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RESEARCH ARTICLE

Chemical facets of environment-friendly corrosion impediment of low-carbon steel in aqueous solutions of inorganic mineral acid

Mahima Srivastava

Abstract
Response of low–carbon steel in hydrochloric acid was studied for various parameters with the use of leaves of white pigweed as an inhibitor. The inorganic mineral acid was applied in a paste state and conventional weight loss techniques were employed for the study of various chemical aspects. The results reveal that low–carbon steel corrodes extensively in acid in the absence of an inhibitor and is protected in the presence of an inhibitor at different concentrations. Also, different time intervals and various temperatures for different concentrations of acids in paste form were considered for best output. Data on rust dissolution in liquid state has also been furnished for comparison. The inhibitor showed good potential in the protection of low–carbon steel.
Keywords: low - carbon steel; corrosion; mineral acid; pigweed; dissolution; inhibition

Introduction
Metals and low–carbon content steel are the backbone of industrial setup in the form of large and small structures, machinery and small and big tools. But metals are prone to corrosion in the presence of moisture and oxygen. Structural defects aggravate the corrosion of metals. Many inhibitors of organic and inorganic nature, along with a mixture of both, are used to protect metals [Putilova *et al*., 1960,]. These chemicals may be toxic and are also a threat to the environment.

To overcome these drawbacks and for the sake of developing an economic inhibitor, natural products have been considered. The aqueous extracts from different parts of some plants such as Henna, *Lawsonia inermis* [Al-Sehaibani H., 2000], *Rosmarinous officinalis* L. [Kliškić *et al*., 2010], *Carica papaya* [Bochuan *et al*., 2021], *Cordia latifolia* and curcumin [Farooqi *et al*., 1999], date palm, *Phoenix dactylifera*, henna, *Lawsonia inermis*, corn, *Zea mays [Rehan H. H., 2003]*, and *Nypa fruticans* Wurmb [Orubite *et al*., 2014] have been found to be good corrosion inhibitors for many metals and alloys. Tobacco (*Nicotiana*), black pepper (*Piper nigrum*), acacia gum, and lignin can be good inhibitors for steel in acid medium.

In this work, wasteland plants and pigweed have been used as inhibitors with hydrochloric acid for cleaning large and small industrial structures and tools. Being a weed, the inhibitor is pocket–friendly, easily available and environment–friendly.

Methods and Materials
Low–carbon steel has a carbon content of 0.05 to 0.25% and can easily be shaped into any structure; hence it finds wide usage as body parts, plates and wire products in the industry. Panels (Fe 99.30%, C 0.076%, Si 0.026%, Mn 0.192%, P 0.012%, Cr 0.050%, Ni 0.050%, Al 0.023%, and Cu 0.135%) of size 10 cm * 7.5 cm were cut from a single sheet of 1.22 mm thickness and were used in all experiments. The specimen panels were cleaned and numbered for identification. All the acid and chemicals used in the experiment were of analytical reagent-grade quality. Deionized water was used for the preparation of the solution. In the study, 4N solutions of hydrochloric acid and 1% concentration of inhibitor was used [Srivastava M., 2022].

Soil with clayey nature was cleaned and exhaustively treated for paste. It was soaked in 4N hydrochloric acid. The

Department of Chemistry, DBS (PG) College, Dehradun, Uttarakhand, India

***Corresponding Author:** Mahima Srivastava, Department of Chemistry, DBS (PG) College, Dehradun, Uttarakhand, India, E-Mail: drmahima11@gmail.com

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soil-soaked acid uniformly for the formation of paste (31.3 mL acid soaked by 100 gm of soil). Panels were exposed to rust-prone conditions to obtain a heavy rust appearance. Weighed rusted low carbon steel panels were exposed to pickling paste for conditions to study different variables. A saturated solution of sodium carbonate was used for washing panels after the experiment. They were treated repeatedly before weighing and for reporting the result in tables. The leaves of *Amaranthus* were cleaned, dried and finely powdered and 1-mg was added to 100 gm of soil. The inhibitor efficiency was calculated from the following equation.

$$\%IE = \frac{W_{uninhibited} - W_{iinhibited}}{W_{uninhibited}} \; X \; 100$$

Where,
%IE = Inhibitor efficiency
$U_{uninhibited}$ = Weight loss without inhibitor
$W_{inhibited}$ = Weight loss with inhibitor

Variables Studied

- Effect of Time of Application
- Coating Thickness
- Temperature

Results

Effect of Time of Application

The effect of time of application on the rate of dissolution of rust and corrosion of low carbon steel due to 4N HCl is shown in Table 1 and Figure 1(a & b) in paste (with and without inhibitor) as well as liquid state. It is evident that rate of dissolution of rust increased with time. Results show that the attack in the liquid state was higher than that in the paste state.

