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Statistical Optimization of Ecofriendly Corrosion Inhibitor for Mild Steel in Acidic Medium

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Abstract

This current study outlines the corrosion inhibitory efficacy of *Aglaonema commutatum* of mild steel in 1N hydrochloric acid (HCl). The corrosion rates were evaluated using the weight loss method and temperature studies The leaves of *Aglaonema commutatum* demonstarted a maximum inhibition efficiency of 98% at varying concentrations. Phytochemical screening revealed the presence of bioactive compounds which may be accounted to contribute for corrosion resistance. Infrared (IR) and UV-Vis spectroscopy confirmed the presence of functional groups that are capable of forming protective layers on the metal surface. Surface analysis using Scanning Electron Microscopy (SEM) revealed reduced surface corrosion and the formation of a protective film. The inhibition efficiency increased with higher extract concentrations but slightly declined at elevated temperatures, indicating temperature sensitivity. A mathematical correlation was drawn by correlating the linear regression pertaining to the inhibitory effect of *Aglaonema commutatum* of mild steel in 1N hydrochloric acid (HCl). Thus, *Aglaonema commutatum* offers itself as an eco-friendly inhibitor, offering a sustainable alternative to conventional chemical inhibitors with promising industrial applications.

1. Introduction

Since its accidental discovery, metals play a vital role down the history of ancient human civilization. Metals are usually characterized by high malleability, ductility, lustrous, thermal and electrical conductivity. Among the numerous ways of classifying metals, the prominent classification includes division of metals into ferrous and nonferrous metals. Ferrous metals include either pure form of iron or its alloys. They form an integral form of metallurgy. Stainless steel, cast iron mild steel and high carbon steel. Mild steel, which is frequently used in industrial cleaning, pickling, and descaling procedures due to its mechanical strength and affordability, is especially susceptible to corrosion in aggressive media like hydrochloric acid (HCl).Metals tend to come back to thermodynamically stable states by forming their oxides, sulphates, sulphides, nitrates by their interaction with the environment/ surrounding.[1-3] One such process is "Corrosion", which is the degradation of metal by the interaction with moieties in the environment. Corrosion poses a major/ threat to industries.[4,5] The economic impact of corrosion includes infrastructural damage, industrial and manufacturing losses, transportation and energy sector costs.[6] The mitigation strategies of corrosion inhibition constitute protective coatings, employing corrosion-resistant materials, cathodic protection, regular inspection and employing advanced technologies like nanocoating. Corrosion inhibitors are substances which when added in relatively low concentrations can slow down the rate of corrosion of a metal.[7-10] Extensive research in the past for the control of corrosion had led to the employment of organic, inorganic and green inhibitors.[11-13] Conventional corrosion inhibitors often use synthetic chemicals which pose major health and environmental threat. These difficulties have fueled the hunt for sustainable, affordable, and environmentally friendly substitutes.[14-16] Additionally, the need to promote sustainable development for the upcoming generations and ensuring a better future for all is the need of the hour.[17.18] Because of their abundance, non-toxicity, biodegradability, and high concentration of bioactive substances such alkaloids, flavonoids, tannins, and phenolic compounds, natural plant extracts have shown great promise as green corrosion inhibitors.[19,20]

Aglaonema commutatum, an ornamental plant known for its rich phytochemical composition, has shown potential as a natural corrosion inhibitor. Despite its bioactive properties, the application of *Aglaonema commutatum* in corrosion inhibition remains largely unexplored.

This study aims to evaluate the corrosion inhibition efficiency of leaves of *Aglaonema commutatum* plant extract for mild steel in 1N HCl. The research investigates the effect of extract concentration and temperature on corrosion rates using the weight loss method and temperature studies. Various analytical techniques were employed to assess the formation of protective layers. This study highlights the potential of *Aglaonema commutatum* as an eco-friendly and cost-efficient corrosion inhibitor, contributing to sustainable solutions in industrial corrosion management.

