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Short Communication

Inhibition of Mild Steel Corrosion in 1N HCl Medium by Acid Extract of *Ephedra alata*

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The inhibition action of the acid extract of *Ephedra alata* leaves against corrosion of mild steel in 1N HCl medium was investigated. Experimental measurements including potentiodynamic polarization and impedance studies were performed. The corrosion rate and the inhibition efficiencies of the extract were calculated. The findings show that the extract could serve as an effective inhibitor for the corrosion of mild steel in HCl media. The results reveal that acid extract of *Ephedra alata* leaves could serve as a good corrosion inhibitor of a mixed type with cathodic predominance and having efficiency as high as 86.90 % at a concentration of 1.65 % v/v of the inhibitor.

Keywords: *Ephedra alata*, Corrosion inhibitor, Plant products, Mild steel, acid medium.

1. INTRODUCTION

Mild steel finds application in many industries due to its easy availability, ease of fabrication, low cost and good tensile strength besides various other desirable properties. Nevertheless it is easily vulnerable to corrosion when it comes in contact with acid solutions during acid cleaning, acid transportation, descaling, storage of acids and other chemical processes.

The heavy loss of metal as a result of its contact with acids can be minimized to a great extent by the use of corrosion inhibitors. Inorganic compounds like chromates, phosphates, molybdates and a variety of organic compounds containing heteroatom like nitrogen, sulphur and oxygen can be used as inhibitors.

Pure synthetic chemicals are costly and some of them are not easily biodegradable and their disposal creates pollution problems. Plant extracts are environment friendly, biodegradable, non-toxic, easily available and of potentially low cost. The possible replacement of some expensive chemicals as corrosion inhibitors for metal in acid cleaning process can be done by naturally occurring substances. Natural products of plant origin contain different organic compounds (alkaloids, tannins, amino acids etc.) and most of them are known to have inhibitive action. Caffeine has been used as inhibitor in controlling corrosion of mild steel immersed in an aqueous solution .

Most of the naturally occurring substances are safe and can be extracted by simple procedures. Recent literature is full of researches which test different extracts for corrosion inhibition applications. Many of these naturally occurring substances proved their ability to act as corrosion inhibitors for the corrosion of different metals and alloys in different aggressive media [1-11].

The aim of the present study is to investigate the corrosion inhibition effect of *Ephedra alata* (Alanda) leaves as a cheap and environment friendly corrosion inhibitor for mild steel in 1N HCl medium by polarization measurements and impedance.

2. EXPERIMENTAL

2.1. Sample preparation

Materials used for the study were mild steel sheets of composition (wt %): Mn (0.97), C (0.10), S (0.002), Gr (0.01), and Si (0.12). For electrochemical studies, mild steel strips of 1 cm^2 surface area were used. Each coupon was degreased by washing with ethanol, dried in acetone and preserved in a desiccator. All reagents used for the study were analytical grade and double distilled water was used for their preparation.

2.2. Choice of acid medium

Acids are widely used in industry, the most important areas of application being acid pickling, industrial acid cleaning, acid descaling and oil well acidizing. HCl is widely used to pickle iron and steel because HCl quickly removes oxide scale and iron rust and filth during acid pickling. Side effects of these processes are corrosion of the substrate metal and atmospheric pollution caused by acid vapor. Inhibitors are generally used in these processes to control the metal dissolution as well as acid consumption.

2.3. Selection of the inhibitor

Use of inhibitors is an important task in the protection of metals from corrosion. Till now the majority of metal corrosion inhibitors used is toxic for human being and environment. The choice of the present inhibitors is based on the following considerations: Less-expensive, Non toxic, eco-friendly and easy available. For the present study, the acid extract of *Ephedra alata* is used as corrosion inhibitor for mild steel in 1 M HCl.

2.4. Extraction of plant materials

Plant materials were dried in shade so as to enrich the active principles, by reducing their moisture content. The extract was prepared by refluxing 250g of powdered dry flowers in 2L of 1M HCl for 48 h and kept overnight. Then it was filtered and the volume was made up to 1.25 L and this was taken as a stock solution.

