

**THERMODYNAMIC, ADSORPTION AND ELECTROCHEMICAL
STUDIES FOR CORROSION INHIBITION OF CARBON STEEL BY
TERMINALIA CHEBULA LEAF EXTRACT IN 0.5 M HCL MEDIUM**Dr. A. Leema Rose¹, S. Vidhya²^{1,2}Department of Chemistry, Holy Cross College, Tiruchirappalli - 620002.

Abstract - Corrosion inhibition of mild steel in presence of *Terminalia chebula* leaf extract in 0.5 M HCl solution was investigated using weight loss, electrochemical impedance spectroscopy and potentiodynamic polarization techniques. The effect of temperature on the corrosion behavior of carbon steel was studied in the temperature range 295–335 K. The inhibition efficiency increases with increasing inhibitor concentration but decreases with increasing temperature. The activation and free energies for the inhibition reaction support the mechanism of physical adsorption. The adsorption of T.C leaves on C- steel is endothermic, Spontaneous and obeys the Langmuir adsorption isotherm. The potentiodynamic study reveals that *T. chebula* leaves is a mixed type inhibitor. Surface and protective film was examined by scanning electron microscopy (SEM). The effect of temperature on the corrosion rate was investigated and some thermodynamic parameters were also calculated in order to explain the mechanism of adsorption. These thermodynamic parameters indicate a strong interaction between the inhibitor and the mild steel surface.

Keywords - *Terminalia chebula* leaves, Corrosion inhibitor, Energy of activation, Mild steel

I. INTRODUCTION

Corrosion is defined as the deterioration of a metal due to its interaction with the environment. Due to corrosion many useful properties of metals such as malleability, ductility and electrical conductivity are compromised. Nowadays, carbon steel has become an important part of our life due to its extensive applications in household appliances as well as in automotive, petroleum, construction, marine and chemical industries. The use of inhibitors is one of the most practical methods for protection metal against corrosion, especially in acidic media [1]. As acidic media, hydrochloric acid (HCl) and sulphuric acid (H₂SO₄) are often used as industrial acid cleaners and pickling acids. Large numbers of organic compounds revealed that N, S and O containing organic compounds acted as promising inhibitors. However, most of these compounds are not only expensive, but also toxic to living beings. The use of corrosion inhibitors is one of the most practical methods for protection against corrosion. Synthetic organic compounds are widely used as corrosion inhibitors for the prevention of corrosion of many metals and alloys in various aggressive environments. Because of their hazardous nature, researchers focus their attention on developing cheap, non-toxic, biodegradable and environment friendly natural products of plant origin as corrosion inhibitors [2–6]. Literature shows a growing trend in the use of natural products known as non-toxic compounds, called also green inhibitors, as corrosion inhibitors. Available literature has shown that naturally occurring plant leaves such as *Azadirachta indica* leaves, *Murraya koenigii* leaves, *Ervatamia coronaria* leaves, *Ananas comosus* leaves, *Purpurea* leaves, Olive leaves [7–12] have been reported to inhibit the corrosion of metals in acidic media. *Terminalia chebula* leaves, a medicinal plant found throughout Tamil Nadu, belongs to the family Combretaceae. The leaves of *T. chebula* are widely used to cure diseases like cough, bronchial asthma, diarrhea, dysentery [13] (Fig. 1).

In the present work, we have evaluated its leaf extract as a green corrosion inhibitor for carbon steel. The aim of the present study was to investigate the inhibitive effect of *T. chebula* leaves extract as a cheap, nontoxic, readily available and novel corrosion inhibitor for the corrosion of mild steel in 0.5 M HCl. The leaf-extract was investigated by weight-loss method and potentiodynamic polarization technique in carbon steel. Surface and protective film analysis was carried out using scanning electron microscopy (SEM).



Fig. 1 *Terminalia chebula* leaf

2. EXPERIMENTAL

2.1. Sample preparation

The mild steel samples were obtained from a locally available industrial Fe–C steel with a very low concentration of carbon. A large sheet of cold rolled mild steel coupons with a chemical composition of (0.026 % S, 0.06 % P, 0.4 % Mn and 0.1 % C and rest Fe) was utilized for the present study. The mild steel samples, with an active surface of $1.0 \times 4.0 \times 0.2$ cm were used for Mass loss measurements and $1 \text{ cm} \times 1 \text{ cm}$ specimen for electrochemical measurements. The mild steel samples were mechanically polished, washed in double distilled water and degreased with acetone and used for the weight-loss method and surface examination studies.

2.2 Preparation of leaf extract

Fresh samples of *T. chebula* were collected from the hill stations of Salem. The leaves were authenticated by Department of Botany, Holy Cross College (Autonomous), Tiruchirappalli. The leaves were washed thoroughly 2–3 times with running tap water and the leaves are air dried under shade. After complete shade drying, the leaves were grinded in the mixer, the powder was kept in small plastic bags with proper labeling. About 50 g of the powder was soaked in a 250 ml of methanol under cold percolation method. At regular intervals of time the extract was filtered and distillation was carried out to collect the crude extract. The extract was stored in an amber bottle and refrigerated [14].

2.3. Solutions preparation

A stock solution of 1 M HCl was prepared from 35.4 % HCl (Merck) using distilled water. The concentration range of *T. chebula* extract employed was varied from 100 to 900 ppm.