2. Materials and Methodology

2.1 Preparation of mild steel and the medium. Mild steel sheets with a thickness of 2 mm were used for the study and were mechanically press-cut into rectangular coupons measuring 5 cm × 2 cm. The samples were polished using emery paper, washed and dried before use. Corrosive medium was prepared by diluting 90 mL of concentrated HCl with 910 mL of distilled water, which served as the blank for corrosion analysis.

2.2 Preparation of Plant Extract. Leaves of *Aglaonema commutatum* plant material were collected from Kaundampalayam, Coimbatore, Tamil Nadu, Southern region of India. The leaves were rinsed with distilled water, allowed to dry in the shade, and then ground into a fine powder. A mixture of 50 g of the powdered plant material and 1 L of 1N HCl was placed in a round-bottom flask and heated under reflux for 5 hours to create a 5% plant extract. The extract was left to sit overnight before being filtered. The resulting filtrate was kept in an airtight container for further examination.

2.3 Preliminary Analysis of Phytoconstituents. Preliminary characterization for the phytoconstituents present in the *Aglaonema commutatum* extract, to identify the presence of bioactive compounds using standard qualitative tests was carried out as per the reported literature.

2.4 UV Spectroscopy Analysis. The extract of *Aglaonema commutatum* (ACP) was subjected to UV Spectroscopic analysis over a range of 200 - 800 nm. UV Spectroscopic analysis was carried out to identify the presence of active components, which may possess potential corrosion inhibiting properties.

2.5 FT-IR Analysis. The identification of the functional groups, that might be responsible for the inhibitory action was analysed using FT-IR. FT-IR analysis was carried on the extract of *Aglaonema commutatum*, the mild steel sample immersed in 1N HCl and mild steel sample immersed in 2% concentration of *Aglaonema commutatum*. The spectral data were utilized to determine the existence of distinct functional groups in the extract and on the surface of mild steel.

2.6 SEM Analysis. SEM analysis was used to study the morphological characteristics of mild steel, while EDAX determined its elemental composition. Micrographs of mild steel with and without ACP extract (blank, 2%) were taken after 3 hours of immersion. The specimens were then dried.

2.7 Gravimetric method. The weight loss method was used to assess the corrosion inhibition efficiency of *Aglaonema commutatum* extract on mild steel in 1N HCl. Pre-weighed steel coupons were immersed in acid solutions with varying extract concentrations for a time duration of 1,3,5,7 and 24 hours. After the specified period of immersion, the coupons were cleaned, dried, and reweighed to determine weight loss. The inhibitory activity rate was calculated using standard formulas, highlighting the extract's effectiveness in reducing corrosion.

2.8 Temperature study. Mild steel samples submerged in 1N HCl and solutions containing various concentrations of the inhibitor was subjected to various temperatures (40°C, 50°C, 60°C, and 70°C) for an immersion period of an hour. After one hour, weight loss of the steel samples were measured, and inhibition efficiency was calculated.

2.9 Adsorption Isotherms. Adsorption occurs at the surface. The interaction between the adsorbate (the inhibitor) and the adsorbent (the metal surface) can best be understood from the adsorption isotherms. Isotherms offer a more comprehensive insight into the process of adsorption (physisorption/ chemisorption), the efficacy of adsorption of the inhibitors, the formation of single layer or multilayer of protection and the arrival of various thermodynamic parameters.

3. Results And Discussion

3.1 Phytochemical Analysis. Phytochemical screening of the *Aglaonema commutatum* extract was carried out using standard qualitative tests as per earlier reported procedure. These tests confirmed the presence of bioactive compounds like anthraquinone, flavonoids, saponins and tannins in the extract of *Aglaonema commutatum*. Among the numerous bioactive components, flavonoids in particular, are known for their antioxidant and metal-binding properties, which can help in creating a barrier on the metal surface.