Coating Thickness

Table 2 and Figure 2 (a & b) show the effect of coating thickness (1-gm/dm^2 to 5 gm/dm^2) on the dissolution of rust and on attack of low carbon steel in paste made with 4N hydrochloric acid with and without inhibitor. It is evident from the results that after a certain thickness of the coating (3 gm/dm^2), the efficiency does not alter much.

Table 1: Effect of time of application on inhibited paste on rate of dissolution of rust and on rate of attack of low carbon steel [4N HCl; RT; 3 gm paste/dm^2 = coating thickness; Amaranthus = 1%] [Srivastava M., 2022]

Time of application (min.)	*Rate of dissolution of rust (gm/dm^2)*	*Weight Loss (mg/dm^2)*		*Inhibitor Efficiency (%)*
		Uninhibited	*Inhibited*	
10	0.5	16.0	6.9	56
30	0.9	18.5	7.1	62
60	1.7	25.9	8.2	68
120	2.5	29.3	9	69
180	2.7	33.1	9.4	72

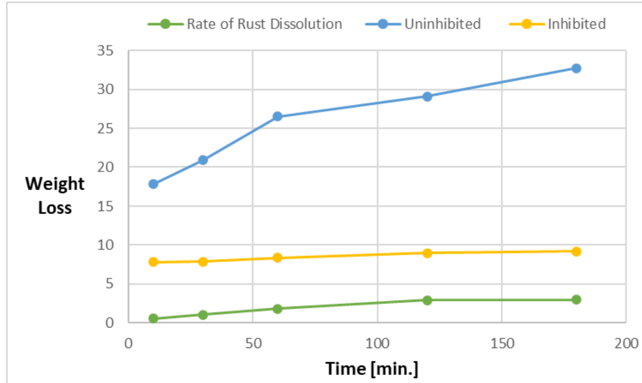

Figure 1a: Effect of time of application on inhibited paste on rate of dissolution of rust and on rate of attack of 1.c. steel[4N HCl; RT; 3 gm paste/dm^2 = coating thickness; *Amaranthus* = 1%]

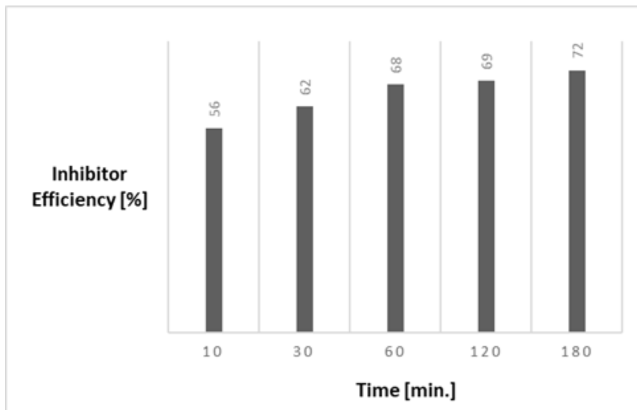

Figure 1b: Effect of time of application on inhibitor efficiency of Amaranthus on [4N HCL; RT; 3 gm paste/dm^2 = coating thickness; Amaranthus = 1%]

Table 2: Effect of coating thickness on inhibited paste on rate of dissolution of rust and on the rate of attack of low carbon steel [4N HCl; RT; 1 hr.; *Amaranthus* = 1%] [Srivastava M., 2022]

Coating Thickness (gm/dm^2)	*Rate of Dissolution of Rust (gm/ dm^2/30m)*	*Weight Loss (mg/dm^2)*		*Inhibitor Efficiency (%)*
		Uninhibited	*Inhibited*	
1	0.29	16.8	6.4	62
2	0.32	21.4	7.3	65
3	0.63	24.7	7.6	68
4	0.94	25.4	8.1	68
5	1.21	29.6	9.2	69

Effect of Temperature

Effect of temperature from 30 to 60°C on the dissolution of rust and on corrosion of low carbon steel due to pasting containing 4N hydrochloric acid with and without 1% inhibitor (Figures 3 a and b). Results show that the inhibitor

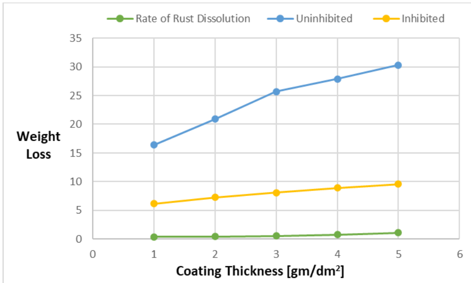

Figure 2a: Effect of coating thickness on inhibited paste on rate of dissolution of rust and on rate of attack of Lc. steel [4N HCL RT: 1 hr; Amaranthus = 1%]