2.3 Weight loss measurements

Weight loss measurements were carried out using a Shimadzu ATP-224 model Electronic top loading balance, with readability/sensitivity of 0.1 mg in 210 g range. The specimens were immersed in beaker containing 100 ml acid solution without and with different concentrations of *T. chebula* leaves extract

using hooks. In order to get good reproducibility, experiments were carried out in triplicate. At the end of exposure period, specimens were cleaned according to ASTM G-81 and the weight recorded. The average mass loss of three parallel mild steel specimens was obtained. The test specimens were removed and then washed with de-ionised water, dried and reweighed. The inhibition efficiency IE% was calculated using the formula:

$$IE = 100 [1 - (W_2/W_1)] \% \quad (1)$$

where W_1 and W_2 are corrosion rate in the absence and presence of inhibitor respectively.

The parameters used for the present study are given by:

1. Concentration of the inhibitor: 100 to 900 ppm
2. Temperatures: (305 K, 315 K, 325 K, 335 K)

From the change in weight of specimens the corrosion rate was calculated using the following relationship:

$$\text{Corrosion rate} = \frac{87.6 \times W}{A \times T \times D} \quad (2)$$

W = loss in weight in mg

A = surface area of the specimen (cm^2)

T = time in hrs

D = density (7.2 g/cm^3)

3. ELECTROCHEMICAL MEASUREMENTS

Electrochemical testing of inhibitors has the major benefit of short measurement time and providing vital information about the mechanism of inhibition. The electrochemical cell is a conventional three-electrode Pyrex glass cell. The mild steel specimen was embedded in Teflon holder using epoxy resin with an exposed area of 1 cm^2 as working electrode. The graphite electrode was used as an auxiliary electrode. The reference electrode was a Saturated Calomel Electrode (SCE) coupled to the working electrode and the auxiliary electrode.

Electrochemical impedance spectroscopy

Electrochemical measurements were run using a potentiostat/galvanostat (Electrochemical System Model Vertex.100mA.D) and a personal computer was used. IVIUM software was used for Electrochemical Impedance Spectroscopy (EIS) and potentiodynamic polarization (PDP) analysis. prior to each experiment, the working electrode was polished successively with different grade of emery papers, then the polished metal surface was rinsed with de-ionized water, ethanol and finally dipped in the tested solution. After 10 min of electrode immersion to attain open circuit potential, the electrochemical measurement was done as follows.

Firstly, the EIS measurements were carried out using AC signals of amplitude 10 mV peak-to-peaks at the open circuit potential in the frequency range of 10 MHz to 1 Hz. The charge transfer resistance (R_{ct}) values have been calculated from the difference in the impedance at low and high frequencies. The capacitances of the double layer (C_{dl}) values are estimated from the frequency (f) at which the imaginary component of the impedance ($-Z''$) is maximum and the double layer capacitance (C_{dl}) was calculated by using following equation [15]:

Obtained from the equation:

$$C_{dl} = 1/2 \times 3.14 \times R_{ct} \times f_{\max} \quad (3)$$

Potentiodynamic polarization

After impedance spectrum was obtained, the potentiodynamic current potential curves was recorded immediately by changing the electrode potential automatically taken from OCP value with scan rate of 5

mV s⁻¹. Tafel lines extrapolation method was used for detecting icorr and Ecorr values for the studied systems. Because of the presence of a degree of nonlinearity in the part of the obtained polarization curves, the corresponding anodic and cathodic Tafel slopes (b_a and b_c) were calculated as a slope of the points after corrosion potential (i) by ±50 mV using a computer least square analysis. All the electrochemical measurements were performed in stagnant, aerated solutions adjusted at 30°C.

$$i_{corr} = b_a \times b_c / 2.303(b_a + b_c)R_p \quad (4)$$

where, R_p is polarization resistance.

Linear polarization measurement

The linear polarization behavior of mild steel in 1 M HCl in absence and presence of different concentration of inhibitor was studied at ± 20 mV versus OCP at a scan rate of 0.125 mV s⁻¹. The polarization resistance (R_p) was calculated from the slope of curve in vicinity of corrosion potential

Scanning electron microscopy

The carbon steel specimens immersed in presence and absence of inhibitor for 3 hrs were taken out, rinsed with double distilled water, dried and subjected to the surface examination. The surface morphology measurements of the carbon steel surface were carried out by SEM using F E I Quanta FEG 200-High Resolution Scanning Electron Microscope, SRM University, Kattankulathur.

Results and discussion

The qualitative phytochemical screening of *T. chebula* leaves [16] was done and the results are shown in Table 1.

Table 1 Qualitative analysis of phytochemical constituents in the methanolic extract of *T. chebula* leaves

Name of the phytochemicals	Presence/absence
Alkaloid	+
Saponin	-
Tannin	+
Flavonoids	+
Protein	-
Steroids	+
Carbohydrates	+
Poly phenol	+
Glycoside	+
Phlobatannins	-
Anthroquinone	-
Terpenoids	+
Triterpenoids	+

3.2. Mass loss measurements

3.2.1. Effect of concentration

The mass loss method of monitoring corrosion rate is useful because of its simple application and reliability [17]. Inhibition efficiencies of mild steel with different concentrations of *T. chebula* leaves extract is 0.5 M HCl at room temperature are presented in Table 2. From Table 2, corrosion rate decreases noticeably with an increase in inhibitor concentration, i.e. the corrosion inhibition enhances with the inhibitor concentration. This behavior is due to the fact that the adsorption and coverage of the inhibitor on the mild steel surface increase with the inhibitor concentration [18]. Maximum inhibition

efficiency of *T. chebula* leaves at 600 ppm concentration was found to be 87.26 % in 0.5 M HCl at 3 h immersion. The high inhibitive performance of *T. chebula* suggests a higher bonding ability of inhibitor on to mild steel surface (Fig. 2).