3.2 UV - Visible Spectroscopy. The UV-Vis spectrum of *Agalenoma commutam* shows absorption peaks around 280 nm and 360 nm. The intense peak at 280 nm could be attributed to π→π* transitions in aromatic rings or conjugated double bonds found in these compounds. A broad peak around 360 nm can be attributed to n→π* transitions. The reduced absorbance in the visible range suggests that there aren't many pigments or chromophores absorbing there, which is in line with a plant extract that is colorless or faintly colored. This spectrum demonstrates the plant's possible phytochemical richness, which might be investigated further through the use of spectroscopic or chromatographic methods for constituent identification.

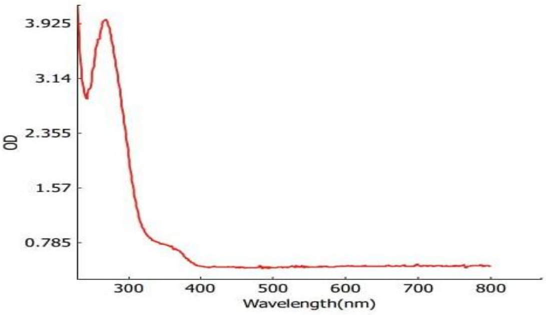

Figure 1. *UV Analysis of extract of Agalenoma commutam*

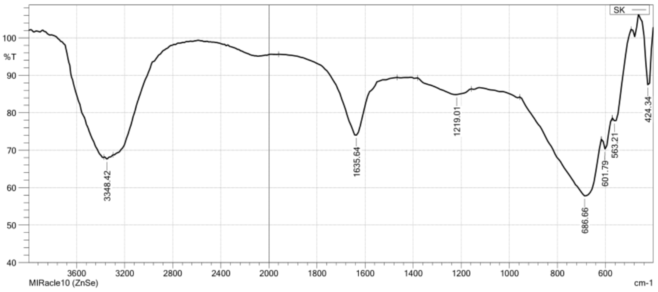

Figure 2. *FTIR analysis of extract of Agalenoma commutam*

3.3 Fourier Transform Infra-Red (FTIR) Analysis

FTIR analysis of *Aglaonema commutatum* (ACP) extract confirmed the presence of functional groups that might be responsible for corrosion inhibition of mild steel in acidic media. A broad band at 3348.42 cm^{-1} indicates hydroxyl (-OH) groups aiding adsorption through hydrogen bonding. The 1655.64 cm^{-1} peak corresponds to C=O stretching, suggesting carbonyl groups forming coordination bonds with metal ions. The 1219.01 cm^{-1} peak (C-O stretching) highlights esters, ethers, or phenolics contributing to film formation. Peaks at 686.66 cm^{-1}, 601.79 cm^{-1}, and 563.21 cm^{-1} indicate C-H bending in aromatic rings, while the 424.34 cm^{-1} band represents metal-oxygen (M-O) stretching, confirming complex formation and protective layer formation on mild steel.

