CHENOPODIUM ALBUM LEAVES EXTRACT AS GREEN CORROSION INHIBITOR FOR MILD STEEL IN 1 M HCL SOLUTION

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Abstract : The inhibition and adsorption effects of the acidic extract of *Chenopodium album* leaves (*CALE*) on mild steel corrosion in 1 M HCl are investigated by weight loss measurement and scanning electron microscopy (SEM) analysis. The experimental results show that CALE is good corrosion inhibitor for mild steel and the inhibition efficiency is increased with the inhibitor concentration. The results obtained from weight loss and SEM studies exhibits the good relationship. Inhibitive effect of CALE was afforded by adsorption of the inhibitor components which was approximated by Langmuir adsorption isotherm. Scanning electron microscopy analyses also supported the protective action of the CALE against mild steel corrosion in 1 M HCL solution.

Keywords: CALE, Mild steel, Corrosion inhibitor, Adsorption and SEM.

Introduction: Acid pickling is a process which involve the immersion of a particular piece of metal in a suitable acid solution to remove undesirable scales such as rust. This process makes use of most frequently used acids like sulphuric, hydrochloric, phosphoric and nitric acids. These acid solutions can dissolves the rust and scale from the metal surface. Once the rust is dissolved, the acid is then free for further attack upon the metal surface. Corrosion inhibitors are added to the pickling solution to reduce the consumption of acids and metal dissolution. [1, 2]. The study of corrosion inhibition of mild steel involving green and sustainable inhibitors in acid solutions is one of the challenging and emerging topic of recent research. Application of green and sustainable inhibitors is the most effective and useful technique to control the corrosion process [3]. Organic compounds are widely used as corrosion inhibitors in acidic media. Although these organic inhibitors shows high inhibition efficacy, but their uses are limited because of their toxicity, cost of synthesis and application. Most of the well-known organic inhibitors contain nitrogen, oxygen, phosphorus and sulphur elements and p-electrons of alkenes and/or aromatic ring [4]. Recently the uses of many organic corrosion inhibitors have been limited because they are hazardous for the environment and human beings and expensive. Generally, plant extracts are degradable, non-hazardous, eco-friendly, cheap, readily available, and renewable sources [5]. In this work, the inhibitive effect of CALE has been investigated for the corrosion of mild steel in 1 M HCl. *Chenopodium album* is a fast-growing weedy annual plant, which belongs to genus *Chenopodium*. Common names include goosefoot, fat-hen, lamb's quarters and melde, though the first two are also applied to other species of the genus *Chenopodium*, for which reason it is often distinguished as white goosefoot.*Chenopodium album* is extensively cultivated and consumed in Northern India as a food crop, and in English texts it may be called by its Hindi name *bathua* or *bathuwa*. It is called Paruppukkirai in Tamil, Pappukura in Telugu, Vastuccira in Malayalam, Kaduoma in Kannada, and Chakvit in Konkani. The aim of the present study is to evaluate the inhibitive effect of extract of *Chenopodium album* leaves on the mild corrosion in 1 M hydrochloric acid solution. The evaluation of the corrosion behaviour was studied using weight loss measurement, and the morphology of inhibited mild steel surface was examined by scanning electron microscope. Thermodynamic data was obtained from adsorption isotherms.

Experimental: Materials preparation*:* The chemical composition (wt. %) of C = 0.25, O = 0.59, Si = 0.68, P = 0.26, S = 0.04 Cr = 0.02 and reminder iron specimen used for all experiments. Mild steel strips were cut into 5 cm x 2cm x 0.1 cm sizes from steel sheet purchased from market and polished sequentially using different grades (400-1200) of emery papers. Next, it was washed with double distilled and dried in desiccator before use. AR grade of hydrochloric acid (Merck) used for all the experiments. Inhibitor solution prepared as per standard method [6].

Weight loss measurement*:* The effect of the addition of studied concentrations of glycine max leaves extract on mild steel corrosion in 1M HCl solution was studied by weight loss measurements at temperatures ranging from (298–328 K) after a 6 h immersion time. The inhibitor efficiency (*IE* %), corrosion rate (ρ) and surface coverage (θ) were determined by using weight loss studies. After 6 h, the specimens were taken out and carefully washed with double distilled water obtained from mili Q and ethanol, then dried and weighed using electronic balance. The corrosion rate (ρ) of CALE were calculated from the following equation [7]:

$$\rho = \frac{\Delta W}{At} \quad (1)$$

Where A is the total area of metal specimen in cm^2, ΔW is the weight loss in mg, and t is the immersion time (6h). Inhibition efficiency of inhibitors were calculated from the following equation [7]:

$$\%I = \left(\frac{\rho^1 - \rho^2}{\rho^1}\right) \times 100 \quad (2)$$

Where ρ^1 and ρ^2 are the corrosion rates of the test coupons with and without inhibitor.

