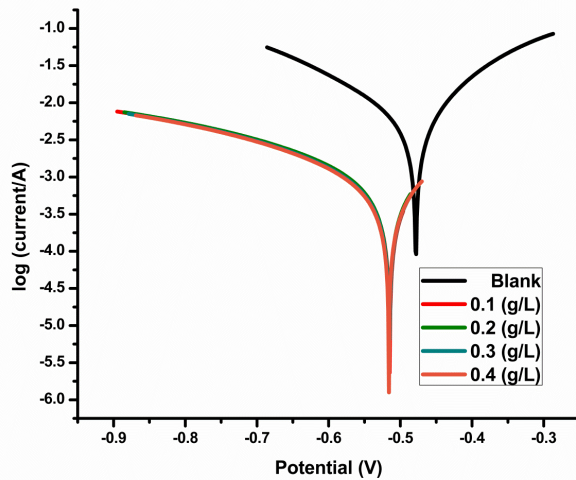
### 3.3. Electrochemical Studies

#### Tafel plot studies

The cathodic and anodic Tafel plots for MS in 3 M HCl solution without and with 0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L of expired Abacavir Sulfate drug are shown in the Figure 2. The Tafel plot parameters such as corrosion potential ( $E_{\text{corr}}$ ), corrosion current density ( $i_{\text{corr}}$ ), cathodic Tafel coefficient ( $\beta_c$ ), anodic Tafel coefficient ( $\beta_a$ ) and protection efficiency of the expired Abacavir Sulfate drug as shown in the Table 3. The  $i_{\text{corr}}$  values reduces with a rise in the amounts of expired Abacavir Sulfate drug which confirms the MS corrosion protection property of expired Abacavir Sulfate drug in the 3 M HCl solution. The decrease in the corrosion current density values enhances the corrosion inhibition property on the surface of MS in an acidic environment. The expired Abacavir Sulfate drug causes no change in the cathodic, anodic Tafel coefficients and corrosion potential values. This shows the MS mixed corrosion inhibition property of expired Abacavir Sulfate drug in the 3 M HCl solution. The expired Abacavir Sulfate drug controls the both cathodic and anodic MS corrosion reaction in the 3 M HCl solution.

**Table 3.** Tafel plot results of mild steel in 3 M HCl solution without and with corrosion inhibitor

Concentration (g/L)	Corrosion potential (mV)	Cathodic Tafel slope (V/dec)	Anodic Tafel slope (V/dec)	Corrosion current (A)	Protection efficiency
Blank	-478	5.792	7.183	0.006398	
0.1	-515	4.812	1.201	0.0004252	93.354
0.2	-515	4.761	1.236	0.0003993	93.758
0.3	-515	4.844	1.301	0.0003437	94.632
0.4	-516	4.857	1.023	0.0002965	95.365



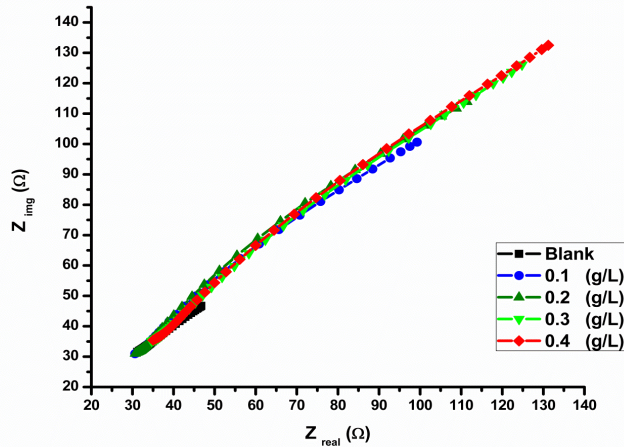
**Figure 2.** Tafel plots without and with inhibitor

### Impedance studies

Figure 3 shows the Nyquist plots for MS in 3 M HCl solution without and with four different types of expired Abacavir Sulfate drug amounts (0.1 g/L, 0.2 g/L, 0.3 g/L and 0.4 g/L of expired Abacavir Sulfate drug). The Nyquist plots are not perfect semicircle which is due to the MS surface heterogeneity. The charge transfer resistance and protection inhibition values obtained from the impedance studies are shown in the Table 4. From the Table 4, it is observed that, the charge transfer resistance values increases with a rise in the amounts of expired Abacavir Sulfate drug amount. The increase in the charge transfer resistance values with a rise in the expired Abacavir Sulfate drug is due to the adsorption of expired Abacavir Sulfate drug molecules on the MS surface in 3 M HCl solution. The phenomena of adsorption process enhances with an increase in the amounts of expired Abacavir Sulfate drug. Hence, protection efficiency increases with expired Abacavir Sulfate drug amounts.

