Research Article

Inhibitory Action of Acalypha Indica Extract On Corrosion of Mild Steel in Hydrochloric Acid Medium

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Abstract

The inhibition efficiency of an acid extract of *Acalypha indica* in controlling corrosion of mild steel in 1M HCl has been studied by weight loss method in the presence and absence of corrosion inhibitor at different time interval at room temperature. The inhibition efficiency increases with extract concentration and immersion period. The effect of temperature studied indicated that inhibition efficiency increased with temperature. The negative value of the free energy of adsorption indicates spontaneous adsorption. The inhibitor obeys Temkin adsorption isotherm. All the reported plant extract were found to inhibit the corrosion of mild steel in acid media.

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Introduction

Corrosion is the deterioration of metal by chemical attack or reaction with its environment. It is a difficult to eliminate completely. Prevention would be more practical and achievable than elimination. The corrosion inhibitors when added in small quantity can delay effectively or even cancel the corrosion process of the metal in contact with a corrosive medium. Mild steel is a material of choice due to easy availability and fabrication of machineries. Hydrochloric acid has been widely used in pickling baths and pickling process and descaling operations. Hence Hydrochloric acid was the chosen medium. Generally, organic compounds containing hetero atoms like O, N and S are normally found to have higher basic properties and electron density, which assist in corrosion inhibition to reduce the corrosion of mild steel. Hydrochloric acid extract was subjected to preliminary phyto- chemical testing for the detection of bioactive ingredients. The result indicates that the acid extracts of acalypha indica contain acalyphine alkaloid cyanogenic and pickling process and descaling operations and pickling process and descaling operations and pickling process and descaling operations and pickling process and descaling operations glucoside, triaetonamine acalyphamide succinimide, aurantiamide acetate and β-sitosterol. Hence, the acid extracts of Acalypha Indica as anticorrosion agent on mild steel in Hydrochloric acid medium.

Methods and Materials

An acid extract of Acalypha Indica was prepared by boiling 50g of dried and crushed leaves of Acalypha Indica with 1000 ml of 1 M HCl for 3 hours and leaving it overnight. Next day the filtrate volume was made up to 1000 ml using the same 1M HCl. Mild steel strips of size 1 × 5 × 0.2 cm with 2mm diameter hole near the upper edge of the specimens, were polished to mirror finish, washed with Clark solution (1l of HCl + 50g of stannous chloride + 20 g antimony trioxide), rinsed with distilled water finally dried with filter paper and stored in desicator.

Weight Loss Measurements

The mild steel specimens were weighed and immersed in 100 ml of acid solution with help of glass hooks, with and without inhibitor at different concentrations (0.05, 0.1, 0.2, 0.3, 0.5, 0.7 and 0.9%). Experiments were carried out in 1M HCl at298K temperature for 0.5, 2, 4, 6, 8, 24 and 48 hours respectively. The weight of the specimen before and after immersion was determined. The influence of temperature on the corrosion of mild steel has also been studied at five different temperatures ranging from 298K to 343K in the absence and presence of the inhibitors at different concentrations for 30 minutes. The inhibition efficiency (IE) was calculated using the following formula

$$IE(\%) = \frac{W_U - W_I}{W_U} \times 100 \qquad (1)$$

W_u -corrosion rate in the absence of inhibitor
W_I -corrosion rate in the presence of inhibitor

Electrochemical Method

Potentiodynamic measurement-Tafel polarization curves were recorded using computerized Solartron model 1284. In this setup a platinum electrode, calomel electrode and MS specimens were used as auxiliary, reference and working electrodes respectively which were immersed in acidic medium in the presence and absence of different concentration of the inhibitor. The inhibitor efficiency was calculated using the formula.

$$\text{Inhibition efficiency} = \frac{I_{corr} - I_{corr\,(i)}}{I_{corr}} \text{ x } 100 \qquad (2)$$

I_{corr} - The corrosion current in the absence of inhibitor
$I_{corr\,(i)}$- The corrosion current in the presence of inhibitor.

Result and Discussion

Phytochemical Screening

The results obtained from preliminary phytochemical screening of extract are displayed in **Table 1**

Table 1 Preliminary phytochemical screening of extract of Acalypha Indica.

Plant	Saponins	Tannins & Glucosides	Flavonoids	Alkaloids	Terpenoids	Anthraquinone & Steroids
AI	+	+	-	+	+	-

Note: (+) = Presence, (-) = Absence

Weight Loss Measurements

The effect of inhibitor concentration on the corrosion rate of mild steel in 1M HCl in the presence and absence of different concentration of Acalypha Indica using weight loss method is shown in **Table 2**. The percentage of inhibition efficiency increases with increase in the extract concentration over the entire concentration range studied in all the cases.

