Corrosion Inhibition study of Nardostachys jatamansi root extract as green inhibitor for mild steel in hydrochloric acid.

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ABSTRACT

In this study, we report the study of the inhibition effect of Nardostachys jatamansi root extract on corrosion of mild steel in hydrochloric acid using weight loss measurements and electrochemical techniques. The inhibitor efficiency of Nardostachys jatamansi root extract extract was found to very with concentration was kept uniform for 24 h and temperatures was kept uniform for 2 h. Experimental results revealed that inhibition efficiency (I.E %) increased with increasing inhibitor concentration. As temperatures increased, percentage of inhibition decreases. Experimental results revealed that inhibition efficiency (I.E %) increased with increasing inhibitor concentration. As temperatures increased, percentage of inhibition decreases. The inhibitive and adsorptive characteristics of ethanol extract of Nardostachys jatamansi root extract for the corrosion of mild steel (MS) in 1M HCl solutions have been studied using following methods for monitoring corrosion. Ethanol extract of Nardostachys jatamansi root extract is a good adsorption inhibitor for the corrosion of mild steel in HCl. The methods used were weight loss, effect of temperature, polarization and Electrochemical Impedance Spectroscopic (EIS). The inhibition efficiency(I.E.) increases with inhibitor concentration. The adsorption study of these compounds of mild steel surface found to obey Nardostachys jatamansi root extract adsorption isotherm. The value of free energy of adsorption (ΔG^0_{ads}), heat of adsorption (Q_{ads}), energy of activation (E_a), enthalpy of adsorption(ΔH^0_{ads}) and entropy of adsorption (ΔS^0_{ads}) were calculated. Present study indicates that Nardostachys jatamansi root extract is a good inhibitor for the corrosion of Mild steel in hydrochloric acid medium.

Keywords : Mild steel, Hydrochloric acid, Nardostachys jatamansi root extract, corrosion, inhibition effect.

[1.0] INTRODUCTION

The importance of the study lies in the fact that naturally occurring plant products are non-polluting, eco-friendly, less toxic, biodegradable, less expensive and easily available. Due to the toxicity of some corrosion inhibitors, there has been increasing search for green corrosion inhibitor. Metals undergo corrosion in the presence of oxygen and moisture and involve two electrochemical reactions. Oxidation occurs at anodic site and reduction occurs at cathodic site. Corrosion inhibitors reduce or prevent these reactions, they are adsorbed on the metal surface and act by forming barrier to oxygen, moisture and some of the inhibitors facilitate formation of passive film on the metal surface.

Generally, organic compounds of higher molecular weight with hetero atoms (having lone pair of electrons like N, S, O) are used as inhibitors in HCl medium for mild steel. Unfortunately, most of the organic and inorganic inhibitors are toxic and non-biodegradable. This is encouraging because it means green inhibitors can be used in low concentration, thus making them cheaper and eco-friendly. The inhibition efficiency decreased with an increase in temperature in most cases, thus proving that the process is efficient at room temperature or low temperatures. In some few cases [3, 23, 27, 28], inhibition efficiency was high at high temperature and this can be an advantage, where mild steel is used in high temperature applications.

[2. 0] MATERIALS AND METHODS

The effects of temperature and concentration of the inhibitors were also studied. The thermodynamic parameters for the process were computed and discussed. In this project both of the methods weight loss and galvanostatic polarization was employed. Many papers have been reported about the investigation of corrosion inhibition process. There are two methods to determine the corrosion rate, (1) weight loss, (2) galvanostatic polarization. The effects of temperature and concentration of the inhibitors were also studied. The thermodynamic parameters for the process were computed and discussed. In this project both of the methods weight loss and galvanostatic polarization was employed.

[2.1] Metal specimen and surface pretreatment : Rectangular specimens of the size 4.4 x 2.0 x 0.2 cm having an area of 0.2011sq. dm. of mild steel with small hole of 0.5 cm diameter near the upper edge, were used for the determination of corrosion rate. The specimens were cleaned by washing with distilled water, degreased by acetone for 1-2 minutes, then dried in warm air by air drier several times and are preserve in desiccators till use. The method gave mirror like finish.

