International Journal of Scientific Research & Engineering Trends
Volume 11, Issue 6, Nov - Dec-2025, ISSN (Online): 2395-566X

Evaluation of Green Plant Extracts as Corrosion Inhibitors for Mild Steel in Acidic Medium

[1]Dr. P.Gowsalya, [2]M.Revathi, [3]K.Palanisamy, [4]S.Saranya
[1]Associate Professor,Dept.Of.Science and Humanities,Surya Engineering College,Erode.Tamilnadu.
[2,3]Dept.Of.Science and Humanities,Surya Engineering College,Erode.Tamilnadu
[4]Dept.Of BiomedicalEngineering,Surya Engineering College,Erode.Tamilnadu.

Abstract - The corrosion inhibition efficiency of Aster chinensis extract on mild steel in 1 M HCl was examined using weight loss and electrochemical techniques. The extract significantly reduced the corrosion rate, and inhibition performance increased with increasing inhibitor concentration. Polarization studies confirmed a mixed- type inhibition behaviour, while EIS results showed higher charge transfer resistance, indicating strong adsorption of phytochemical constituents on the steel surface. Adsorption obeyed the Langmuir isotherm, suggesting monolayer formation. Surface characterization by FT-IR and SEM supported the formation of a protective film on the metal surface. The extract also facilitated the reduction of Ag^{+} to Ag^{0} nanoparticles, confirming its dual function as a green corrosion inhibitor and an effective reducing agent. Overall, Aster chinensis demonstrates excellent potential as an eco-friendly and sustainable corrosion inhibitor.

Keywords - Aster chinensis extract, Corrosion inhibition, Mild steel, silver nanoparticles, Langmuir isotherm (Adsorption), Potentiodynamic polarization.

INTRODUCTION

Corrosion of metals remains a significant industrial challenge, leading to economic losses, operational failures, and safety concerns. Mild steel is widely used in construction, chemical processing, and petroleum industries due to its strength and affordability; however, it corrodes rapidly in acidic solutions such as hydrochloric and sulfuric acids, which are commonly used in pickling and cleaning operations[4]. Corrosion in these environments is an electrochemical process involving anodic dissolution of iron and cathodic hydrogen evolution, mechanisms first explained by Wagner[2] and later elaborated by subsequent researchers[3]. To combat corrosion, synthetic inhibitors have been widely applied. These compounds function by adsorbing onto the metal surface and forming protective films that reduce electrochemical reaction rates[5]. Despite their efficiency, many synthetic inhibitors pose environmental and health hazards due to their toxicity and poor biodegradability[9,10]. This concern has driven increasing interest in eco-friendly corrosion-mitigation strategies.

Plant-derived green inhibitors have emerged as promising alternatives. Plant extracts contain phytochemicals such as tannins, flavonoids, phenols, alkaloids, and saponins, which possess heteroatoms and π-electron systems capable of binding strongly to metal surfaces[8]. Their adsorption behavior aligns with theoretical inhibitor design principles outlined by previous studies[7]. Additional research[1,6] confirms the effectiveness of natural molecules in reducing corrosion through the formation of protective films.

This study evaluates selected plant extracts as green corrosion inhibitors for mild steel in acidic media, focusing on inhibition efficiency, adsorption characteristics, and underlying mechanisms using weight-loss and electrochemical techniques.

Motivation of Research

- Addressing the Limitations of Traditional Inhibitors: The high economic and safety costs of corrosion, particularly in acidic industrial processes (like pickling), necessitate effective corrosion control. However, the most effective conventional corrosion inhibitors are often synthetic, toxic, non-biodegradable, and harmful to human health and the environment. This creates a critical need for safe, sustainable, and "green" alternatives.
- Developing Eco-Friendly Alternatives: This research is motivated by the principles of Green Chemistry, focusing on finding and validating natural, biodegradable materials, specifically the Aster chinensis plant extract. The goal is to prove that this abundant plant resource can offer comparable or superior inhibition efficiency to hazardous chemicals, thus providing an environmentally benign and cost-effective solution for protecting mild steel.

© 2025 IJSRET

II. METHODOLOGY

Corrosion Study
The corrosion inhibition performance of Aster chinensis extract on mild steel (MS) in 1 M HCl was examined through standard corrosion analysis methods. The Weight Loss technique was initially employed to determine inhibition efficiencies at different extract concentrations and temperatures (303–333 K), following widely accepted corrosion evaluation procedures4,9.

The adsorption behaviour of the extract on the MS surface followed the Langmuir Adsorption Isotherm, indicating monolayer formation similar to many phytochemical-based inhibitors7,10. Thermodynamic parameters derived from adsorption data further supported spontaneous and stable inhibitor adsorption.