Table 2 Inhibition efficiency of Acalypha Indica extract on mild steel in 1M HCl at different immersion periods from weight loss method at room temperature.

CONC. (%)	**Inhibition Efficiency(%)**					
	½ hr	**2 hrs**	**4 hrs**	**6 hrs**	**8 hrs**	**24 hrs**
0.05	38.55	80.33	87.03	82.41	74.12	74.56
0.1	51.93	85.75	89.11	84.66	82.35	81.01
0.2	63.55	91.80	93.88	88.84	85.93	84.29
0.3	68.23	93.32	95.47	91.86	89.10	86.01
0.5	74.67	94.45	96.21	95.41	94.56	91.05
0.7	78.95	96.72	97.55	97.25	95.70	93.26
0.9	76.12	94.22	94.11	94.17	93.78	91.26

The maximum inhibition efficiency was observed for 4 hours of contact ata 298K temperature. **Table 3** shows the values of percentage of inhibition efficiency (IE) obtained from weight loss measurement for different concentrations of the extract in 1M HCl at 298K to 343K temperature. The inhibition efficiency was found to increase with increasing temperature.The chemisorption increases with temperature due to the strengthening of chemical bonds, and as a result inhibition efficiency increases with temperatures up to 333K and thereafter the decomposition of the inhibitor may occur. This indicates the chemical adsorption of the inhibitor on the metal surface. Energy of activation (Ea) was calculated with the help of Arrhenius equation by Ebenso et al [4].

$$\mathrm{Log}\,\frac{\rho_2}{\rho_1} = \frac{E_a}{2.303 \times R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right] \qquad (3)$$

ρ_1 and ρ_2 are the corrosion rates at T_1 and T_2 temperatures respectively. 'R' is a gas constant. The change in free energy of adsorption for different higher temperatures in comparison with room temperature at various concentration of inhibitor was calculated using the equation (4),

$$\Delta G_{ads} = -2.303 \times 8.314 \times T \times \text{Log}(K \times 55.5)$$

$$K = \frac{\theta}{(1-\theta)C} \quad (4)$$

Where,θ = Surface coverage of the metal surface, C = Concentration of the inhibitorin percentage ,
T = Temperature in Kelvin and K is the equilibrium constant.

Table 3 Inhibition efficiency of Acalypha Indica extract on mild steel in 1M HCl for different concentrations using weight loss method at different temperatures.

CONC. (%)	Inhibition Efficiency (%)				
	298K	**313K**	**323K**	**333K**	**343K**
0.05	38.55	47.32	57.21	67.51	55.76
0.1	51.93	59.19	64.90	72.18	60.27
0.2	63.55	69.00	71.88	78.88	70.41
0.3	68.23	73.97	74.76	81.93	76.29
0.5	74.67	77.00	81.00	83.25	80.28
0.7	78.95	81.83	84.85	89.54	82.41

Table 4 shows that the calculated average value of activation energy (Ea) over the temperature range of 298 K to 333K and free energy of adsorption (Gads) for mild steel corrosion with and without inhibitor. **Table 4** shows that the Ea value is less than that of the uninhibited system. The magnitude of Ea obtained supports the assertion that chemical adsorption is involved .To explain the nature of the adsorption of the inhibitor, adsorption isotherm model of Temkin was employed. The negative values of (Gads) indicated spontaneous adsorption and a string interaction of the compound on mild steel surface.

Tafel Polarization Studies

Figure 1 shows the Tafel polarization curves for mild steel in 1M HCl with and without Ai extract. **Table 5** comprises of the electrochemical parameters such as I_{corr}, E_{corr}, Tafel constants (b_a and b_c), polarization resistance (R_p), and percentage of inhibition efficiency (IE %). It is evident that the extract brings about considerable polarization of the cathode as well as anode. It is observed that the inhibitive action is of mixed type. The corrosion current (I_{corr}) values decreases significantly in the presence of the inhibitor. As the concentration of the Ai extract increases, the corrosion current decreases. The calculated polarization resistance (R_p) is increased with the increase of inhibition efficiency .From the results obtained, Ai extract is found to be a good corrosion inhibitor. The results are in agreement with the weight loss measurement.