Table 2 Corrosion rates of carbon steel in 0.5M HCl by weight-loss method

S. No.	Concentration (ppm)	Corrosion rate (mpy)	Surface coverage(θ)	Percentage inhibition
1	Blank	13.1135	-	—
2	100	9.0459	.31	31.01
3	200	5.9801	.54	54.39
4	300	4.2497	.67	67.59
5	350	3.3087	.73	73.14
6	400	2.6106	.75	75.92
7	450	2.3070	.77	77.08
8	500	2.3070	.82	82.40
9	550	1.8820	.85	85.64
10	600	1.6695	.87	87.26
11	700	1.9427	.85	85.18

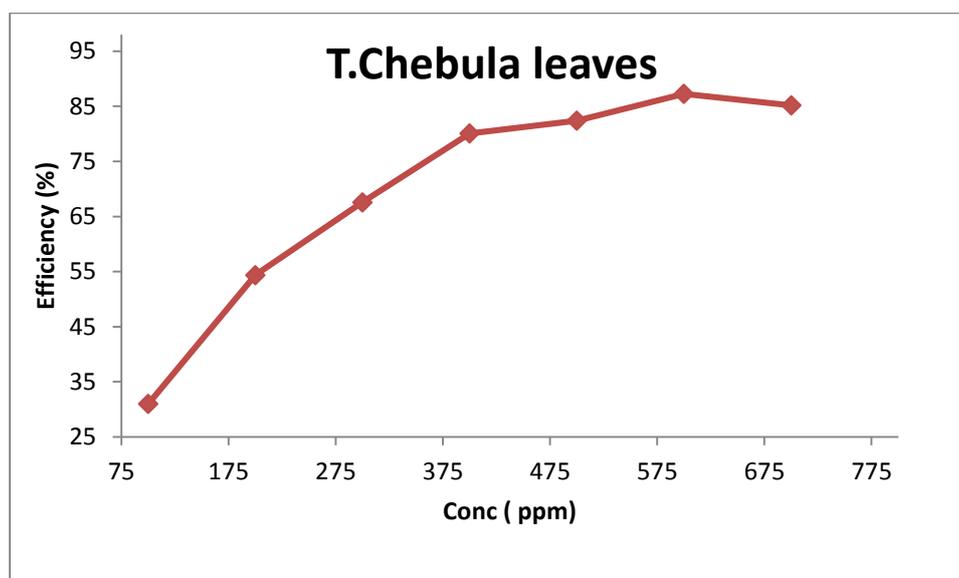


Fig. 2 Inhibition efficiency of *T. chebula* leaves at different concentration

3.2.3. Effect of temperature

To show the effect of temperature on inhibition efficiency of *T. chebula* leaves, weight loss experiment was performed in the temperature range of 305–335 K at optimum concentration of *T. chebula* leaves. The variation of inhibition efficiency with temperature at optimum concentration of *T. chebula* leaf is shown in Fig. 3. From Fig. 3, it is clear that corrosion rate is temperature dependent and increases with increasing the temperature. This decrease in inhibition is due to desorption of inhibitors from metal surface [19]. Thus, at higher temperature, more desorption of inhibitor molecules takes place and larger surface area of metal come in contact with acid, resulting in an increase in corrosion rate [20]. The values of percentage inhibition efficiency (η %), corrosion rate (CR), surface coverage) and

corresponding efficiency obtained from weight loss method at different temperatures are summarized in Table 3.

Table 3 Effect of temperature on the CR of carbon steel in 0.5M HCl by *T. chebula* leaf extract (TCLE) at different temperatures

S. No.	Temperature (K)	Corrosion rate (Blank)	Corrosion rate (Inhibitor)	Surface coverage (θ)	% I.E.
1	305	13.1135	1.6695	0.87	87.26
2	315	18.2436	5.9496	.67	67.38
3	325	26.7128	13.4899	.49	49.5
4	335	33.952	44.53	.23	23.75

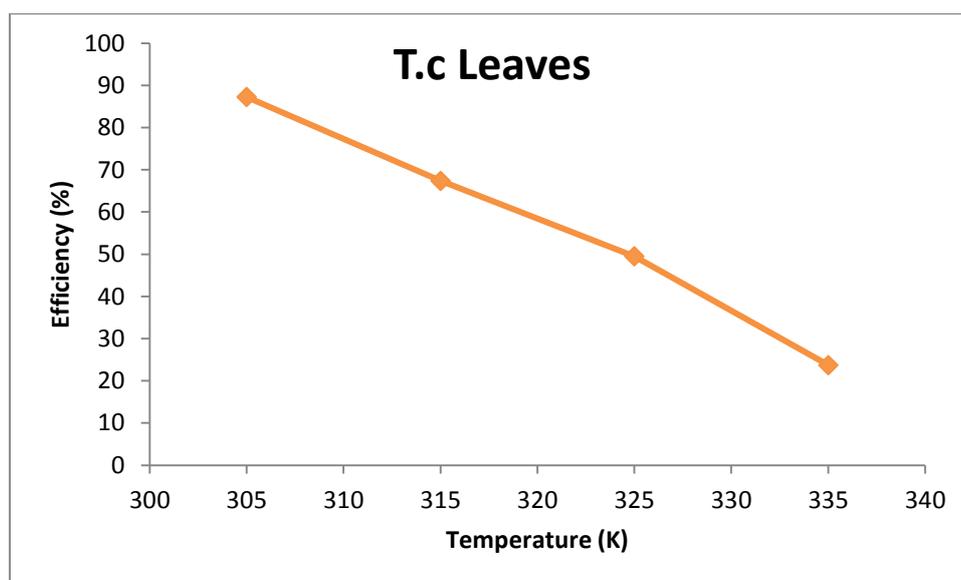


Fig. 3 Inhibition efficiency of *T. chebula* leaves at different temperature

Adsorption isotherm

The surface coverage (θ) values for different concentrations of the inhibitors in the acid medium have been evaluated from the weight loss data. At any instant a fraction of the metal surface is covered by the inhibitor molecules and the uncovered fraction ($1 - \theta$) reacts with acid as it does in the absence of the inhibitor. The nature of the inhibitor interaction with the corroding surface has been deduced from the adsorption characteristics of the inhibitor. Surface coverage values are much useful to measure the adsorption characteristics. Addition of inhibitor molecules adsorb on the metal surface and interaction between them can be described by adsorption isotherms [21].

