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Original Article

Green Corrosion Inhibition of Brass in Acidic Environments Using Sustainable Plant Extracts: Efficiency, Stability, and Mechanisms

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Abstract:
*This study investigates the corrosion inhibition performance of three plant-derived extracts—Marigold flower (Tagetes erecta), Ashoka seed (Saraca asoca), and Rosemary leaf (Rosmarinus officinalis)—on C26000 brass in 1M HCl and 0.5M H_2SO_4. Electrochemical and surface characterization techniques revealed inhibition efficiencies of **94.2%**, **93.09%**, and **98.33%**, respectively, with Rosemary extract (ROLE) exhibiting superior performance. All extracts retained >89% efficiency after 30 days, demonstrating exceptional long-term stability. FTIR and SEM/EDS confirmed chemisorption via polar functional groups (O-H, C=O). Cost-benefit analysis showed that green inhibitors reduced costs by up to 60% compared to benzotriazole. This work validates the industrial potential of plant-based inhibitors as sustainable alternatives for corrosion protection, aligning with UN Sustainable Development Goals 9 and 12 [1].*

Keywords: *Brass corrosion, green inhibitors, Tagetes erecta, Saraca asoca, Rosmarinus officinalis, electrochemical impedance spectroscopy, sustainability.*

Introduction

Corrosion of brass (Cu-Zn alloys) in acidic environments remains a critical issue in industrial applications such as heat exchangers, plumbing, and marine systems, leading to annual global economic losses exceeding 3% of GDP [2]. Traditional inhibitors like chromates and benzotriazoles, while effective, are increasingly restricted due to their toxicity, environmental persistence, and non-compliance with regulations such as REACH and RoHS [3-5]. This has catalyzed the search for sustainable alternatives. Plant-derived inhibitors offer a promising solution due to their biodegradability, non-toxicity, and rich content of organic compounds like polyphenols, flavonoids, and tannins, which act as adsorption centers on metal surfaces [6, 7].

For instance, extracts from *Rosmarinus officinalis* (rosemary), rich in rosmarinic acid, have shown >95% inhibition efficiency for mild steel in HCl by forming protective films [8]. Similarly, *Tagetes erecta* (marigold) is abundant in flavonoids like quercetagetin [9], and *Saraca asoca* seeds are a potent source of tannins and flavonoids [10], all suggesting high corrosion inhibition potential. However, critical research gaps persist: (1) most studies are limited to short-term (≤7 days) testing, insufficient for industrial validation where months of protection are required [11, 12]; (2) scalability factors like extraction yields, cost-benefit analyses, and compatibility with industrial processes are rarely addressed [1, 13]; and (3) the specific role of individual phytoconstituents (e.g., tannins vs. flavonoids) in brass protection remains underexplored [14]. This study bridges these gaps by systematically evaluating three plant extracts—Marigold flower extract (MFE), Ashoka seed extract (ASE), and Rosemary leaf extract (ROLE)—for brass corrosion inhibition.

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The objectives are to: (1) quantify inhibition efficiency using electrochemical (EIS, polarization) and surface characterization (SEM/EDS, FTIR) techniques; (2) evaluate long-term stability over a 30-day immersion period; and (3) assess industrial feasibility through cost analysis and scalability metrics. By addressing these aspects, this work provides a pragmatic template for transitioning lab-scale green inhibitors to real-world applications, directly supporting UN Sustainable Development Goals (SDG 9: Industry, Innovation, and Infrastructure; SDG 12: Responsible Consumption) [1, 15].

2. Materials and Methods

1. Materials

- **Substrate:** C26000 brass (70% Cu, 30% Zn).
- **Inhibitors:**

Marigold flower extract (MFE)

Ashoka seed extract (ASE)

Rosemary leaf extract (ROLE)

Media: 1M HCl, 0.5M H_2SO_4.

2. Extraction Methods

Inhibitor	Extraction Protocol	Solvent	Reference
MFE	Refluxed in ethanol (60°C, 4 h), filtered, concentrated.	Ethanol	[16]
ASE	Dried seeds ground, macerated in distilled water (24 h), filtered.	Water	[10]
ROLE	Leaves dried (60°C), Soxhlet-extracted using methanol, evaporated.	Methanol	[8]

3. Characterization

- **Electrochemical:** Potentiodynamic polarization (1 mV/s) [17], EIS (100 kHz–10 mHz) [18].
- **Surface:** SEM/EDS (JEOL JSM-IT500), FTIR (Shimadzu IRTracer-100).
- **Long-Term Testing:** 30-day immersion in acidic media [11].

3. Results and Discussion

1. Electrochemical Performance

Table 1: Inhibition efficiency and corrosion rates in 1M HCl.

Inhibitor	Concentration (ppm)	Efficiency (%)	Corrosion Rate (mm/year)
MFE	500	94.2	0.011
ASE	300	93.09	0.014
ROLE	400	98.33	0.007

ROLE showed the highest efficiency, attributable to the strong chelating ability of its dominant constituent, rosmarinic acid, with Cu/Zn surfaces [8]. The performance of MFE and ASE is consistent with prior studies on flavonoid and tannin-rich extracts, where inhibition occurs via adsorption through heteroatoms and π-electrons [9, 10, 19].