[2.2] Preparation of inhibitor

Stock solution of Nardostachys jatamansi root extract was extracted by refluxing of 10 gm of dry material in 100mL alcohol for 1 hours. The refluxed solution was filtered to remove any contamination. The concentration of the stock solution was calculated in terms of g/l.

The effects of temperature and concentration of the inhibitors were also studied. The thermodynamic parameters for the process were computed and discussed. In this project both of the methods weight loss and galvanostatic polarization was employed.

[2.3] Weight Loss:

Weight loss method is simple, cheap and widely used method. It gives a quantitative data. It is a valid measure of corrosion only if corrosion is perfectly uniform. The specimens were degreased by immersion in A. R. grade acetone and dried in warm air using air dryer and preserve in desiccators till use.

The test specimens were immersed in 0.1, 0.5 and 1.0 M Hydrochloric acid solution with and without inhibitor. At any instant a fraction 'θ' of the metal surface is covered by the inhibitor molecules and uncovered fraction (1-θ) 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 very useful in explaining the adsorption characteristics. The inhibition efficiency (η%) and degree of surface coverage (θ) at each concentration of inhibitors was calculated by comparing the corrosion loss in the absence (W_u) and presence of inhibitor (W_i) using the relationships:

$$\eta\% = \frac{W_u - W_i}{W_i} \times 100 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\theta = \frac{W_u - W_i}{W_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Table: 1 Immersion period: 24h Effective specimen area: 0.2011dm^2

Inhibitors	Inhibitor Conc. (gm/lit.)	Acid concentration 0.1 M Mass loss (mg/dm^2)	0.1 M I.E. (%)	0.5 M Mass loss (mg/dm^2)	0.5 M I.E. (%)	1.0 M Mass loss (mg/dm^2)	1.0 M I.E. (%)
Blank	-	321.54	-	581.38	-	873.61	-
Nardostachys jatamansi	0.1 g/l	51.76	83.90	117.81	79.74	228.95	73.79
	0.5 g/l	48.91	84.79	80.63	86.13	109.43	87.47
	1.0 g/l	41.55	87.08	57.66	90.08	74.29	91.50

Table :2 Corrosion rate (Log ρ) of mild steel in **0.1 M HCl** in absence and presence of Nelumbo nucifera petal for an immersion period of 24 h**.**

Inhibitor Conc. (gm/lit)	C.R (ρ)	Log ρ	I.E (%)	Surface coverage (θ)	1-θ	Log (θ/1–θ)
Blank	321.54	2.5072	-	-	-	-
0.1 gm/lit	51.76	1.7139	83.90	0.8390	0.1610	0.7170
0.5 gm/lit	48.91	1.6894	84.79	0.8479	0.1521	0.7462
1.0 gm/lit	41.55	1.6186	87.08	0.8708	0.1292	0.8286

Table :3 Corrosion rate (Log ρ) of mild steel in **0.5 M HCl** in absence and presence of Nelumbo nucifera petal for an immersion period of 24 h**.**

Inhibitor Conc. (gm/lit)	C.R (ρ)	Log ρ	I.E (%)	Surface coverage (θ)	1-θ	Log (θ/1–θ)
Blank	581.38	2.7645	-	-	-	-
0.1 gm/lit	117.81	2.0712	79.74	0.7974	0.2026	0.5949
0.5 gm/lit	80.63	1.9065	86.13	0.8613	0.1387	0.7931
1.0 gm/lit	57.66	1.7609	90.08	0.9008	0.0992	0.9582

Table :4 Corrosion rate (Log ρ) of mild steel in **1.0 M HCl** in absence and presence of Nelumbo nucifera petal for an immersion period of 24 h**.**

Inhibitor Conc. (gm/lit)	C.R (ρ)	Log ρ	I.E (%)	Surface coverage (θ)	1-θ	Log (θ/1–θ)
Blank	873.61	2.9413	-	-	-	-
0.1 gm/lit	228.95	2.3597	73.79	0.7379	0.2621	0.4496
0.5 gm/lit	109.43	2.0391	87.47	0.8747	0.1253	0.8441
1.0 gm/lit	74.29	1.8709	91.50	0.9150	0.0850	1.0318

