

Corrosion Inhibition of Mild Steel in Hydrochloric Acid Medium Using a Plant Extract as a Green Inhibitor

Selvam Raj¹, Bhuvana Sundaram², Karthik Eswaran³, Nandhini Rajan⁴, Saravanan Pillai⁵

ABSTRACT

Mild steel is widely used in industry but corrodes readily in acidic environments such as those encountered during acid cleaning and pickling, and inhibitors are added to reduce this attack. Plant extracts have attracted attention as green inhibitors that are inexpensive, non-toxic, and environmentally acceptable, in contrast to many conventional inhibitors. This paper reports the corrosion inhibition of mild steel in hydrochloric acid medium using a plant extract as a green inhibitor. The inhibition was studied by weight-loss and electrochemical methods at several inhibitor concentrations and temperatures, and the adsorption of the inhibitor on the steel surface was analysed. The results show that the plant extract acted as an effective inhibitor, the inhibition efficiency increasing with inhibitor concentration and decreasing with temperature, reaching a high value at the highest concentration tested. The electrochemical measurements confirmed the reduction in corrosion rate, and the adsorption of the inhibitor followed the Langmuir isotherm. The study demonstrates that the plant extract is an effective green corrosion inhibitor for mild steel in acidic medium and discusses the inhibition mechanism.

KEYWORDS: *Corrosion Inhibition, Mild Steel, Green Inhibitor, Plant Extract, Hydrochloric Acid, Inhibition Efficiency, Adsorption*

INTRODUCTION

Mild steel is the most widely used structural and industrial metal because of its strength and low cost, but it is susceptible to corrosion, particularly in the acidic solutions used for cleaning, pickling, and descaling. The economic and safety consequences of corrosion make its control essential (1, 2).

The addition of inhibitors is among the most practical methods of reducing acid corrosion, but many effective conventional inhibitors are toxic or environmentally harmful. This has motivated the search for green inhibitors, and plant extracts, rich in compounds that adsorb on metal surfaces, have proved especially promising (1, 2, 10).

This paper reports the corrosion inhibition of mild steel in hydrochloric acid using a plant extract as a green inhibitor. The inhibition is studied by weight-loss and electrochemical methods over a range of concentrations and temperatures, and the adsorption behaviour of the inhibitor is analysed (3, 5, 6).

LITERATURE REVIEW

The use of natural products as corrosion inhibitors has been reviewed extensively, establishing plant extracts as effective, inexpensive, and environmentally acceptable inhibitors for metals in acidic media (1, 2). Numerous extracts have been shown to inhibit the corrosion of mild steel and other metals in hydrochloric and sulphuric acid (3, 5, 6, 9).

The inhibition is generally attributed to the adsorption of phytochemical compounds on the metal surface, forming a protective barrier, and is commonly analysed through adsorption isotherms and thermodynamic parameters (4, 7, 8). Weight-loss and electrochemical techniques are the standard means of evaluating inhibition efficiency (10).

Aspects of Green Corrosion Inhibition

The literature identifies several aspects of corrosion inhibition by plant extracts (1, 2, 7). The principal ones considered here can be summarised as follows:

- The inhibitor concentration, which affects the degree of surface coverage.
- The temperature, which influences adsorption and corrosion rate.
- The inhibition efficiency determined by weight-loss and electrochemical methods.
- The adsorption isotherm describing inhibitor adsorption on the metal.
- The formation of a protective adsorbed layer on the surface.

RESEARCH GAP

Although many plant extracts have been studied as inhibitors, concise investigations that combine weight-loss and electrochemical measurements across concentration and

temperature with an adsorption analysis remain useful for establishing performance and mechanism together.

This study addresses that need by evaluating a plant extract as an inhibitor for mild steel in hydrochloric acid across these methods and conditions.

OBJECTIVES

- To evaluate a plant extract as a green corrosion inhibitor for mild steel in hydrochloric acid.
- To determine the inhibition efficiency by weight-loss measurements at several concentrations.
- To study the effect of temperature on the inhibition.
- To confirm the inhibition by electrochemical measurements.
- To analyse the adsorption of the inhibitor on the steel surface.

METHODOLOGY

Mild steel specimens were exposed to hydrochloric acid containing various concentrations of the plant extract, and the corrosion was assessed by weight loss and by electrochemical measurement. The experiments were conducted at several temperatures, and the adsorption of the inhibitor was analysed from the surface coverage (3, 5).

Materials and Methods

Mild steel specimens were cleaned and weighed, then immersed in hydrochloric acid with and without the plant extract for a fixed period, after which the weight loss was measured to determine the corrosion rate and inhibition efficiency. Electrochemical measurements were also made to obtain the corrosion current, as summarised below (6, 10).

Table 1: Materials and Experimental Conditions

Parameter	Value
Specimen	Mild steel coupons
Corrosive medium	1 M hydrochloric acid

Inhibitor	Plant extract
Inhibitor concentrations	50 to 500 ppm
Temperature range	303 to 323 K
Methods	Weight loss and electrochemical

Adsorption Analysis

The surface coverage at each inhibitor concentration was obtained from the inhibition efficiency and fitted to adsorption isotherm models to identify the mode of adsorption. The dependence of inhibition on temperature was used to infer whether the adsorption was predominantly physical or chemical in nature (4, 7).