2.5. Corrosion Studies

2.5.1. Potentiodynamic polarization measurements

Potentiodynamic polarization studies were carried out using Solartron 1280 B. acidic solution at different inhibitor concentrations was taken in an electrochemical cell. The polished electrode was introduced and placed at 0.750 mV to its open circuit potential. Then the potential was scanned at -0.200 mV/sec towards the anodic direction in Tafel extrapolation. Applied potential *vs.* current was plotted and on extrapolation of linear portion to the corrosion potential gives the corrosion current. In anodic and cathodic plot, the slope of the linear portion gives Tafel constants ‘ b_a’ and ‘b_c’ respectively. According to the Stern-Geary equation, the steps of the linear polarization plot are substituted to get corrosion current [12-13].

$$I_{corr} = (b_a \times b_c)/ (2.303 (b_a + b_c) \times R_p)$$

Where: R_p is the polarization resistance.

- *Determination of inhibition efficiency By Tafel method*

$$I.E (\%) = [(I_{corr} – I_{corr}(1))/ Icorr] X100$$

Where: I_{corr} is corrosion current without inhibitor
$I_{corr}(1)$ is corrosion current with inhibitor.

- *By LPR (Linear Polarization Resistance) method*

$$I.E (\%) =[(R_p(inh) - R_p(blank))] / [R_p(inh) X100]$$

where, $R_p(inh)$ is the polarization resistance in the presence of inhibitor.
$R_p(blank)$ is the polarization resistance in the absence of inhibitor.

2.5.2. Impedance measurements

The electrochemical AC-impedance measurements were performed using a solatron-electrochemical analyzer (Model 1280). Experiments were carried out in a conventional three-electrode cell assembly such as that used for potentiodynamic polarization studies. The working electrode was carbon steel specimen of 1 cm^2 in area exposed and the rest was covered with red lacquer. A rectangular Pt foil is used as a counter electrode. A sine wave with amplitude of 10 mV was superimposed on the steady open circuit potential. The real part *(Z0)* and the imaginary part (*Z00*) were measured at various frequencies in the range of 100 kHz to 10 MHz. A plot of *Z0 vs Z00* was made. From the plot, the charge transfer resistance (*R*t) were calculated and the double layer capacitance (*C*dl) was then evaluated using the equation,

$$C_{di} = \frac{1}{2\pi f_{max} R_t}$$

where R_t is charge transfer resistance and C_{di} is double layer capacitance. The experiments were carried out in the absence and presence of different concentrations of inhibitors. The percentage of inhibition efficiency was calculated using the equation,

$$IE(\%) = ((R^*_t - R_t) / R^*_t) \times 100$$

where R^*_t and R_t are the charge transfer resistance in the presence and absence of inhibitors, respectively.