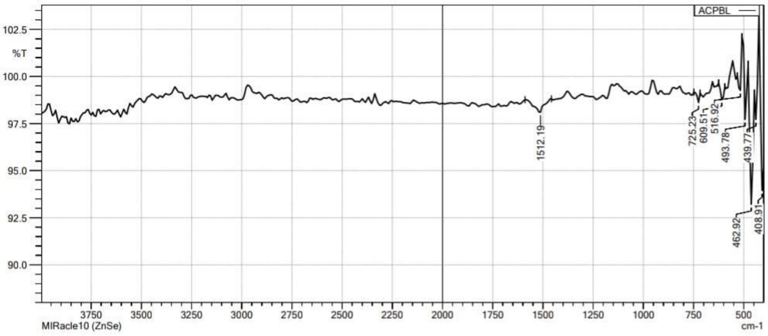

Figure 3. *IR Spectrum of Mild Steel in Blank HCl*

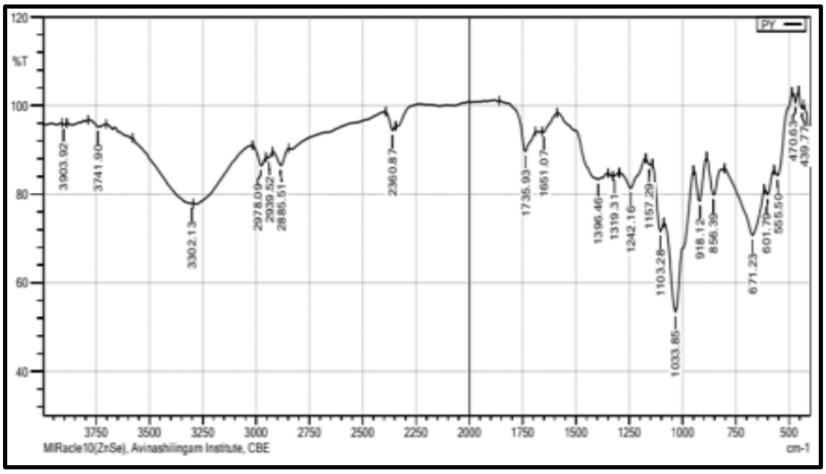

Figure 4. *IR Spectrum of Mild Steel in 2% Concentration of Agalenoma commutam*

A comparison of the FTIR spectra of mild steel in blank HCl and mild steel in 2% concentration of *Agalenoma commutam* is depicted in Fig 3.3 and 3.4. A close observation reveals *the presence of f*our distinct peaks in Fig 3.4 (IR spectrum of mild steel in 2% concentration of *Agalenoma commutam)*. The broad peak at 3294.42 cm^{-1} showed the presence of O-H stretch, peak at 2360.87 cm^{-1} and 1735.93 cm^{-1} corresponded to the presence of C=C and C=O stretching respectively, and at 1033.85 cm^{-1} corresponding to C-O stretching.

3.4 SEM Analysis

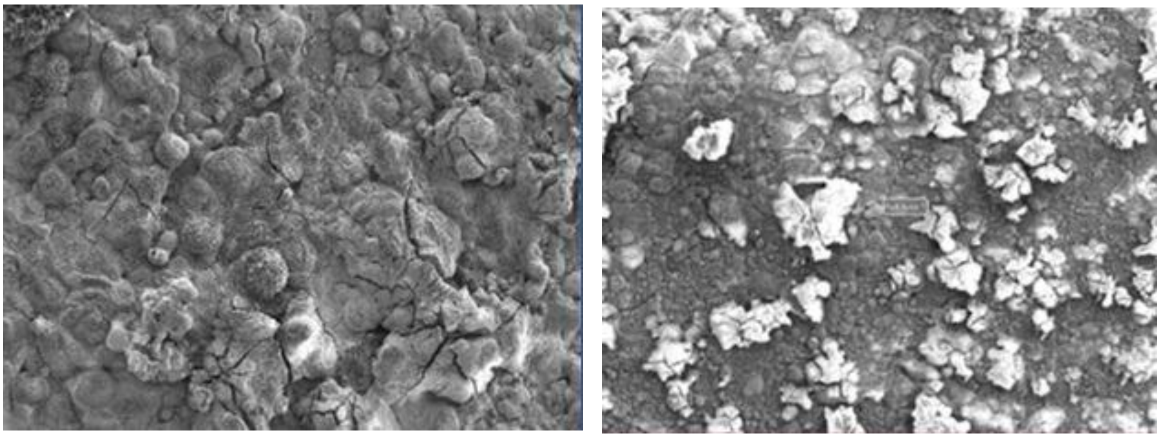
(a) (b)

Figure 4. (a) - *SEM Images of mild steel in blank HCl*
(b) - *SEM Images of mild steel in in 2% concentration of Agalenoma commutam*

SEM analysis was performed to examine the surface morphology of mild steel immersed in 1N HCl, both with and without the addition of *Aglaonema commutatum* (ACP) extract. The sample without treatment exhibited significant corrosion, roughened surfaces, and noticeable pits, reflecting a strong acid attack. Conversely, the sample treated with ACP revealed a smoother surface with a reduced number of defects, indicating that the extract formed a protective layer that limited corrosion and surface deterioration.