SEM Analysis: The surface morphology of mild steel coupons were examined using SEM analysis. Scanning electron microphotographs were taken to establish that inhibition is due to the formation of a protective film on the mild steel surface. Scanning electron microscope ZEISS EVO SEM 18 model Oxford was used for SEM analysis.

Result and discussion: Weight loss measurement: Table 1 represents the values of corrosion rate (ρ), inhibition efficiency (%IE), and surface coverage obtained from weight loss measurement at different concentrations of inhibitors (0.1-0.4 g l^{-1}) at studied temperatures (298-328 K). The variation of surface coverage (θ) and corrosion rate with increase in inhibitor concentrations is shown in Figure 1 and 2 respectively. The maximum inhibition efficiency value of 92.58% obtained at the optimum concentration of inhibitor at 308 K. The decrease in corrosion is clearly observed with increase in CALE concentration, whereas high corrosion rate values observed with the rise in temperature shows desorption of inhibitor molecules and increased dissolution rate of metal in 1 M HCl solution [8]. The decrease of inhibition efficiency with increase in temperature could be due to decomposition and gradual desorption of inhibitor molecules from the mild steel surface.

Table 1: Corrosion parameters of mild steel obtained from gravimetric analysis in 1 M HCl solution, with and without inhibitor at different concentrations of CALE and temperatures.

Temperature (*K*)	Concentration (g L^{-1})	Corrosion Rate ρ (mg cm^{-2} h^{-1})	Inhibition efficiency (% *IE*)
298	0.0	1.594	-
	0.1	0.338	78.79
	0.2	0.287	81.99
	0.3	0.235	85.25
	0.4	0.177	88.89
308	0.0	4.068	-
	0.1	0.400	90.16
	0.2	0.348	90.90
	0.3	0.287	92.94
	0.4	0.231	94.32
318	0.0	7.203	-
	0.1	1.163	83.85
	0.2	1.096	84.78
	0.3	1.026	85.75
	0.4	0.974	86.47
328	0.0	9.532	-
	0.1	2.960	68.94
	0.2	2.679	71.89
	0.3	2.444	74.36
	0.4	2.320	75.66

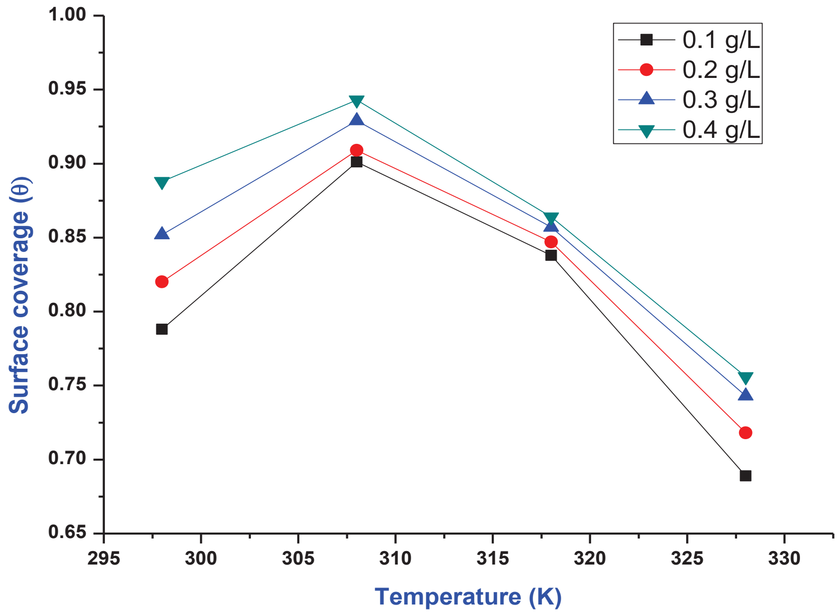


Fig. 1. Variation of surface coverage with different temperatures for corrosion of mild steel in 1 M HCl solution.