Electrochemical investigations were conducted using a three-electrode cell system.

Potentiodynamic polarization measurements identified the extract as a mixed-type inhibitor, reducing both anodic dissolution of iron and cathodic hydrogen evolution reactions2,3.

Electrochemical Impedance Spectroscopy (EIS) provided additional insight, showing a significant increase in charge transfer resistance (Rct) upon inhibitor addition. This behaviour confirmed the formation of a protective film that hindered corrosion processes at the metal–solution interface5.

Surface and Film Analysis
Changes in the surface morphology of mild steel, before and after exposure to the inhibitor, were examined using SEM-EDX. The analysis verified the development of a uniform protective layer on the steel surface6.

Complementary FT-IR analysis revealed the functional groups from the plant extract responsible for adsorption, confirming chemical interaction between the inhibitor molecules and the metal surface8.

Nanoparticle Synthesis
Lastly, Aster chinensis extract served as an efficient reducing and capping agent for the green synthesis of silver nanoparticles (AgNPs). This demonstrates its dual utility in corrosion inhibition and sustainable nanomaterial production, aligning with modern green chemistry approaches1.

Results & Verification

Inhibition Efficiency (Weight Loss Method)
The non-electrochemical weight loss method confirmed the strong inhibitive performance of the Aster chinensis extract1.

- Concentration Effect: The corrosion rate of mild steel in 1 M HCl significantly decreased in the presence of the extract2. The inhibition efficiency increased with a rise in the concentration of Aster chinensis3.
- Maximum Efficiency: The extract yielded a maximum efficiency of 92.23% at the highest tested concentration (500 ppm) at pm1K$4.

Temperature Effect: The corrosion rate showed a progressive increase with a rise in temperature, indicating that the protective mechanism is sensitive to thermal energy5

MassLoss (g)

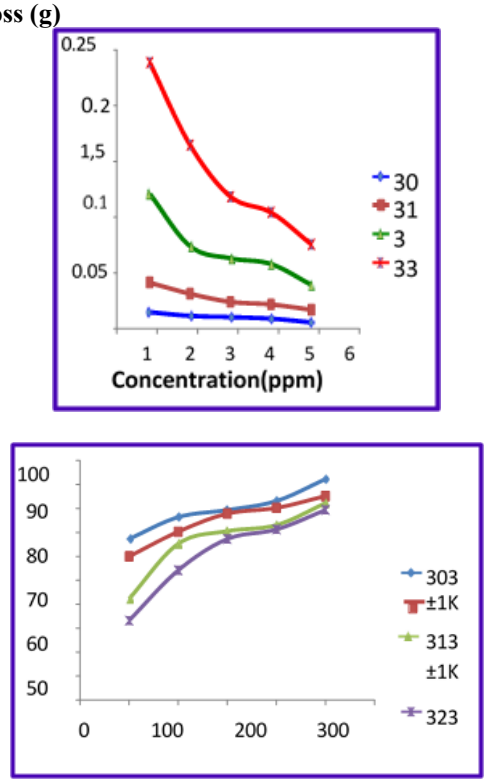


Figure:2 Effect of concentrations on the inhibition efficiency of Aster chinensison mild steel in 1 M HCl

CorrosionRate(CR)

© 2025 IJSRET

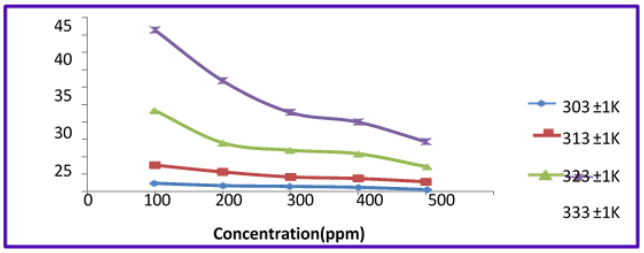


Figure:3Effectofconcentrationsonthecorrosionrateof Asterchinensisonmildsteelin 1M HCl

Adsorption and Thermodynamics

The adsorption characteristics of Aster chinensis extract on mild steel were evaluated by fitting the weight loss data to established adsorption models. The adsorption process was found to follow the Langmuir Adsorption Isotherm, which assumes monolayer adsorption on a homogeneous metal surface and is widely applied in corrosion inhibitor studies7,10.

The thermodynamic behaviour of adsorption was analysed by calculating the Gibbs Free Energy of Adsorption (ΔG^{o}_ads) over the temperature range 303 ± 1 K to 333 ± 1 K. The obtained negative values of ΔG^{o}_ads indicate that the adsorption of inhibitor molecules onto the metal surface is spontaneous, consistent with classical corrosion thermodynamics4,9.