**Table 4.** Impedance results of mild steel metal

Concentration (mg/L)	Charge transfer resistance ( $\Omega$ )	Protection efficiency (%)
Blank	37.8	
1	75.12	49.680
2	123.2	69.318
3	132	71.363
4	138.2	72.648



**Figure 3.** Impedance plots

The protection efficiency obtained from different techniques as shown in the Table 5.

The different techniques and experimental condition are the main reason for the observed deviation in the protection efficiency values.

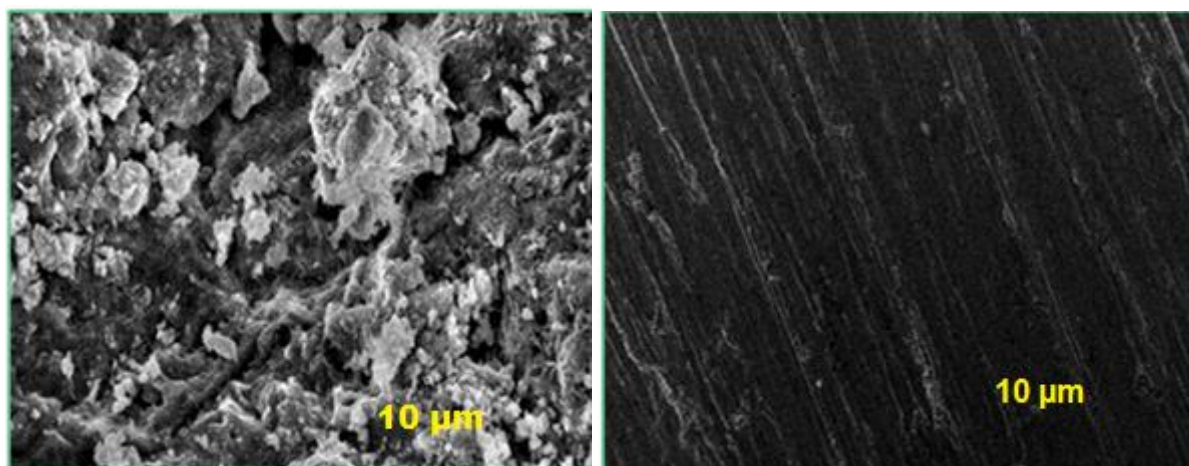
**Table 5.** Protection efficiency obtained from different techniques

Technique	Optimum concentration (g/L)	Protection efficiency (%)
Weight loss	0.4 (g/L)	95.000
Atomic absorption spectroscopy	0.4 (g/L)	94.000
Tafel plots	0.4 (g/L)	72.648
Impedance spectroscopy		

### 3.4. Scanning Electron Microscopy (SEM) Technique

The SEM images of MS surface in protected and unprotected condition as shown in the Figure 4 (a, b). From the SEM images, it is clear that, without expired Abacavir Sulfate drug, the MS surface is fully damaged and with expired Abacavir Sulfate drug of 0.4 g/L, the MS surface become smooth. The variation in MS surface morphology is due to adsorption of expired Abacavir Sulfate drug molecules on the electrode surface. The differences in the MS surfaces in without and with expired Abacavir Sulfate drug conditions are an indication of corrosion inhibition property of expired Abacavir Sulfate drug on the MS surface in 3 M HCl solution.





**Figure 4.** SEM images without and with inhibitor

#### 4. CONCLUSION

Results obtained from the various techniques, weight loss, atomic absorption spectroscopy, Tafel plot, impedance, quantum chemical and scanning electron microscopy studies show that, nontoxic corrosion inhibition property of expired Abacavir Sulfate drug on the MS surface in 3 M HCl solution. All the studied technique shows that, corrosion protection property enhances with a rise in the expired Abacavir Sulfate drug concentrations. Tafel plot studies show that, expired drug A act a as mixed type of corrosion inhibitor on the MS surface in 3 M HCl solution. Impedance studies show that, highest charge transfer resistance value obtained at 0.4 g/L of expired Abacavir Sulfate drug on the MS surface in 3 M HCl solution. SEM results support the weight loss, atomic absorption spectroscopy, Tafel plot, impedance methods.

#### CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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