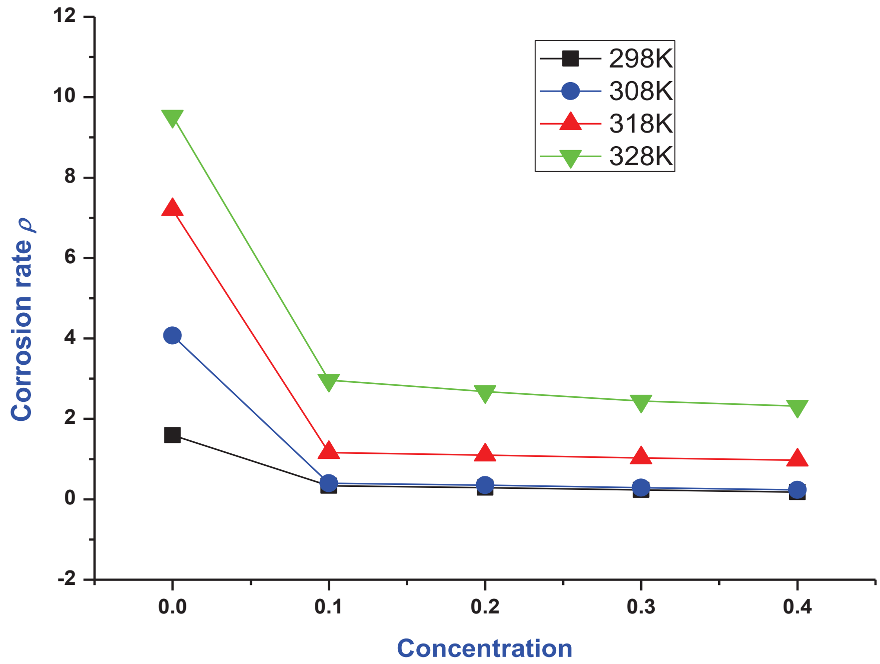


Fig. 2. Variation of corrosion rate with different concentration of CALE for corrosion of mild steel in 1 M HCl solution.

Adsorption isotherm: Study of adsorption isotherms provide the elementary evidence on the relationship between the corrosion inhibitor and the metal surface in solution. An inhibitor can be considered to be a potent corrosion inhibitor in aqueous solution only when the interaction force between the metal surface and the inhibitor molecules is greater than the interaction force of the metal surface and water molecules adsorbed on it [9]. In this work the Langmuir adsorption isotherm fitted well and it is expressed by the mathematical equation [10]:

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C \quad (3)$$

Where C is the inhibitor concentration, θ is the surface coverage, and K_{ads} is equilibrium constant, which is related to the Gibbs energy of adsorption (ΔG_{ads}) according to given equation:

$\Delta G_{ads} = -RT \ln (55.5 K_{ads})$ (4)

Where T is the absolute temperature, K is the binding constant and R is gas constant. Figure 3 represents the relationship between C/θ and inhibitor concentration (C_{inh}) which represents Langmuir adsorption isotherm.