Furthermore, the magnitude of ΔG^{o}_ads (typically between –20 kJ/mol and –40 kJ/mol for organic inhibitors) suggests that the inhibition mechanism is predominantly physical adsorption (physisorption), involving electrostatic interaction between charged species and the steel surface7,8.

R^2	Gibb's free($\Delta G°ads$) KJ/mol
0.988	-0.2124
0.998	-0.5399
0.987	-2.2720
0.991	-3.5764

Electrochemical Verification

Electrochemical studies were carried out to further verify the inhibition mechanism operating at the metal–solution interface. Potentiodynamic polarization measurements demonstrated that Aster chinensis extract behaves as a mixed-type inhibitor, simultaneously reducing the anodic metal dissolution and cathodic hydrogen evolution reactions. This behaviour aligns with classical electrochemical corrosion theory and mixed-inhibition mechanisms described in literature 2,3,4

.

The AC-Impedance Spectroscopy (EIS) results provided additional confirmation of film formation on the metal surface. Increasing inhibitor concentration led to a significant increase in Charge Transfer Resistance (Rct) and a decrease in Double Layer Capacitance (Cdl). This trend indicates adsorption of inhibitor molecules that increases the double-layer thickness and lowers the local dielectric constant, consistent with established interpretations of inhibitor adsorption 5,7,10.

To complement the electrochemical results, the amount of dissolved iron in 1 M HCl, both in the absence and presence of Aster chinensis extract, was quantified using the AAS (Atomic Absorption Spectroscopy) method. The observed reduction in iron concentration confirms the inhibitor's protective efficiency and supports the film-forming behaviour discussed in corrosion analysis texts4,9.

Inhibitor Concentration(ppm)	Amountofironin corrodent(mg/I)	Inhibitionefficiency (%)
Blank	518	
100	241	53.47
300	113	78.19
500	85	83.59

Surface Verification (SEM-EDX and XRD)

Scanning Electron Microscopy (SEM) and supporting surface characterization techniques provided visual and analytical confirmation of the protective action of Aster chinensis extract on mild steel6.

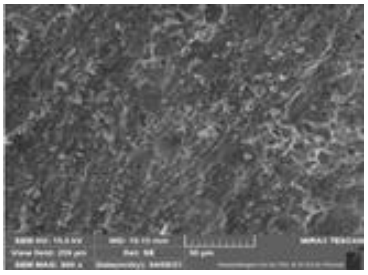
Surface Morphology

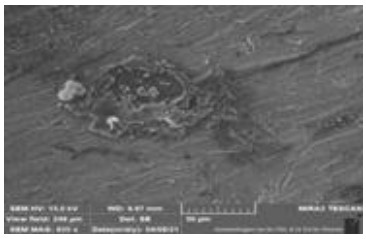
In the absence of the inhibitor, the mild steel surface exhibited severe corrosion, showing deep pits, cracks, and extensive etching due to the aggressive 1 M HCl medium. However, in the presence of Aster chinensis extract, the surface appeared significantly smoother, with corrosion damage strongly suppressed. SEM images clearly indicated the formation of a thin, uniform adsorbed protective film, consistent with the inhibition mechanism5,9.

Film Analysis

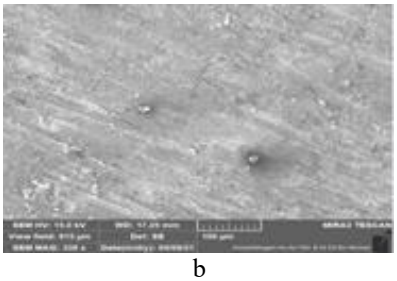
© 2025 IJSRET

Further confirmation of film formation was obtained using FT-IR and XRD analyses. FT-IR spectra revealed the functional groups from the plant extract involved in adsorption, while XRD supported the presence of an organic- inhibitor-covered surface layer. Together, these techniques verified the extract's strong film-forming ability and its role in inhibiting acid-induced corrosion7,8,10.