3. RESULTS AND DISCUSSION

3.1. Potentiodynamic polarization results

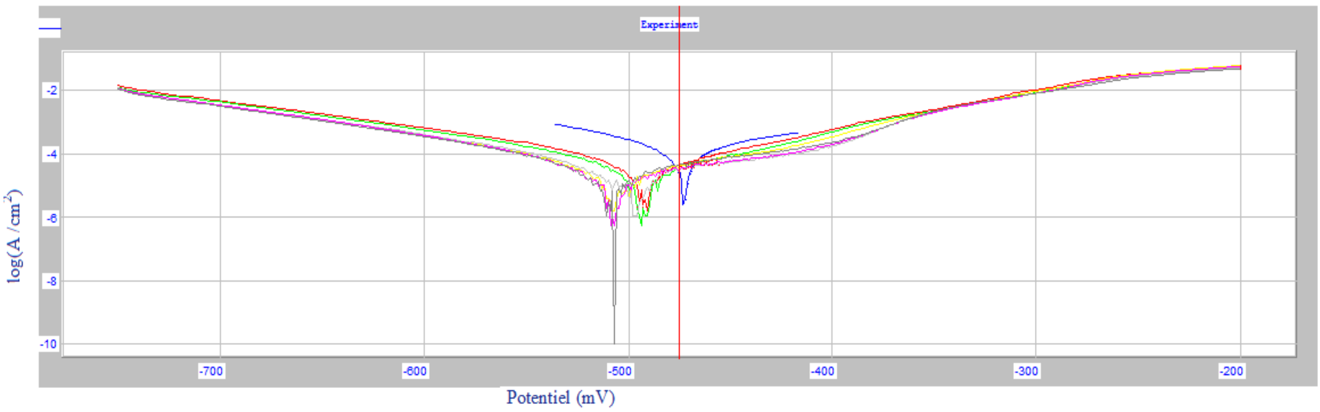

Figure 1. Potentiodynamic polarization for mild steel in 1 N HCl solution in the absence and presence of different concentrations of *Ephedra alata* extract, (1) blank; (2) 0.25 (% in v/v); (3) 0.50 (% in v/v); (4) 1.00 (% v/v) (5) 1.65 (% in v/v); (6) 1.75 (% in v/v) ; (7) 2.00 (% in v/v)

The various electrochemical parameters calculated from Tafel plot (Figure1) are given in Table 1.

The lower corrosion current density (I_{corr}) values in the presence of inhibitors without causing significant changes in corrosion potential (E_{corr})(475.30-512.00mV) suggests that the compound is cathodic type inhibitor and are adsorbed on the surface thereby blocking the corrosion reaction. In all concentrations ba is greater than bc suggesting that though the inhibition is under cathodic control, the effect of the inhibitor on the cathodic polarization is more pronounced than on the anodic polarization.

Similar studies have been carried out by our group on some local plant species and revealed moderate corrosion inhibition effect. In this context the inhibitive effect of extracts of *Cotula cinerae*, *Retama retam* and *Artemisia herba alba* plants on the corrosion of X52 mild steel in aqueous 20 % (2.3 M) sulfuric acid was investigated. Weight-loss determinations and electrochemical measurements were performed. Polarization curves indicated that the plant extracts behave as mixed-type inhibitors. The inhibition efficiencies of the extracts were ranging between 84% and 88% [**14**].

Moreover, the aqueous extract of *Zygophyllum album*. L revealed that it can be used as corrosion inhibitor of steel in acidic medium at room temperature and at a concentration of 1400 ppm to reach an inhibition rate around 98% [**15-16**].

Table 1. Electrochemical parameters for mild steel in 1M HCl containing extract.

Concentration of Inhibitor % v/v	E_{corr} mV	I_{corr} μA/cm²	b_a mV/dec	b_c mV/dec	R_p Ohm /cm²	% Inhibitor Efficiency Tafel	Linear
Blank	-475.3	116.8214	87.6	-69.0	106.79	-	-
0.25	-495.1	35.2396	77.4	-69.2	371.01	69.83	71.21
0.50	-495.3	29.5379	90.3	-72.2	537.82	74.71	80.14
1.00	-509.6	28.6616	123.2	-78.8	661.91	75.46	83.86
1.65	-499.8	15.3053	60.5	-60.2	720.12	86.898	85.17
1.75	-509.9	25.0670	164.6	-73.0	711.36	78.54	84.98
2.00	-512.0	32.5392	156.4	-85.0	692.71	72.14	84.58

3.2. Electrochemical impedance spectroscopy results

The corrosion behavior of mild steel in 1 N HCl in the absence and presence of *Ephedra alata* extract was also investigated by EIS method. Impedance measurements were studied to evaluate the charge transfer resistance (R_t) and double layer capacitance (C_{dl}) and through these parameters the inhibition efficiency was calculated. Figure 2 shows the impedance diagrams for mild steel in 1 N HCl with different concentrations of *Ephedra alata* extract and the impedance parameters derived from these investigations are given in Table 2.

Table 2. Impedance parameters for the corrosion of mild steel in 1N HCl containing different concentrations.