3.3.1. Langmuir Isotherm

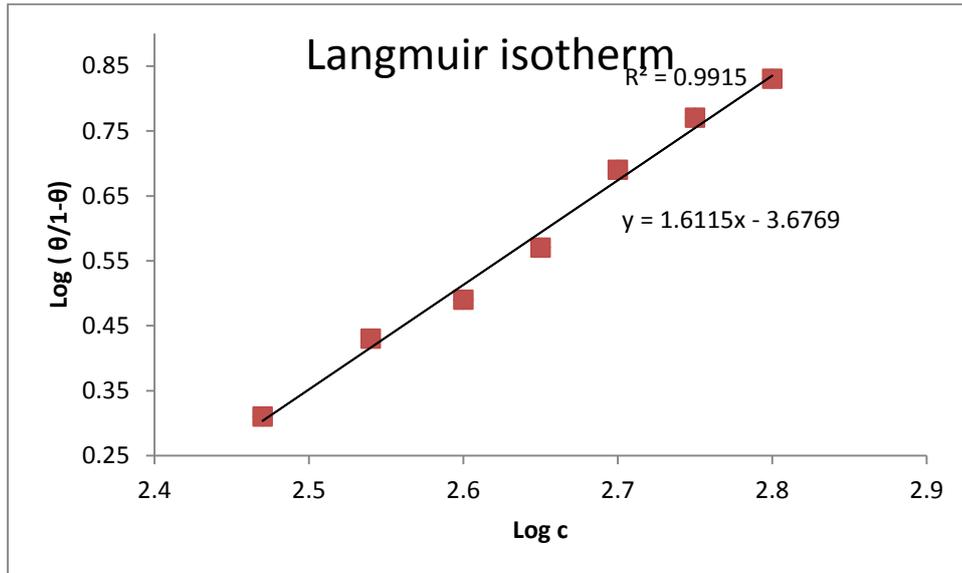


Fig. 4 Langmuir adsorption isotherm plots for carbon steel in 0.5 M HCl with different concentrations of *T. chebula* extract

Langmuir adsorption isotherm was found to be best fit which assumes that the solid surface contains a fixed number of adsorption sites and each site holds one adsorbed species [22]. *T. chebula* leaf obeys Langmuir adsorption isotherms by giving a straight line for a plot of $\log C$ versus $\log (\theta/1 - \theta)$ and C/θ versus c , respectively. These straight lines obtained reveal that the main process of inhibition is adsorption (Fig. 4). It can also be explained that the increase in inhibition efficiency with increase in extract concentration is an indication of an increase in the number of components of the extract adsorbed over the mild steel surface blocking the active sites, in which direct acid attacks proceed and protect the metal from corrosion. The R^2 value is 0.991 and slope is very close to unity, indicating strong adherence to Langmuir adsorption isotherm [23].

Thermodynamic parameters

Langmuir adsorption isotherm can be expressed according to Equation (6) [24],

$$C/\theta = 1/K + C \quad (6)$$

where C is the concentration of the inhibitor, K is the adsorption equilibrium constant and θ is degree of surface coverage of the inhibitor (Fig. 5).

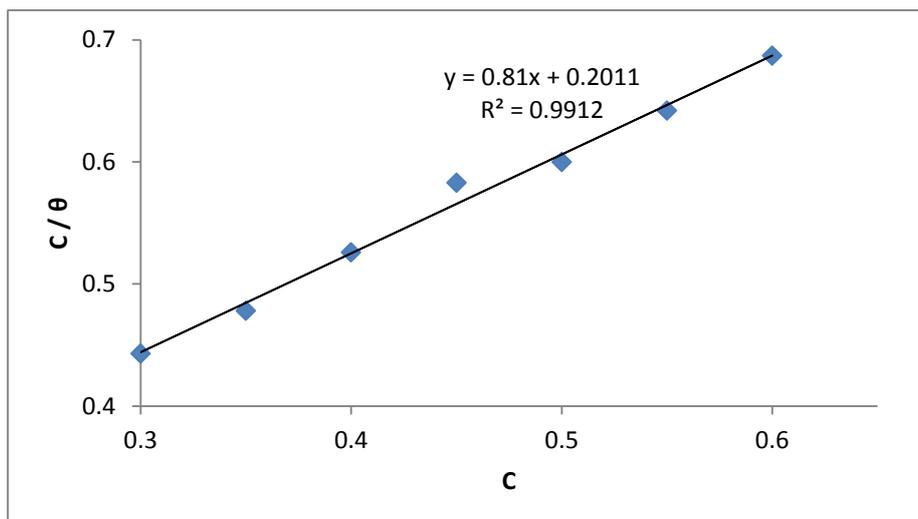


Fig. 5 Langmuir adsorption isotherm plots for carbon steel in 0.5 M HCl with different concentrations of *T. chebula* extract. The standard free energy of adsorption, ΔG°_{ads} and the values of equilibrium constant, K_{ads} at given temperatures is calculated from the equation [25]

$$C_{inh}/\theta = 1/K_{ads} + C_{inh} \quad (6)$$

The K_{ads} values can be calculated from the intercept lines on the C_{inh}/θ axis.

$$\Delta G^{\circ} = -RT \ln(55.5 K_{ads}) \quad (7)$$

where 55.5 is the water concentration of the solution ml/l.