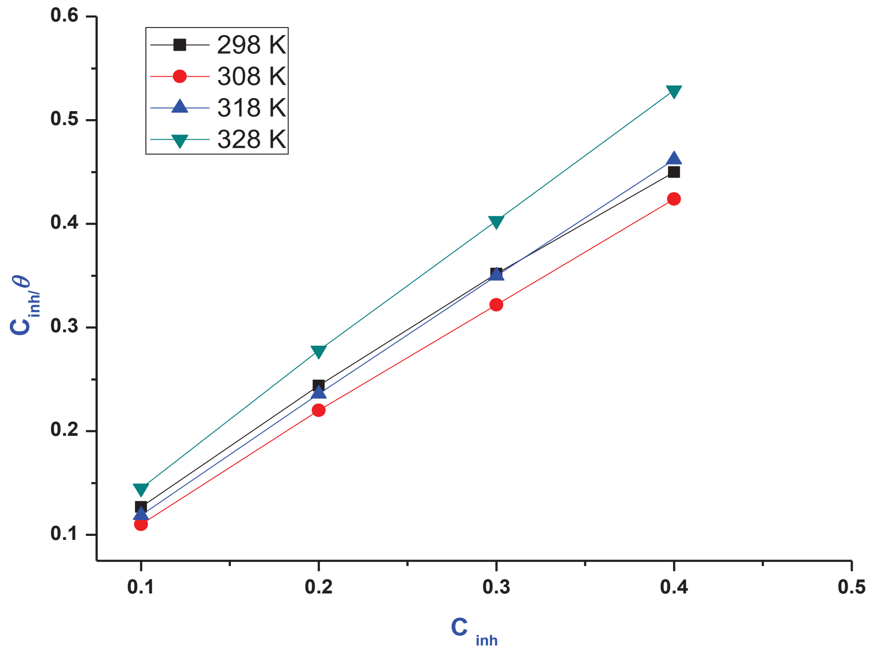
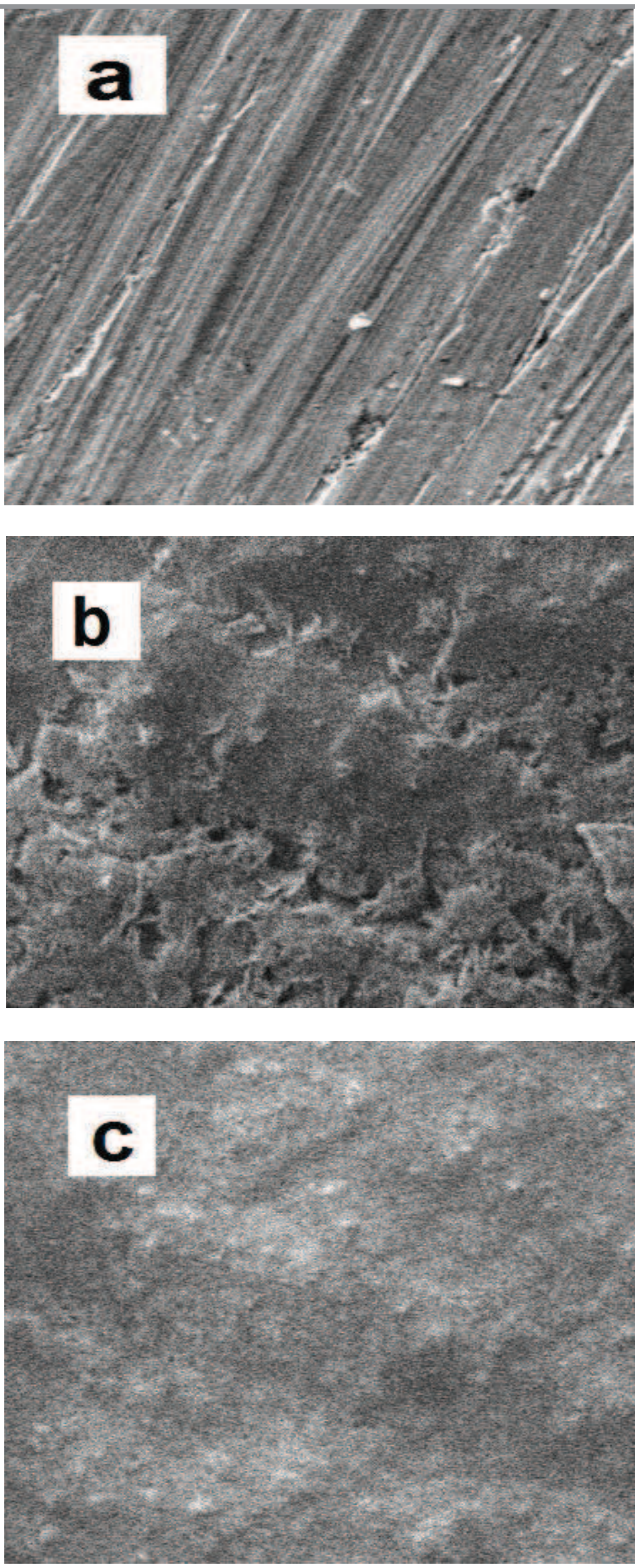


Fig. 3 Linear fitting of CALE to Langmuir adsorption isotherm at different temperatures.

Table 2: Thermodynamic parameters for the adsorption of sulfacetamide and sotalol on the mild steel surface at different temperature.

Temp. (K)	R^2	Slope	K_{ads} (L mol $^{-1}$)	ΔG_{ads} (kJ mol $^{-1}$)
298	0.997	1.077	41.66	-18.32
308	0.999	1.044	125.0	-17.45
318	0.999	1.143	166.0	-19.53
328	0.999	1.277	5.128	-18.70

SEM analysis: Figure 4 represents the SEM microphotographs of mild steel surface in the presence and absence of CALE in 1 M HCl solution. SEM analysis of micrographs in Figure 4b clearly shows the damage and rough surface in the corrosive solution for 6 h of immersion period. However Figure 3c exhibit the smooth and homogeneous surface compare to Figure 4b clearly indicates the protective adsorption of inhibitors molecules on metal surface [11].



Conclusion: The results obtained from gravimetric analysis showed that CALE behaves as a potential corrosion inhibitor for mild steel in 1 M HCl solution. The adsorption isotherm is Langmuir adsorption isotherm. The extract of CALE inhibits corrosion of mild steel in 1 M HCl media by adsorption mechanism. SEM analysis results show that inhibitor molecules form protective layer on the mild surface and protect from the further corrosion.

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