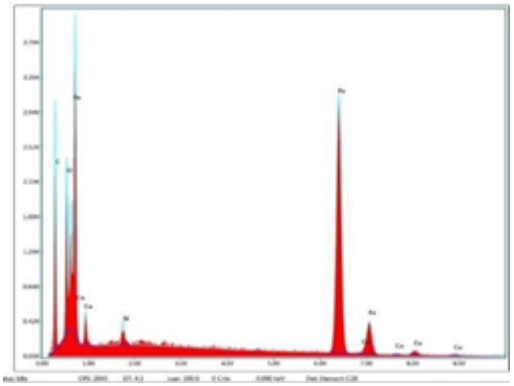


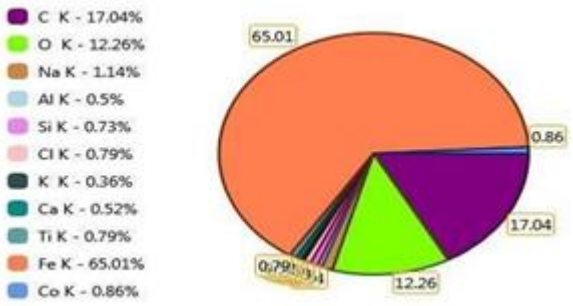
a



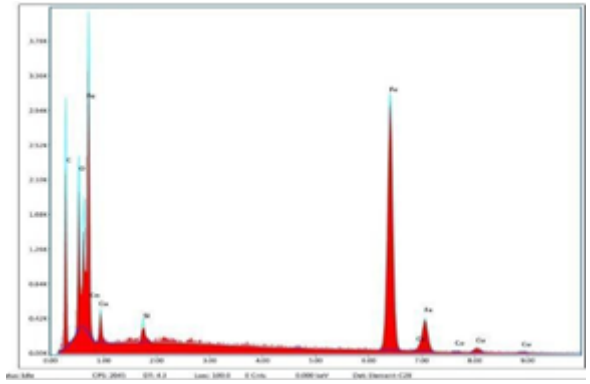
b

Figure:(a, b) SEM photographs for mild steel dipped in 1MHCl in Aster chinensisat 300 ppm and 500 ppm

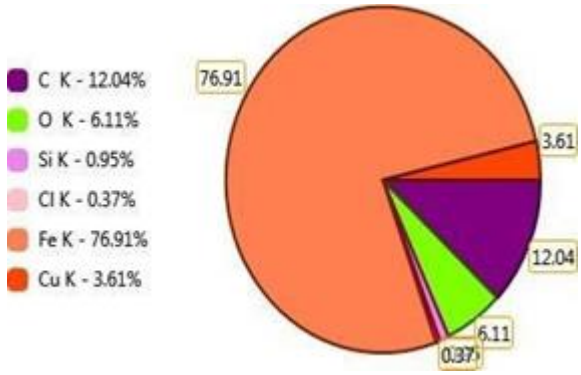




EDX photographs mild steel dipped in 1 M HCl



© 2025 IJSRET



EDX photographs for mild steel dipped in 1MHCl in Aster chinensis(500ppm)

III. CONCLUSION

The Aster chinensis extract is verified as a highly efficient > 92% and eco-friendly mixed-type corrosion inhibitor for mild steel in 1 M HCl. Its inhibition mechanism involves spontaneous physical adsorption onto the metal surface, which follows the Langmuir Isotherm. Electrochemical (EIS) and surface analyses (SEM-EDX, FTIR) confirmed the formation of a protective layer that significantly increases the charge transfer resistance. Furthermore, the extract was successfully used for the green synthesis of silver nanoparticles, demonstrating its dual utility.

REFERENCES

1. L.Mania, S. Benedetto, and M.Vitali, Proceedings of the international gas research Conference,8, 2001,343.
2. C.Wagner, W. Traud, JournalofZeitElectrochemicalscience,44,1938,391.
3. J.O.M. Bockris, A.K.N. Reddy, Modern Electrochemistry, PlenumPress,4,1970,1091.
4. D.AJones, Principles and Prevention of corrosion, Prentice-Hall International (UK)Ltd, 23, 1996, 538.
5. C.O.AOlsson,P. Agarwal,M.FreyandD.Landolt, CorrosionScience,42,2000,1197.
6. R.CJohn,A.D. Pelton,A.L. Young,W.T. Thompson,I.G.Wright,T.M.Besmann,Materials Research (Sao Carlos,Brazil),4,2004,163.
7. V.S.Sastri, P. R. Roberge and J. R. Perumareddi, Selection of Inhibitors Based on Theoretical Considerations, Canadian Institute of Mining, Metallurgy and Petroleum,17,1992,242.
8. M.AshandI.Ash, Handbook of Corrosion Inhibitors, NACE, Texas Houston, USA,18,2001,285.
9. P.A.Schweitzer,FundamentalsofMetallicCorrosion,2nded., CRCPress,London,10, 2007,118.
10. V.S.Sastri, Corrosion Inhibitors: Principles and Applications, Wiley-VCH, Weinheim, Germany, 7, 1998,343.

© 2025 IJSRET