3.5 Weight loss method. The weight loss method was used to assess the corrosion rate and the inhibition efficiency of mild steel in blank HCl and various concentrations of *Aglaonema commutatum* extract. The corrosion rate and inhibition efficiency were calculated using standard formulas. It was observed that with increasing concentrations of *Aglaonema commutatum* extract, the corrosion rate decreases and the inhibition efficiency increases. It was also observed at concentrations higher than 2% *Aglaonema commutatum* extract, the inhibition efficiency remained constant and further increase in concentration of *Aglaonema commutatum* resulted in increased rate of corrosion, which can be accounted for the increased rate of desorption of the inhibitor from the surface of the absorbent, ie, the mild steel.

Table 1. The effect of variation of Corrosion Rate (mpy) and IE (%) with concentration of *Agalenoma commutam* extract in 1N HCl with time

Conc. of Extract	**1 hour**		**3 hours**		**5 hours**		**7 hours**		**24 hours**	
	CR (mpy)	**IE %**	**CR (mpy)**	**IE %**	**CR (mpy)**	**IE %**	**CR (mpy)**	**IE %**	**CR (mpy)**	**IE %**
Blank	270	-	248	-	879	-	683	-	351	-
0.1	143	47	36	85	180	79	65	90	125	64
0.25	122	54	19	92	81	90	50	92	55	84
0.5	109	59	15	93	65	92	47	93	40	89
0.75	83	69	10	95	46	94	35	94	38	89
1	48	82	7	97	29	96	21	97	30	91
2	39	85	6	97	24	97	9	98	10	97

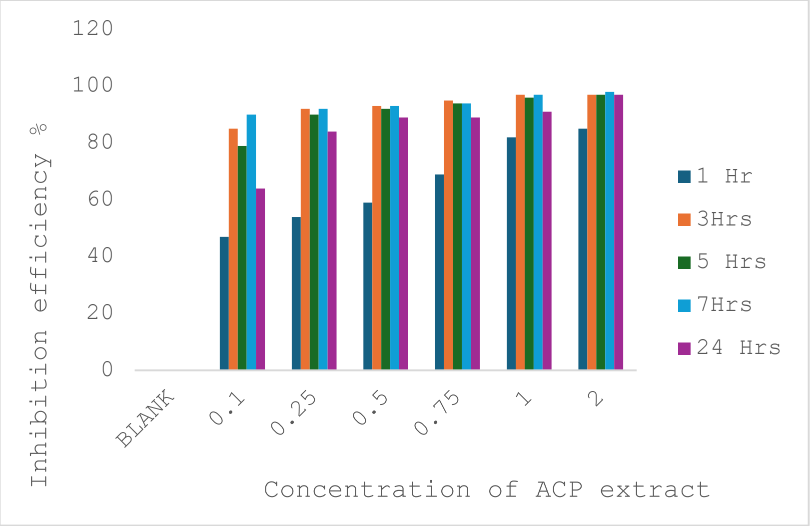

Figure 5. *The effect of Inhibition efficiency at varying concentration and different immersion time intervals*

3.6 Temperature study. The temperature study was conducted to evaluate the effect of temperature on the corrosion inhibition efficiency of *Aglaonema commutatum* extract. Mild steel coupons were immersed in 1N HCl containing the extract at various temperatures (40°C, 50°C, 60°C, and 70°C) for 1 hour. After immersion, weight loss was measured, and inhibition efficiency was calculated. The results showed a decrease in efficiency at higher temperatures, suggesting possible desorption of inhibitor molecules from the metal surface.