Figure . 1 :

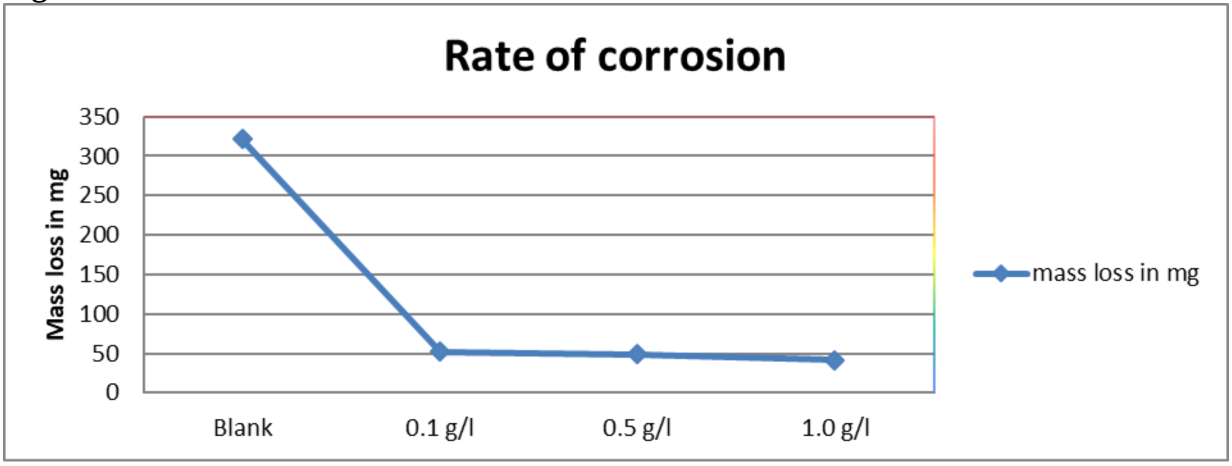


Figure . 2 :

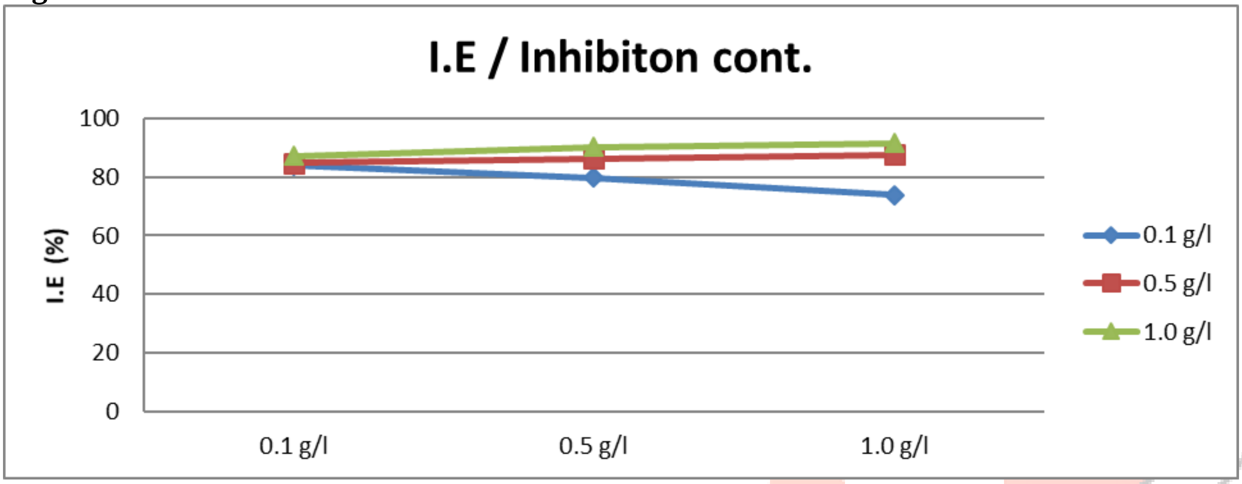


Figure 1 & 2: Corrosion rate in 0.1 M hydrochloric acid and I.E (%) of mild steel in presence of different concentration of Nardostachys jatamansi root extract for an immersion period of 24 h.