The values of ΔG° for the inhibitor on the surface of C-steel are given in Table 4. The negative values of ΔG° indicate the stability of the adsorbed layer on the steel surface and spontaneity of the adsorption process. ΔG° decreased (become more negative) with increasing temperature, indicating the occurrence of endothermic process. In the present work, the calculated values -14.257 kJ/mol, less than the threshold value (-40 kJ/mol) required for chemical adsorption and the IE% decreased with increasing temperature. These support the mechanism of physical adsorption [26]

The corrosion rate (CR) depends upon temperature and this temperature dependence corrosion rate of a chemical reaction can be expressed by following Arrhenius and transition state equation [27].

$$\text{Log}(C_R) = -\frac{Ea}{2.303RT} + \log \lambda \quad (4)$$

$$C_R = \frac{RT}{Nh} \exp\left(\frac{\Delta S^*}{R}\right) \exp\left(-\frac{\Delta H^*}{RT}\right) \quad (5)$$

where h is the Planck's constant 6.6261×10^{-34} Js and N is the Avogadro's number 6.0225×10^{23} mol⁻¹. where Ea is activation energy for the corrosion of Mild Steel in 0.5 M HCl, λ pre-exponential factor, R is the gas constant, A the Arrhenius pre-exponential factor and T is the absolute, h is Plank's constant, N is Avogadro's number, ΔS^* is the entropy of activation and ΔH^* is the enthalpy of activation temperature.

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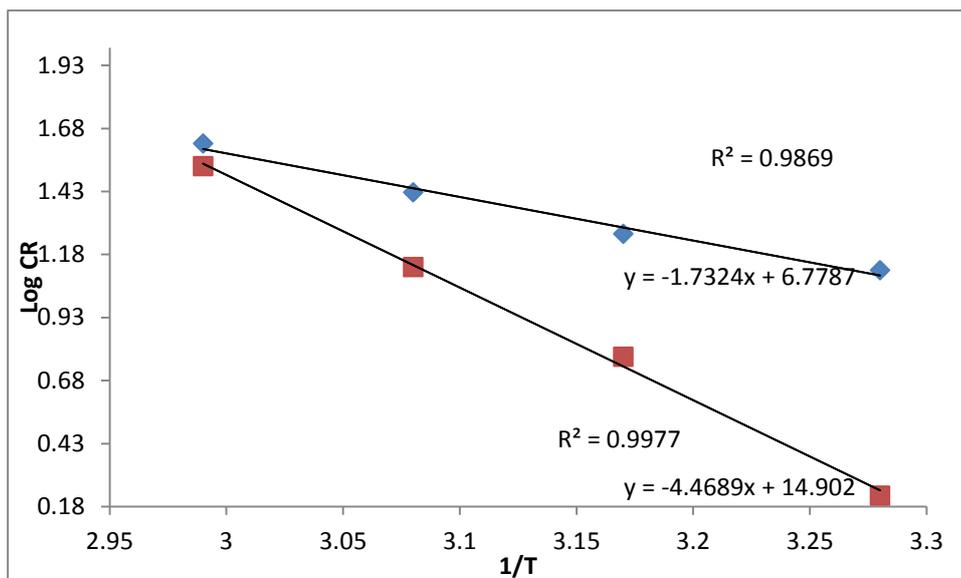


Fig. 6 Arrhenius plots of log CR versus 1/T

The Arrhenius plot for mild steel immersed in 0.5 M HCl in inhibitor-free and with inhibitor solution is depicted in Fig. 6. The plot obtained was straight lines and apparent activation energies (E_a) at optimum concentration of inhibitors were determined by linear regression between log CR versus $1/T$ and listed in Table 4. All the linear regression coefficients are close to unity. Inspection of Table 4 reveals that E_a values are higher in presence of *T. chebula* leaves than in absence of *T. chebula* leaves. The addition of inhibitor modified the values of E_a ; this modification may be attributed to the change in the mechanism of the corrosion process in the presence of adsorbed inhibitor molecules [29]. A decrease in inhibition efficiency with rise in temperature with analogous increase in corrosion activation energy in the presence of inhibitor compared to its absence is frequently interpreted as being suggestive of formation of an adsorption film of a physical nature [30,31].

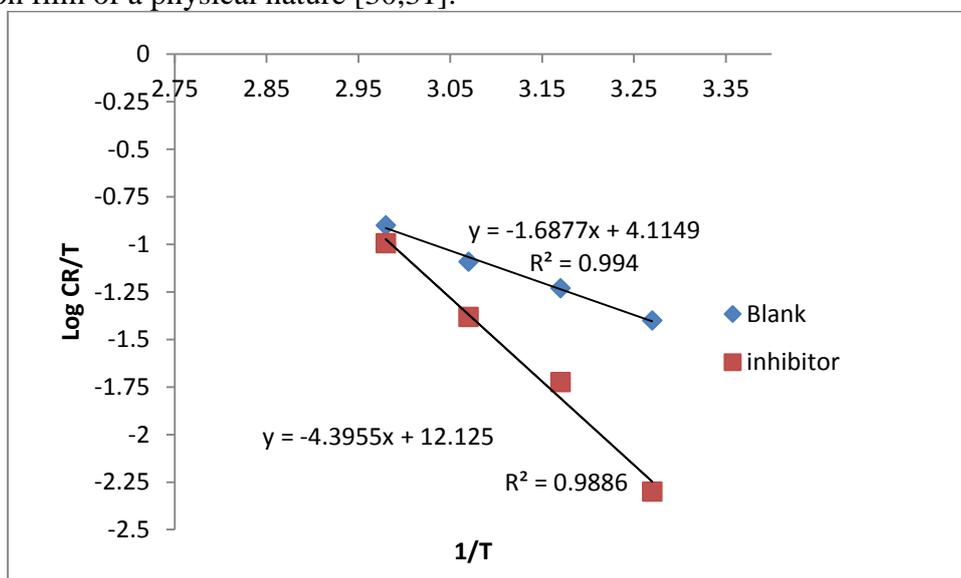


Fig. 7 Transition state plots of log CR/T versus 1/T

Figure 7 represents the plot between log CR/T vs. $1/T$ which give a straight lines from their gradient ($\Delta H^* = -\text{slope}/2.303R$) and intercept ($\log(R/Nh) + (\Delta S^*/2.303R)$) of which values of the ΔH^* and ΔS^*