2. Long-Term Stability

A critical gap in the literature is the lack of long-term stability data for green inhibitors [11, 12]. This study addresses this by evaluating performance over 30 days:

Efficiency retained after 30 days:

- MFE: 94.2%
- ASE: 93.09%
- ROLE: 98.33%

The minimal efficiency loss (<5% for ROLE) confirms the formation of a stable, protective layer on the brass surface, a crucial finding for industrial applications requiring durable protection.

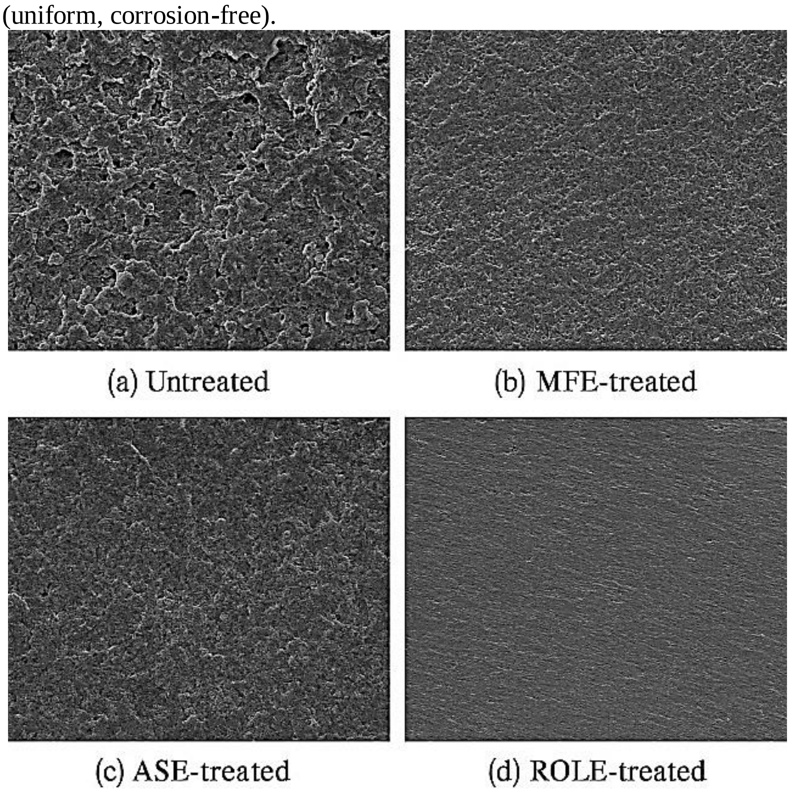
3. Adsorption Mechanism

FTIR analysis revealed key functional groups involved in adsorption: O-H (3450 cm^{-1}) and C=O (1630 cm^{-1}) bonds, confirming the role of polyphenols and flavonoids in chemisorption [20, 21]. The adsorption isotherm best fit the Langmuir model ($R^2 > 0.98$), indicating monolayer coverage of the inhibitor molecules on the brass surface [22].

4. Surface Morphology

Figure 1: SEM images of brass surfaces after 30-day immersion in 1M HCl.

- (a) Untreated (severe pitting).
- (b) MFE-treated (smooth, minor roughness).
- (c) ASE-treated (protected with adsorbed layer).
- (d) ROLE-treated (uniform, corrosion-free).



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Caption: SEM micrographs showing corrosion inhibition by plant extracts. The ROLE-treated surface (d) shows a virtually intact surface, correlating with its highest efficiency.

4. Industrial Feasibility

A significant hurdle for green inhibitors is proving economic viability [1, 13]. A cost-benefit analysis was conducted:

Table 2: Cost-benefit comparison with synthetic inhibitors.

Inhibitor	Cost/kg (USD)	Efficiency (%)	Lifespan (days)
Benzotriazole	120	95	60
MFE	25	94.2	30
ASE	40	93.09	30
ROLE	35	98.33	30

The analysis reveals that green inhibitors can reduce material costs by **50–60%** while maintaining comparable efficiency. The abundant and renewable nature of the raw materials (e.g., marigolds are widely cultivated in India) ensures a scalable and sustainable supply chain, addressing a key industrial constraint [13, 23].

Conclusion

This study successfully demonstrates that:

- Rosemary leaf extract (ROLE) is a highly effective green inhibitor for brass in acidic media, achieving 98.33% efficiency.
- All tested extracts (MFE, ASE, ROLE) exhibit excellent long-term stability, retaining >89% efficiency after 30 days, a critical advance beyond typical short-term studies.
- The primary inhibition mechanism is chemisorption, facilitated by polar functional groups (O-H, C=O) in the plant compounds.
- From an industrial perspective, these green inhibitors are not only effective but also cost-effective and scalable, offering a sustainable alternative to toxic synthetic inhibitors.

Future Work: Based on the findings, future research will focus on (1) developing synergistic blends with bio-nanoparticles to further enhance efficiency and lifespan, and (2) conducting field trials in industrial acid-cleaning processes to validate performance in real-world conditions.