S. No	Concentration of Inhibitor % v/v	$\square_{dl}$ µ farads	R_{ct} ohms^2	% Inhibitor Efficiency Tafel	Linear
1	Blank	714.90	55.65	-	-
2	0.25	578.70	69.09		19.45
3	0.50	462.60	139.10		59.99
4	1.00	357.30	144.70		61.54
5	1.65	405.70	247.90		77.55
6	1.75	370.20	284.40		80.43
7	2.00	327.30	239.10		83.98

Phyto-constituents in the flowers of *Ephedra alata* contain alkaloids and flavonoids. Due to the presence of these heterocyclic compounds adsorption of the plant constituents on the metal surface is facilitated. Inhibition efficiency could be explained due to the adsorption of these compounds on the metal surface thereby blocking the surface and protecting the metal from the aggressive environment.

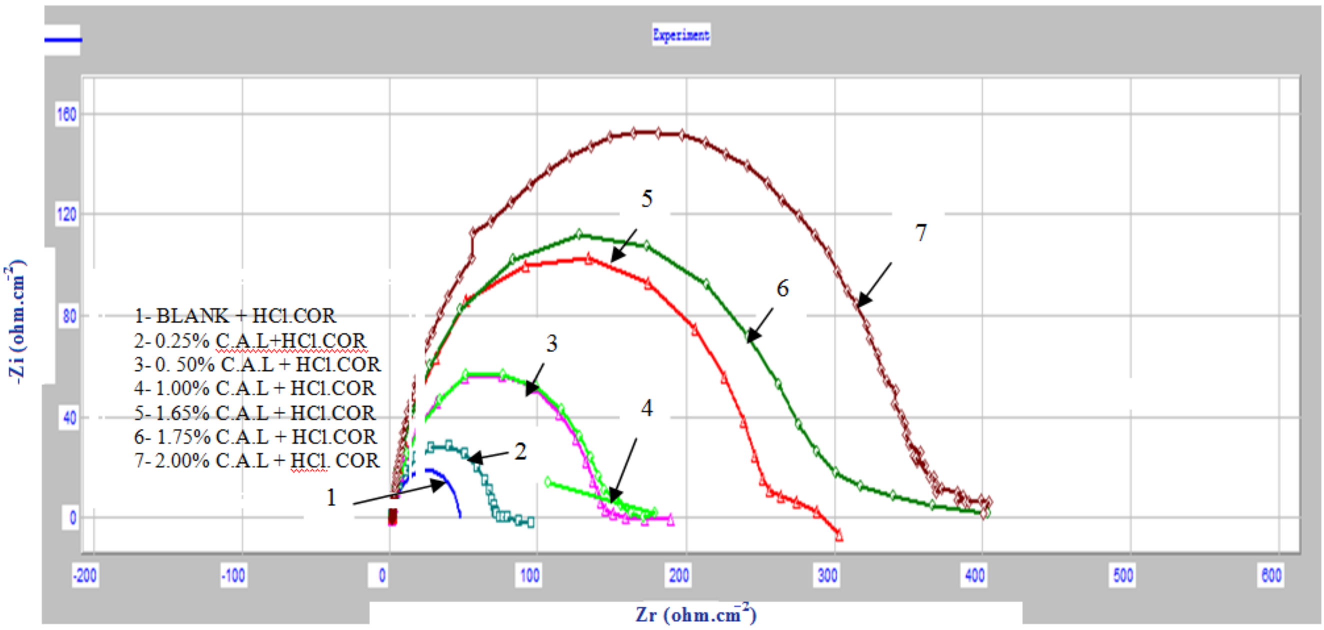

Figure 2. Impedance parameters for mild steel in 1 N HCl solution in the absence and presence of different concentrations of *Ephedra alata* extract, (1) blank ; (2) 0.25 (% in v/v) ; (3) 0.50 (% in v/v) ; (4) 1.00 (% v/v) (5) 1.65 (% in v/v) ; (6) 1.75 (% in v/v) ; (7) 2.00 (% in v/v) .

4. CONCLUSION

Acid extract of *Ephedra alata* flowers acts as a good corrosion inhibitor for mild steel in 1N HCl medium . Inhibition efficiency increases with inhibitor concentration and maximum inhibition efficiency was 86.90 % at the inhibitor concentration 1.65 % v/v. Corrosion inhibition may be due to the adsorption of the plant constituents on the mild steel surface. Polarization studies indicate the inhibitor to be of a cathodic type.

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