were calculated and given in Table 4. Study of Table 4 reveals that the value of ΔH^* for dissolution of mild steel in 0.5 M HCl in presence of *T. chebula* leaves is higher ($81.85 \text{ kJ mol}^{-1}$) than that in absence of *T. chebula* leaves ($36.32 \text{ kJ mol}^{-1}$). The positive sign and higher value of ΔH^* reflected the endothermic nature of mild steel dissolution process, which mean that dissolution of mild steel is in presence of T.C leaves is difficult [32]. The shift towards positive value of entropies (ΔS^*) shows that the activated complex in the rate determining step represents dissociation rather than association, meaning that disordering increases on going from reactants to the activated complex [33]. The change of ΔH^* and ΔS^* with concentration of the inhibitor suggests that the process is enthalpic and entropic controlled [34].

Table 4 Thermodynamic parameters for mild steel in 0.5M HCl in absence and presence of optimum concentration of *T. chebula* leaves

	$E_a(\text{kJmol}^{-1})$	$\Delta H^*(\text{kJmol}^{-1})$	$\Delta S^*(\text{JK}^{-1}\text{mol}^{-1})$	$\Delta G(\text{kJmol}^{-1})$
Blank	33.922	32.30	0.302	-
Inhibitor	85.714	84.151	0.463	-14.257

Electrochemical impedance spectroscopy

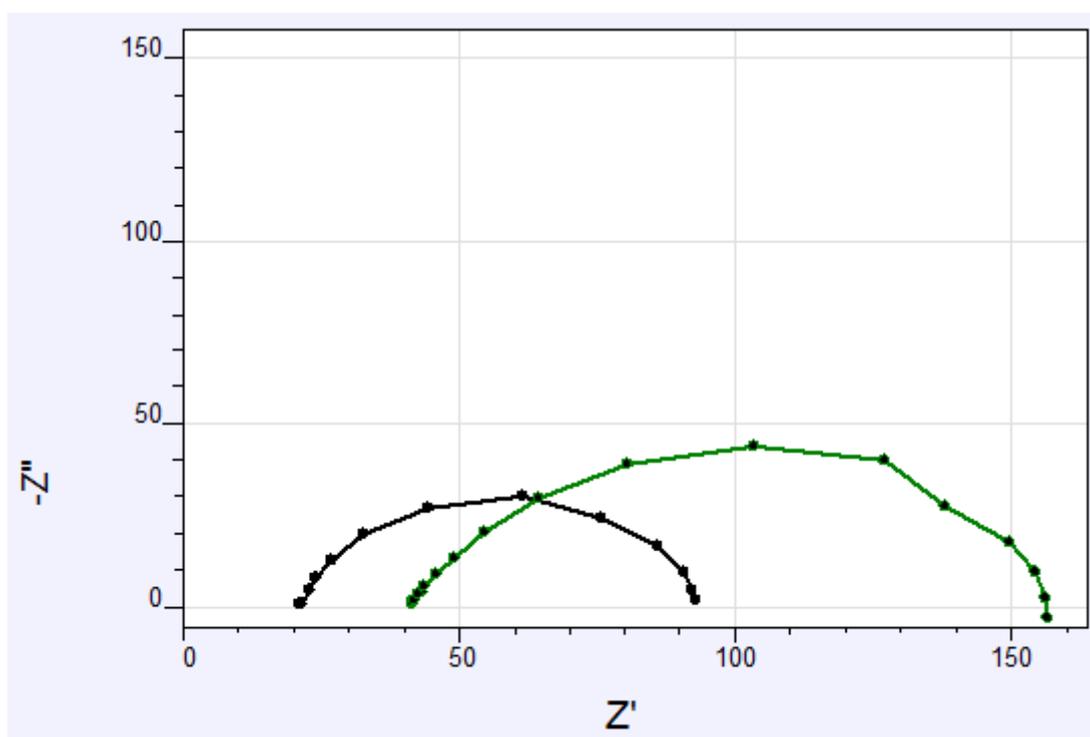


Fig. 8 Nyquist plot in absence and presence of optimum concentrations of *T. chebula* leaves

The impedance behavior of mild steel in 0.5 M HCl in absence and presence of different concentration of M.C leaves is shown as Nyquist plot in Fig. 8 and EIS parameter such as R_s , R_{ct} , and C_{dl} were derived from the Nyquist plot are given in Table 5. The ω_{max} represents the frequency at which the imaginary component reaches a maximum. It is the frequency at which the real part (Z_r) is midway between the low and high frequency x-axis intercepts. It is clear from the result that value of R_{ct} increases from $66.5 \Omega \text{ cm}^2$ (Blank) to $103.9 \Omega \text{ cm}^2$ on addition of 600 ppm of inhibitor. The value of C_{dl} decreases from $1.226 \times 10^{-4} \text{ F cm}^{-2}$ to $1.11 \times 10^{-8} \text{ F cm}^{-2}$. The decrease in capacitance (C_{dl}) on

addition of inhibitor may be due to increase in local dielectric constant and/or may be due to increase in the thickness of the double layer, showing that *T. chebula* leaves inhibited Iron metal corrosion in by adsorbing at metal/acid interfaces [35]