Table 4 Calculated values of activation energy Ea and free energy of adsorption for mild steel corrosion in 1M HCl with and without acid extract of Acalypha Indica

Conc. (%)	E_a kJ/mol	(ΔH) (kJ/mol) 298K	313K	323K	333K	343K	Average	(ΔH) (kJ/mol)	(ΔS) (kJ/mol)
Blank	67.01	-	-	-	-	-	-	64.33	-
0.05	61.79	21.92	23.96	25.79	27.81	27.22	25.06	59.11	0.261
0.1	60.80	21.55	23.4	24.8	26.51	25.77	24.21	58.12	0.256
0.2	60.45	21.02	22.71	23.81	25.58	25.08	23.39	61.77	0.264
0.3	59.74	20.53	22.29	23.12	25.01	24.79	22.82	60.06	0.257
0.5	58.78	20.05	21.39	22.72	23.85	24.00	22.15	60.1	0.255
0.7	55.31	19.81	21.29	24.43	24.43	23.44	22.13	62.63	0.263

Table 5 Electrochemical polarization (Tafel) parameters for the corrosion of mild steel in 1MHCl containing with and without Ai extract at room temperature

Con. (%)	$-E_{corr}$ (mV)	I_{corr} (mA/Cm^2)	I_{corr} IE (%)	b_a (mV/dec)	b_c (mV/dec)	R_p (Ωcm^2)	R_p IE(%)
blank	488	0.750	-	59.5	168	25.44	-
0.05	484	0.480	36.00	58.2	170	39.22	35.14
0.2	483	0.300	60.00	59.0	163	62.70	59.43
0.3	480	0.250	66.66	59.5	168	76.32	66.67
0.5	463	0.175	77.33	58.3	163	106.55	76.12
0.7	460	0.150	80.00	56.7	160	121.19	79.01

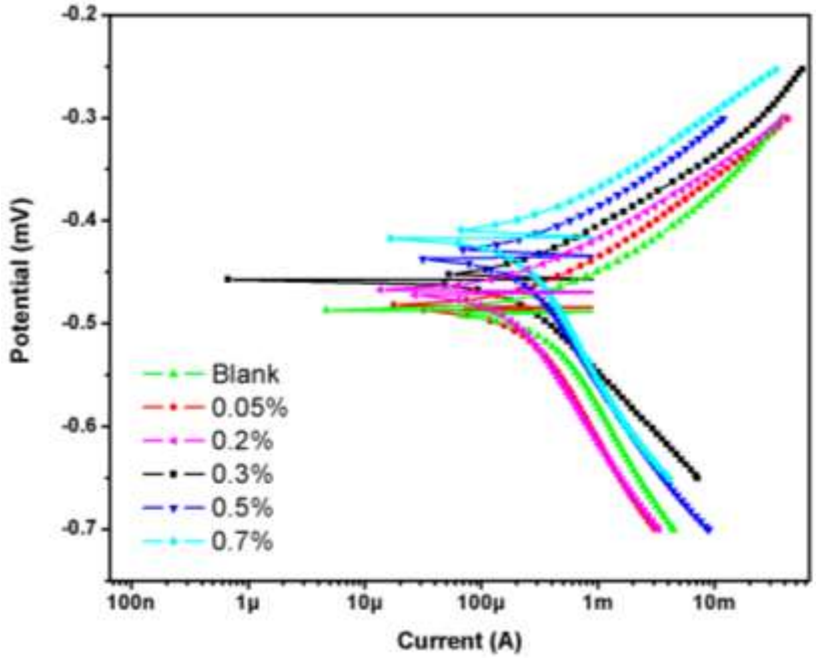


Figure 1 Potentiodynamic polarization curves for mild steel in 1MHCl in the absence and presence of different concentrations of Ai extract