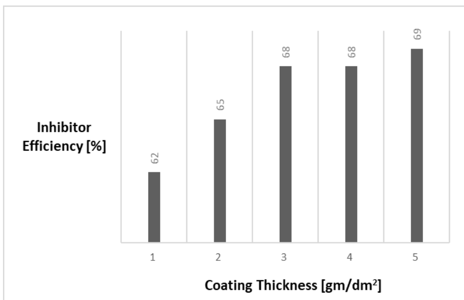

Figure 2b: Effect of coating thickness on inhibitor efficiency of Amaranthus on [4N HCL RT: 1 hr Amaranthus= 1%]

Table 3: Effect of temperature on inhibited paste on rate of dissolution of rust and on rate of attack of low carbon steel [4N HCl; 3 gm paste/dm^2 = coating thickness; 1-hour.; Amaranthus = 1%] [Srivastava M., 2022]

Temperature (°C)	Rate of Dissolution of Rust (gm/dm^2/30m)	Weight Loss (mg/dm^2)		Inhibitor Efficiency (%)
		Uninhibited	Inhibited	
30	0.81	21.7	4.9	77
35	1.7	23.9	5.3	78
40	2	26.1	6.1	77
45	2.4	26.9	7	74
50	2.5	28.3	7.6	73
55	2.7	29.6	8.2	72
60	2.8	30.2	8.1	73

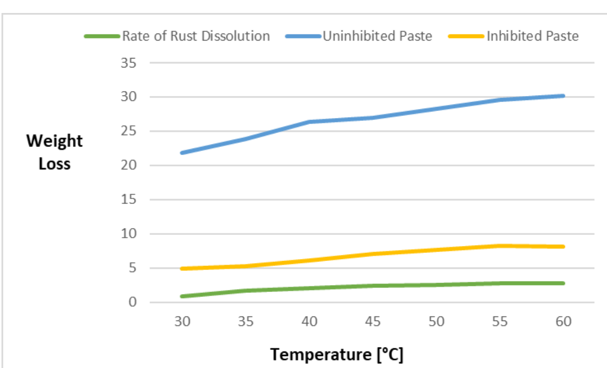

Figure 3a: Effect of temperature on inhibited paste on the dissolution of rust and on rate of attack of low carbon steel[4N HCl; [4N HCl; ; 1 hour.; 3 gm paste/dm2 = 3 gm paste/dm^2 = coating thickness; Amaranthus = 1%] [Srivastava M., 2022]

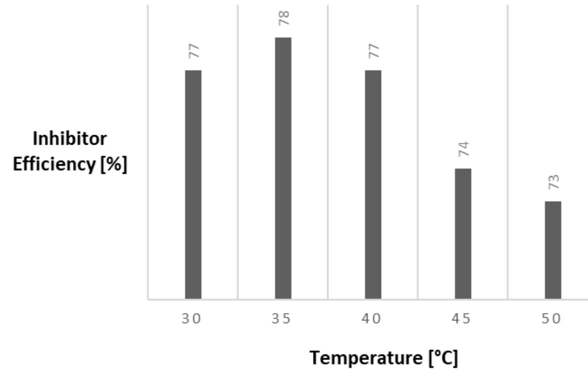

Figure 3b: Effect of temperature on inhibitor efficiency of Amaranthus [4N HCl; ; 1-hour.; 3 gm paste/dm^2 = coating thickness; Amaranthus= 1%] [Srivastava M., 2022]

maintained its effectiveness over the entire temperature range, providing maximum efficiency of 78% (Table 3).

Discussion

The results depict that the inhibitor efficiency was recorded significantly for 1-hour with an efficiency of 68%; for 3 hours, it raised the maximum to 72%. With a coating thickness of 3 gm/dm^2 for the paste, the inhibitor showed good efficiency of inhibition. The inhibitor worked well at optimum temperature; however, there was no significant upgradation in the results at higher temperatures.

Conclusion

The study concludes that leaf extracts of *Amaranthus* in paste containing 4N hydrochloric acid act as a good inhibitor for low-carbon steel. The extract forms a uniform layer on the surface by adsorption. The electron rich atoms as nitrogen and oxygen attach to the surface of metal and form a well-adhered barrier layer. Data proves good inhibition in an hour at room temperature with a coating thickness of 3 gm paste/dm^2.

Declaration of conflicting interests

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