Table 5 The electrochemical impedance parameters of *T. chebula* leaves in 0.5 M HCl at 600 ppm concentration

System	R_s Ω	R_{ct} Ωcm^2	C_{dl} F cm^{-2}
Blank	23	66.5	$1.226 * 10^{-4}$
Inhibitor	65	103.9	$1.11 * 10^{-8}$

Linear polarization measurement

The inhibition behavior of *T. chebula* leaves in 0.5M HCl in presence and absence of different concentration of inhibitor were also calculated linear polarization parameters given in Table 6. The efficiency found by linear polarization shows good agreement to efficiency obtained from Tafel and EIS that data.

Potentiodynamic polarization measurements

The potentiodynamic polarization behavior of mild steel in 0.5 M HCl in absence and in presence of *T. chebula* leaves is shown as Tafel plot in Fig. 9. The various electrochemical potentiodynamic parameters such as corrosion potential (E_{corr}), corrosion current density (I_{corr}), anodic and cathodic slope (β_a and β_c) were calculated from Tafel plots are given in Table 6. It is seen that addition *T. chebula* leaves decreases the corrosion current (I_{corr}) density from $197 \mu\text{A}/\text{cm}^2$ (Blank) to $134 \mu\text{A}/\text{cm}^2$ at the 600 ppm concentration. The addition of inhibitor E_{corr} shift from -416.4 to -446 mV/SCE did not cause significant shift of E_{corr} . The shift in the E_{corr} value to a more negative value indicates that the inhibitor functions as anodic inhibitor. This shows that the inhibitor controls both the anodic and cathodic reactions but predominantly behaves as anodic inhibitor [36].

The cathodic slope was practically unaffected by the addition of the *T. chebula* leaves which indicates that hydrogen evolution reaction is diminished exclusively by the surface blocking effect of adsorbed inhibitor [37]. Regarding the anodic region of the potentiodynamic polarization curves, there is clearly an active-passive behavior either in presence or in absence of the inhibitor. The maximum shift was 24 mV towards noble direction thus investigated compound behaves as mixed type of inhibitor. The addition of *T. chebula* leaves extract to HCl solution therefore reduces the anodic dissolution of iron and also retards the cathodic evolution reaction..

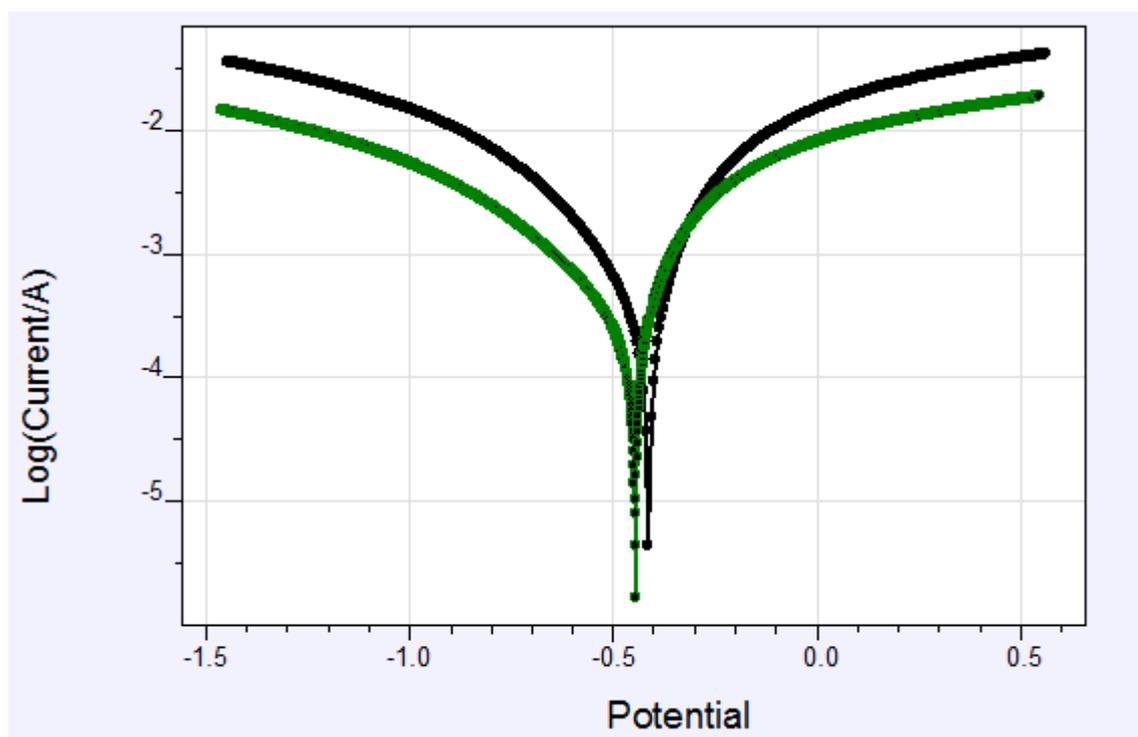


Fig. 9 Tafel polarization curves for corrosion of mild steel in 0.5 M HCl in the absence and presence of *T. chebula* leaves

Table 6 The potentiodynamic polarization and linear polarization parameters of *T. chebula* leaves

System	E_{corr} mV/SCE	I_{corr} $\mu\text{A}/\text{cm}^2$	β_a mV/dec	β_c mV/dec	R_p	Corro rate mm/y
Blank	-416.4	197	943	750	110.1	93.95
Inhibitor	-446	134	1097	730	161.1	47.56

SEM analysis

The SEM images were recorded to establish the interaction of inhibitor molecules with metal surface. Figure 10 represents the SEM images of plain mild steel, mild steel immersed in 0.5 M HCl, mild steel immersed in the presence of *T. chebula* in 0.5 M HCl. The SEM images revealed that the mild steel specimen immersed in inhibited solution is in better condition having a smooth surface while the metal surface immersed in blank acid solutions is rough covered with corrosion products and appeared like full of pits and cavities [38]. Result shows that the phytochemical constituents present in the T.C form a protective layer of the mild steel specimen and thereby reduce the corrosion rate.