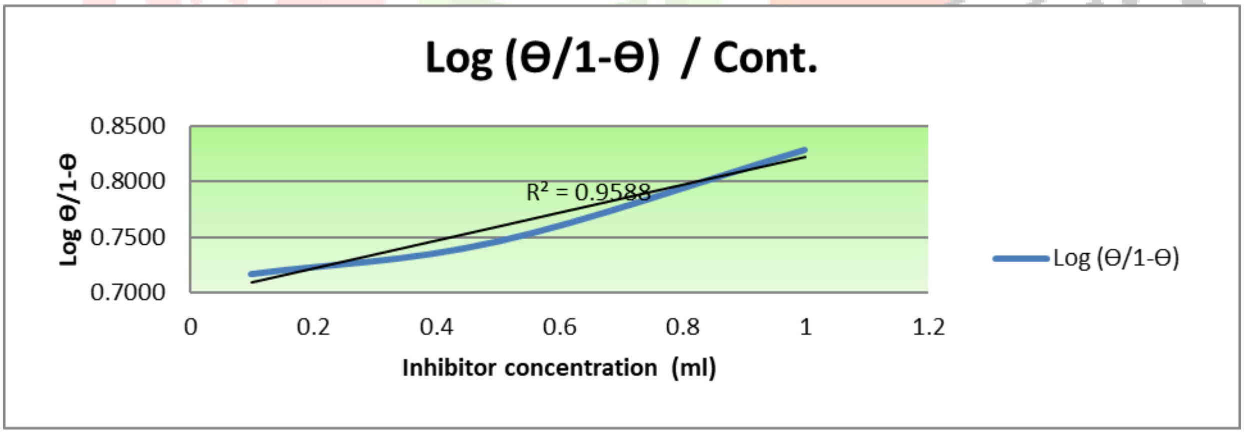


Figure 3: Langmuir adsorption isotherm for corrosion of mild steel in 0.1M hydrochloric acid Solution containing different concentration of Nardostachys jatamansi root extract for an immersion period of 24 h.

Corrosion rate (Log ρ) of mild steel in 0.1 M HCl in absence and presence of Nardostachys jatamansi for an immersion period of 24 h**.**

[3.0] Effect of temperature

The study the effect of temperature on corrosion rate, the specimen were immersed in 230 ml of 0.1 M hydrochloric acid solution with Nardostachys jatamansi root extract inhibitor. Corrosion rate was measured in 0.1 M hydrochloric acid containing temperature of 313, 323 and 333 K at 0.1, 0.5 and 1.0 g/l inhibitor concentration for 2 hours exposure time. The effect of temperature was used thermostat assembly with an accuracy of ± 0.5.

Energy of activation (Ea) was calculated from the slopes of log ρ versus 1/T (ρ = corrosion rate, T = absolute temperature) and also with the help of Arrhenius equation.

$$\log\frac{\rho_2}{\rho_1} = \frac{Ea}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \quad \text{-----------------------} \quad (3)$$

where ρ_1 and ρ_2 are the corrosion rate at temperature T_1 and T_2 respectively. The enthalpy of adsorption (ΔH^0_{ads}) and entropy of adsorption (ΔS^0_{ads}) will be calculated using the following equations (4) and (5).