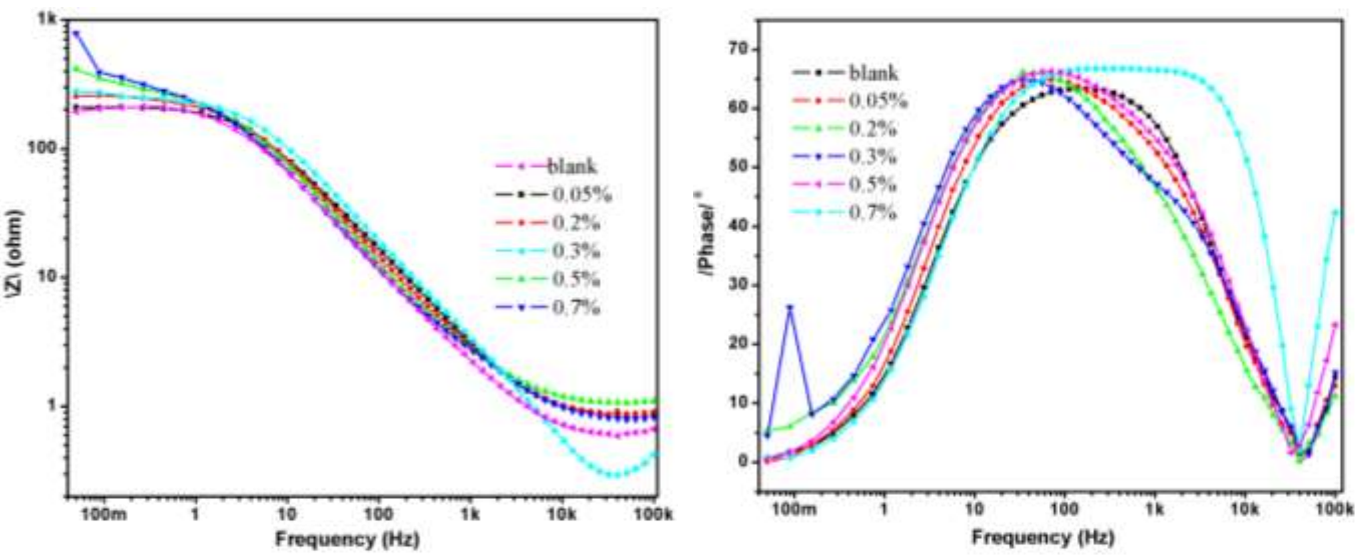
Electrochemical Impedance Measurement

The Nyquist representation of impedance behavior of mild steel in 1M HCl with and without Ai extract is shown in **Table 6**. It is observed that the charge transfer resistance (R_{ct}) values had increased and the double layer capacitance (C_{dl}) the values had decreased with increase in concentrations of Ai extract. The decrease in C_{dl} values could be attributed to the adsorption of the inhibitor molecules at the metal surface. Furthermore, the decreased values of C_{dl} may be due to the replacement of water molecules at the electrode interface by the organic inhibitor of lower dielectric constant through adsorption. The semi circle curves of impedance indicate that the corrosion of mild steel is mainly controlled by charge transfer process.

Table 6 Electrochemical impedance parameters for mild steel in 1M HCl containing different concentrations of Ai extract at room temperature

Conc. (%)	**R_{ct} (Ωcm^2)**	**C_{dl} $\mu F/cm^2$**	**IE (%)**
blank	40.33	850	-
0.05	66.68	514	39.52
0.20	110.30	310	63.44
0.30	145.90	235	72.35
0.50	188.60	181	78.61
0.70	211.00	162	80.88

Figures 2(a) and **2(b)** shows the Bode plot for mild steel in 1M HCl in the presence and absence of Ai extract. It can be seen from **Figure 2(a)** that there is a marked difference in the resistance value, the resistance value increases with concentration. **Figure 2(b)** reveals that there is a marked shift in the phase angle with concentration. The phase angle obtained indicates the uniform adsorption of inhibitor on the mild steel surface.



(a) **(b)**

Figure 2 Bode plots for mild steel in 1M HCl in the presence and absence of Ai extract

Conclusion

The plant extract of *Acalypha indica*, under study behave as an effective inhibitors for mild steel in 1M HCl by weight loss method and electrochemical methods. The inhibition efficiencies (IE) of plant extracts are found to increase with increase of concentration and exposure time. The inhibition efficiencies increase with increase in temperature. Hence it was found to be highly temperature resistance. The temperature resistant inhibitors could play an important role in cooling water system. The inhibitors are found to obey Temkin adsorption isotherm. Activation energies decrease in the presence of the extract, probably implying that chemical adsorption of the plant phytochemical constituents may be responsible for the observed inhibition action. The negative values of free energy of adsorption of inhibitor indicate the spontaneity of adsorption. Electrochemical impedance (Nyquist plots and bode plots) results indicate that the charge transfer process controls the dissolution mechanism of mild steel across the phase boundary in the absence and presence of the plant extracts Tafel polarization studies revealed that the extracts act through mixed mode of inhibition. The results obtained from weight loss, electrochemical impedance and Tafel polarization methods are found to agree very well with each other. In future, surface examination of mild steel specimen may be carried out using Atomic Force Microscopy (AFM) and X-ray Diffraction (XRD) studies. The plant extracts studied under investigation may be applied in industries for acid pickling, acid descaling and oil well acidizing purposes

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