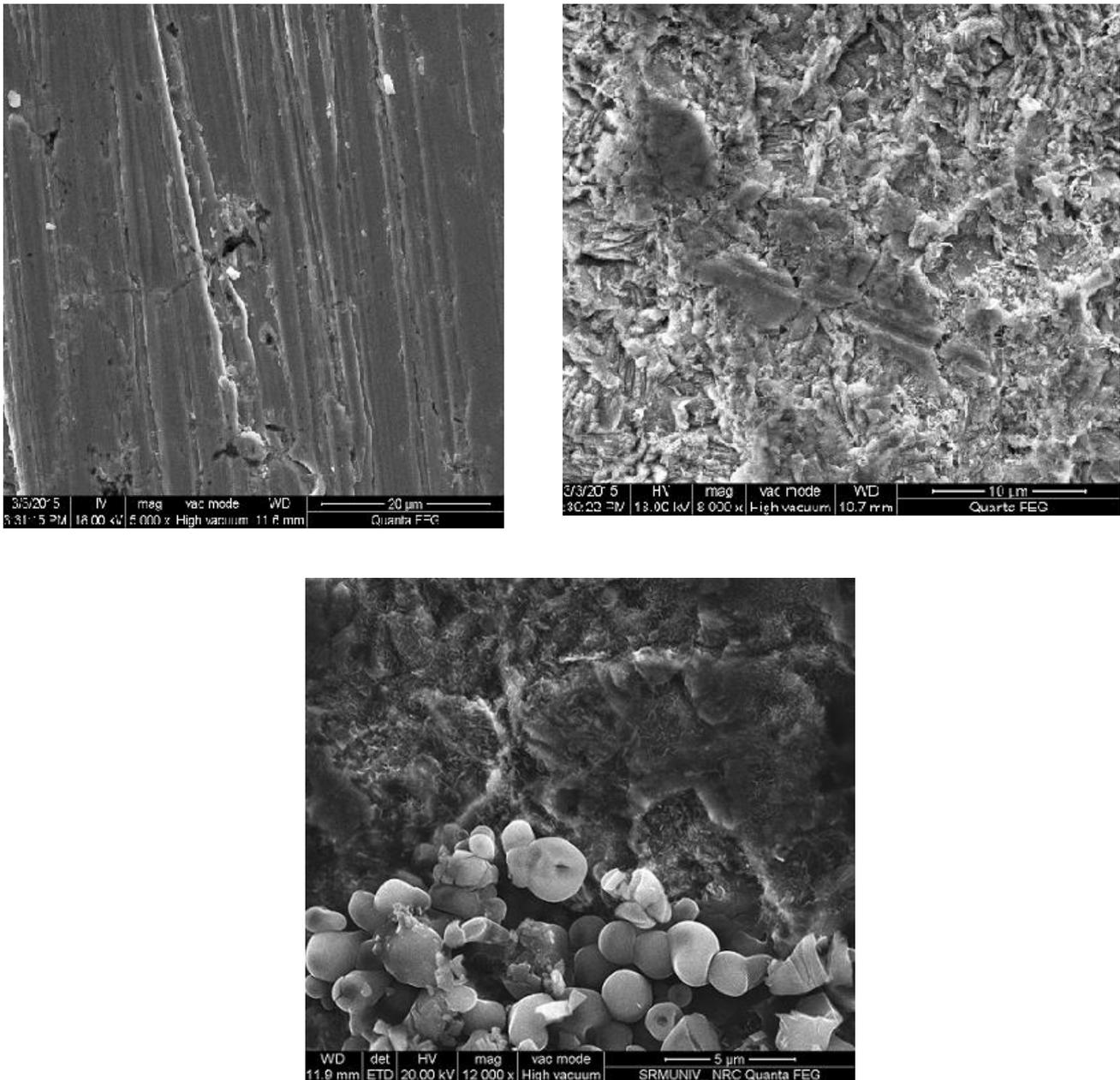


Fig. 10 SEM micrograph of (a) plain mild steel, (b) mild steel immersed in acid, (c) mild steel immersed in the presence of T.CLE in 0.5M HCl

CONCLUSION

From above study it is concluded that:

1. *T. chebula* leaves is good corrosion inhibitors for corrosion of mild steel in 0.5 M HCl solution. The maximum efficiency was found to be 87.26 % at 600 ppm concentration.
2. The adsorption of *T. chebula* leaves on mild steel surface obeyed the Langmuir isotherm.
3. The potentiodynamic studies reveal that *T. chebula* leaves is a mixed type inhibitors but predominantly behaves as anodic inhibitor.
4. EIS measurement results indicated that the resistance of the mild steel electrode increased greatly and its capacitance decreases by increasing the inhibitor concentration.

5. The negative values of ΔG shows that adsorption of *T. chebula* leaves on mild steel is a spontaneous process.
6. The increase in E_a is proportional to the inhibitor concentration, indicating that the energy barrier for the corrosion interaction is also increased.
7. The results obtained from weight loss and electrochemical methods show that *T. chebula* leaves act as good inhibitor.

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