$$\Delta H^0_{ads} = Ea - RT \quad (4)$$

$$\Delta S^0_{ads} = \frac{\Delta H^0_{ads} - \Delta G^0_{ads}}{T}$$

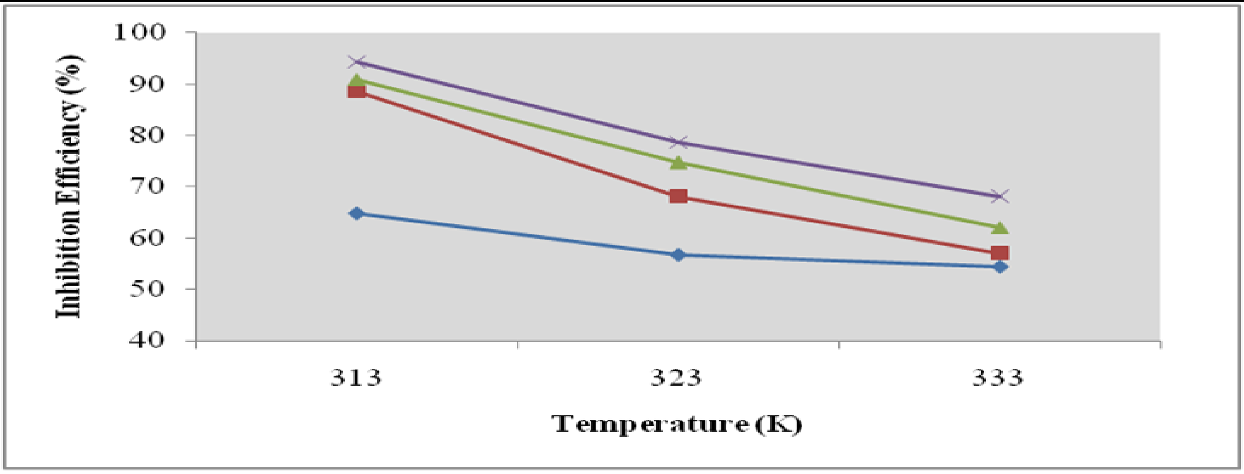
The values of the free energy of adsorption (ΔG^0_{ads}) were calculated with slope of the following equation.

$$\log C = \log\left(\frac{\theta}{1-\theta}\right) - \log B \quad (6)$$

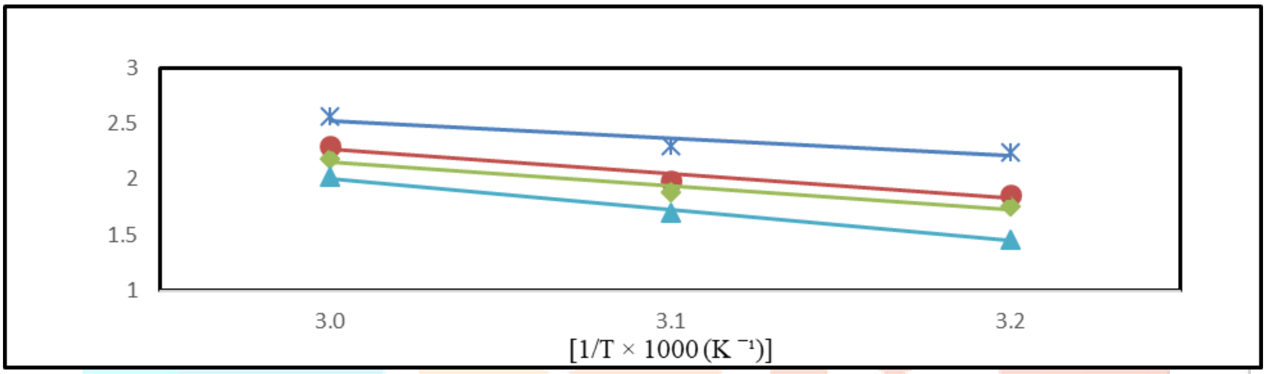
where $\log B = -1.74 - \left(\frac{\Delta G^0_{ads}}{2.303RT}\right)$ and C is the inhibitor concentration. The values of heat of adsorption (Q_{ads}) calculated by the following equation (7).

$$Q_{ads} = 2.303R\left[\log\left(\frac{\theta_2}{1-\theta_2}\right) - \log\left(\frac{\theta_1}{1-\theta_1}\right)\right] \times \frac{T_1 T_2}{T_2 - T_1} \quad (7)$$

Inhibitor Concentration	**Temperature K**						**Mean (Ea) from equation (kJ/Mol)**
	313K		**323K**		**333K**		
	C.R mg/dm²	**I.E. %**	**C.R mg/dm²**	**I.E. %**	**C.R mg/dm²**	**I.E. %**	
Blank	168.51	-	192.13	-	363.44	-	200.30
0.1 gm/lit	50.05	70.30	66.26	65.51	133.13	63.37	218.69
0.5 gm/lit	44.64	73.51	57.65	69.99	119.30	67.17	223.84
1.0 gm/lit	41.23	75.53	50.84	73.54	104.08	71.36	219.61



Effect of temperature on I.E (%) for mild steel corrosion in 0.1 M HCl at different inhibitor concentration of Nardostachys jatamansi extract for immersion period of 2 h.