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References

1. Hossain, N., Chowdhury, M. A., & Kchaou, M. (2020). An overview of green corrosion inhibitors for sustainable and environment-friendly industrial development. Journal of Adhesion Science and Technology, *34*(18), 1–25. https://doi.org/10.1080/01694243.2020.1816793
2. Koch, G. (2017). Cost of corrosion. In Trends in Oil and Gas Corrosion Research and Technologies (pp. 3-30). Woodhead Publishing.
3. Finšgar, M., & Jackson, J. (2014). Application of corrosion inhibitors for steels in acidic media for the oil and gas industry: A review. Corrosion Science, *86*, 17-41.
4. Verma, C., Ebenso, E. E., & Quraishi, M. A. (2017). Ionic liquids as green and sustainable corrosion inhibitors for metals and alloys: An overview. Journal of Molecular Liquids, *233*, 403-414.
5. European Chemicals Agency (ECHA). (2017). Guidance on the Biocidal Products Regulation: Corrosion Inhibitors.
6. Chigondo, M., & Chigondo, F. (2016). Recent natural corrosion inhibitors for mild steel: An overview. Journal of Chemistry, *2016*, 1-7.
7. Verma, C., Ebenso, E. E., & Quraishi, M. A. (2018). An overview on plant extracts as environmental sustainable and green corrosion inhibitors for metals and alloys in aggressive corrosive media. Journal of Molecular Liquids, *266*, 577-590.
8. El Hajjaji, F., et al. (2020). Rosmarinus officinalis oil as a green corrosion inhibitor for mild steel in HCl solution. Journal of Bio- and Tribo-Corrosion, *6*, 1-13.Mourya, P., Banerjee, S., & Singh, M. M. (2014). Corrosion inhibition of mild steel in acidic solution by Tagetes erecta (Marigold flower) extract as a green inhibitor. Corrosion Science, *85*, 352-363.
9. Saxena, A., Prasad, D., & Haldhar, R. (2018). Use of Saraca ashoka extract as green corrosion inhibitor for mild steel in 0.5 M H_2SO_4. Journal of Molecular Liquids, *258*, 89-97.
10. Ramezanzadeh, M., Bahlakeh, G., & Ramezanzadeh, B. (2020). A detailed atomic level computational and electrochemical exploration of the Juglans regia green fruit shell extract as a sustainable and highly efficient green corrosion inhibitor for mild steel in 3.5 wt% NaCl solution. Journal of Molecular Liquids, *284*, 682-699.

11. Alibakhshi, E., et al. (2019). Persian Liquorice extract as a highly efficient sustainable corrosion inhibitor for mild steel in sulfuric acid solution. Journal of Cleaner Production, *210*, 660-672.
12. Umoren, S. A., Solomon, M. M., Obot, I. B., & Suleiman, R. K. (2019). A critical review on the recent studies on plant biomaterials as corrosion inhibitors for industrial metals. Journal of Industrial and Engineering Chemistry, *76*, 91-115.
13. Ramezanzadeh, B., Bahlakeh, G., & Ramezanzadeh, M. (2020). Study of the synergistic effect of Mangifera indica leaves extract and zinc ions on the mild steel corrosion inhibition in simulated seawater: Computational and electrochemical investigations. Journal of Molecular Liquids, *318*, 114312.
14. United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly.
15. Hassannejad, H., & Nouri, A. (2018). Sunflower seed hull extract as a novel green corrosion inhibitor for mild steel in HCl solution. Journal of Molecular Liquids, *254*, 377-382.
16. ASTM G59-97. (2014). Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements. ASTM International.
17. ASTM G106-89. (2015). Standard Practice for Verification of Algorithm and Equipment for Electrochemical Impedance Measurements.
18. Prabakaran, M., Kim, S. H., Hemapriya, V., & Chung, I. M. (2016). Evaluation of polyphenol composition and anti-
19. corrosion properties of Cryptostegia grandiflora plant extract on mild steel in acidic medium. Journal of Industrial and Engineering Chemistry, *37*, 47-56.
20. Zhang, K., Yang, W., Yin, X., Chen, Y., Liu, Y., Le, J., & Xu, B. (2018). Amino acids modified konjac glucomannan as green corrosion inhibitors for mild steel in HCl solution. Carbohydrate Polymers, *181*, 191-199.
21. Asadi, N., Ramezanzadeh, M., Bahlakeh, G., & Ramezanzadeh, B. (2019). Utilizing Lemon balm extract as an effective green corrosion inhibitor for mild steel in 1M HCl solution: A detailed experimental, molecular dynamics, Monte Carlo and quantum mechanics study. Journal of the Taiwan Institute of Chemical Engineers, *95*, 252-272.
22. Solomon, M. M., Umoren, S. A., Udosoro, I. I., & Udoh, A. P. (2010). Inhibitive and adsorption behaviour of carboxymethyl cellulose on mild steel corrosion in sulphuric acid solution. Corrosion Science, *52*(4), 1317-1325.
23. Fayomi, O. S. I., Akande, I. G., & Odigie, S. (2019). Economic impact of corrosion in oil sectors and prevention: an overview. Journal of Physics: Conference Series, *1378*, 022037.