RESULTS AND FINDINGS

The inhibition efficiency as a function of inhibitor concentration at two temperatures is shown in Figure 1. The efficiency rose steadily with concentration as surface coverage increased, and was lower at the higher temperature, behaviour characteristic of inhibitors that adsorb physically on the metal (3, 5).

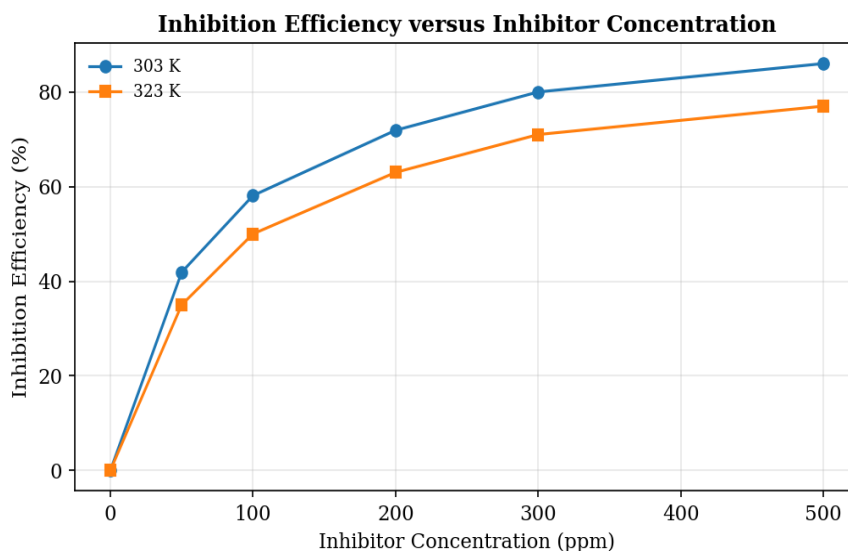


Figure 1: Inhibition Efficiency versus Inhibitor Concentration at Two Temperatures

Table 2 reports the corrosion rate and inhibition efficiency from the weight-loss measurements, and Table 3 presents the electrochemical results and adsorption behaviour.

The corrosion rate fell sharply as the inhibitor concentration increased, and the adsorption followed the Langmuir isotherm.

Table 2: Weight-Loss Results at 303 K

Inhibitor Concentration (ppm)	Corrosion Rate (mm/y)	Inhibition Efficiency (%)
0 (blank)	5.20	Reference
50	3.02	41.9
100	2.18	58.1
200	1.46	71.9
300	1.04	80.0
500	0.73	86.0

Table 3: Electrochemical Results and Adsorption Behaviour

Parameter	Blank	With Inhibitor (500 ppm)
Corrosion potential, E_{corr} (mV)	-490	-475
Corrosion current density ($\mu A/cm^2$)	420	62
Inhibition efficiency (%)	Reference	85.2
Adsorption isotherm	Not applicable	Langmuir

DISCUSSION

The results establish the plant extract as an effective green inhibitor. The rise in inhibition efficiency with concentration reflects increasing coverage of the steel surface by adsorbed phytochemical molecules, which form a barrier that hinders the access of the corrosive acid to the metal (1, 7). At the highest concentration the efficiency was high, comparable with values reported for other plant-extract inhibitors (5, 6).

The decrease in efficiency with rising temperature indicates that the inhibitor adsorbs predominantly through physical interactions, which weaken as temperature increases, a common finding for extract-based inhibitors (3, 8). The adsorption followed the Langmuir isotherm, implying monolayer adsorption on the surface, consistent with the formation of a protective film (4, 7).

The electrochemical measurements corroborated the weight-loss results, showing a marked fall in corrosion current in the presence of the inhibitor, which confirms the reduction in corrosion rate, while the small shift in corrosion potential is consistent with an inhibitor affecting both the anodic and cathodic processes (10). Together the results demonstrate that the plant extract provides effective, environmentally acceptable corrosion protection for mild steel in acidic medium (2, 9).

CONCLUSION

This study demonstrated the corrosion inhibition of mild steel in hydrochloric acid using a plant extract as a green inhibitor. The inhibition efficiency increased with inhibitor concentration and decreased with temperature, reaching a high value at the highest concentration, the electrochemical measurements confirmed the reduction in corrosion rate, and the inhibitor adsorption followed the Langmuir isotherm.

The findings establish the plant extract as an effective and environmentally acceptable corrosion inhibitor for mild steel in acidic medium, acting through the adsorption of a protective layer. Such green inhibitors offer a promising alternative to toxic conventional inhibitors.

LIMITATIONS

- A single plant extract and acid medium were studied.
- The temperature range examined was limited.
- The specific active compounds in the extract were not isolated.
- Long-term inhibition performance was not assessed.

FUTURE SCOPE

- Evaluation of additional plant extracts and acid media.
- Study over a wider temperature range and longer durations.

- Identification of the active phytochemical compounds.
- Surface characterisation of the protective adsorbed layer.
- Assessment of inhibition under industrial operating conditions.

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