It was found that the value of Ea for inhibited system was higher than that of uninhibited system. It indicate that the inhibitors are more effective at lower temperature [12].

→ The enthalpy of adsorption (ΔH^0 ads) were calculated by using the equation.

$$\Delta H^0_{ads} = Ea - RT \; (R = 8.314) \quad \text{-----------} \quad (2)$$

Where, Ea is activation energy at absolute temperature T in Kelvin and R is the gas constant.

→ The entropy of adsorption (ΔS^0 ads) were calculated by using the equation.

$$\Delta S^0_{ads} = (\Delta H^0_{ads} - \Delta G^0_{ads}) / T \quad \text{-------------} \quad (3)$$

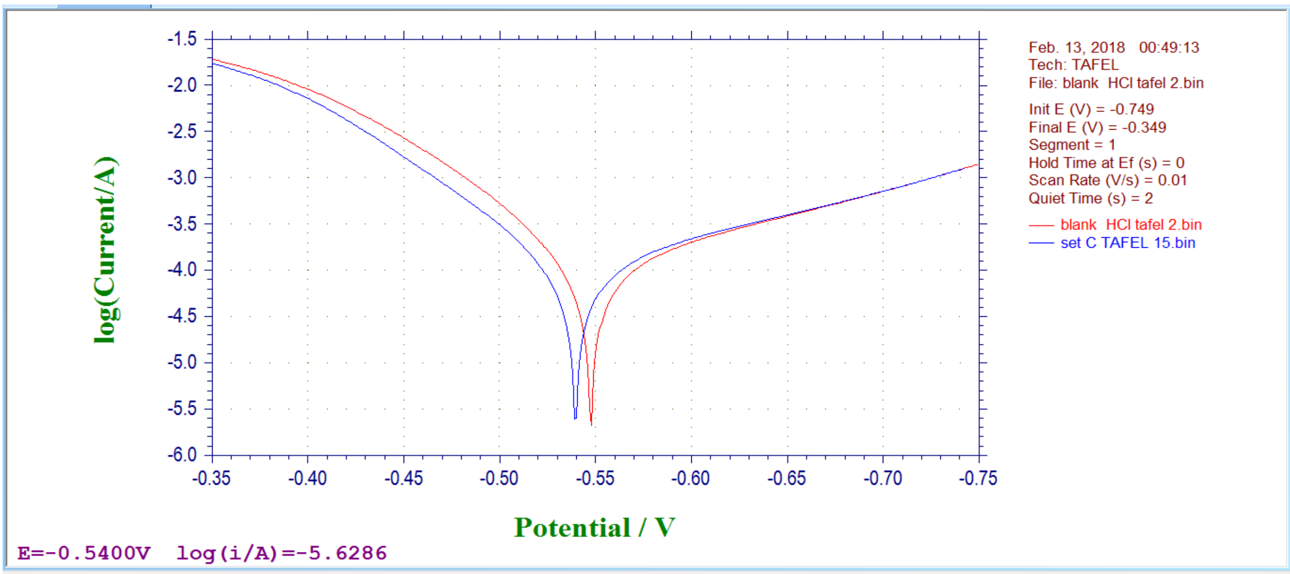
[4.0] Polarization Measurements:

When electrochemical corrosion occurs, the current that flows between anode and cathode causes a change in the electrode potential, this change is termed as polarization. Auxiliary platinum electrode was placed in a corrosive media through which external current was supplied from a regulated power supply. The electrochemical theory of corrosion had its origins of course, in more than one source.

TABLE-4

Potentiodynamic data and inhibition efficiency I.E (%) for mild steel in 0.1 M hydrochloric acid at 1.0 g/l Nardostachys jatamansi root extract inhibitor.

System	Ecorr (mV)	Icorr (μA)	Tafel Slop			Inhibition efficiency (I.E %)	
			Anodic +βa	Cathodic -βc	β (mV)	By Polarization Method	By Mass Loss Method
Blank	-0.5479	8.832×10^{-3}	12.804	5.356	1.6419	-	-
Nardostachys jatamansi	-0.5398	1.183×10^{-4}	13.777	5.097	1.6176	86.64	87.08



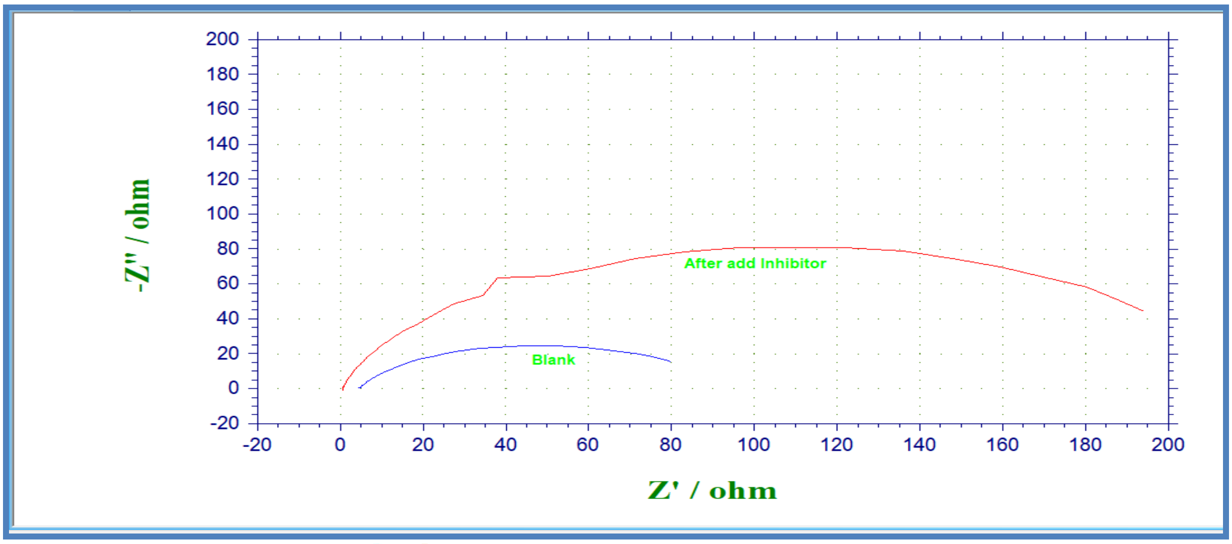
[5.0] Tafel Plot:

In the electrochemical cell mild steel specimens having an area of $1cm^2$ was used as a working electrode, Ag / AgCl electrode as a reference electrode and platinum electrode as an auxiliary electrode and allowed to established a steady-state open circuit potential (OCP) for approximately 15 min. Polarization curves were plotted with potential against log current density (called Tafel plots). This technique is used to measure the corrosion current (i_{corr}) so that the corrosion rate can be calculated. A Tafel plot can yield i_{corr} directly or it can yield the Tafel constants (βa and βc). The Tafel constants can then be used with the Rp value to calculate i_{corr}.

The inhibition efficiency IE (%) was evaluated from the Potentiodynamic polarization data of corrosion current density (i_{corr}) by the following formula.

$$IE(\%) = \frac{i_{corr\ (uninhi)} - i_{corr\ (inhi)}}{i_{corr\ (uninhi)}} \times 100 \qquad (4)$$

Where , $i_{corr\ (uninhi)}$ and $i_{corr\ (inhi)}$ are corrosion current densities of metal in the absence and presence of inhibitors respectively.



[6.0] CONCLUSIONS

From the present study, it is concluded that Nardostachys jatamansi root extract can be used as an effective inhibitor for mild steel corrosion in HCl medium. At all concentration of acid, as the inhibitor concentration increases inhibition efficiency increases and corrosion rate decreases. As the temperature increases corrosion rate increases in plain acid. It has also been found that the inhibitive action of Nardostachys jatamansi root extract is basically controlled by temperature and the concentration of the inhibitor.

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