Table 2. The effect of variation of Corrosion Rate (mpy) and IE (%) with concentration of *Agalenoma commutam* extract in 1N HCl with temperature

Conc. Of extracts	303 K		313 K		323 K		333 K		343 K	
	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %
Blank	270		1138		2918		2386		3365	
0.1	143	47	309	72	1809	37	737	69	1399	58
0.25	122	54	187	83	1513	48	344	85	962	71
0.50	109	59	180	84	508	82	357	85	611	81
0.75	83	69	136	88	257	91	241	89	505	84
1	48	82	117	89	186	93	177	92	266	92
2	39	85	53	95	155	94	106	95	206	93

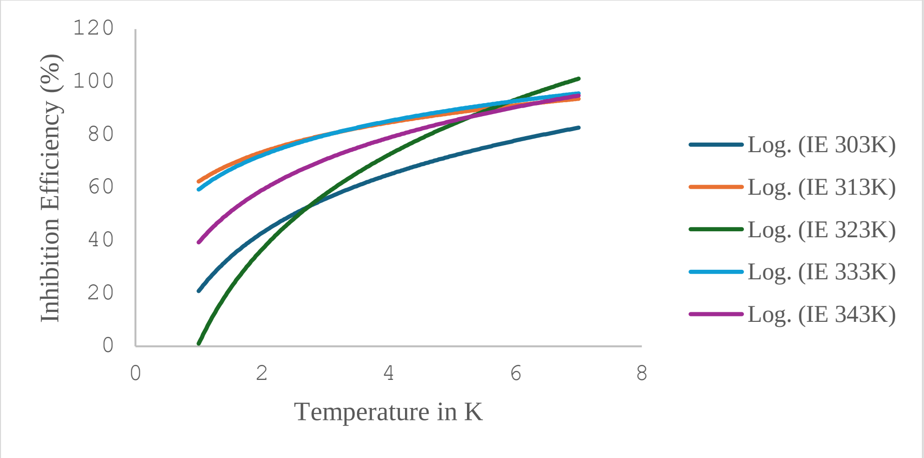

Figure 6. *The effect of Inhibition efficiency at varying concentration and different temperatures*

3.7 Linear Regression Analysis

Adsorption isotherms relate surface coverage (θ) to inhibitor concentration (C) at constant temperature, with the best fit determined using correlation coefficients (R^2). The Temkin isotherm plot confirms a strong fit (R^2: 0.9411–0.9929), indicating chemisorption and thermal stability of the corrosion inhibitor. The Freundlich isotherm plot confirms multilayer adsorption, surface heterogeneity, and temperature-dependent physisorption behavior. The El-Awady isotherm plot indicates mixed adsorption behavior, with R^2 (0.8769–0.9508) confirming both physisorption and chemisorption. The Langmuir isotherm plot suggests predominant monolayer adsorption, with slight deviations at higher temperatures due to molecular motion or desorption.

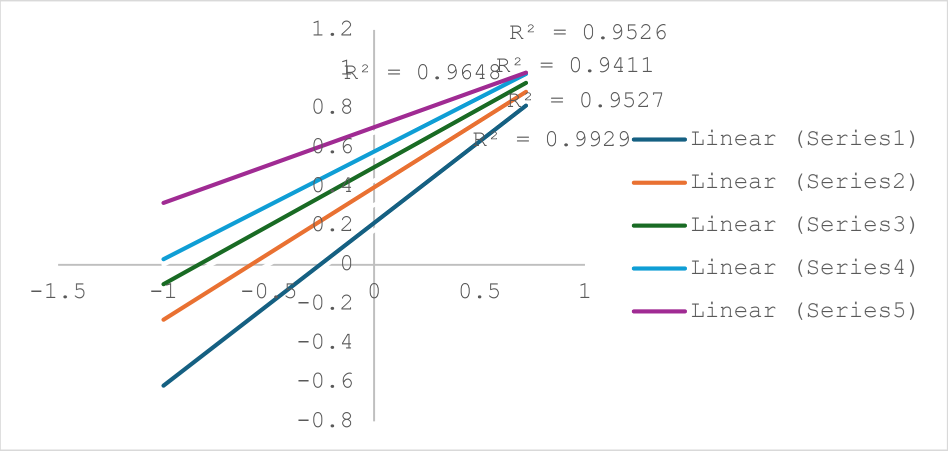

Figure 7. *Temkin plots of mild steel in 1N HCl solution without and with different concentrations of ACP*

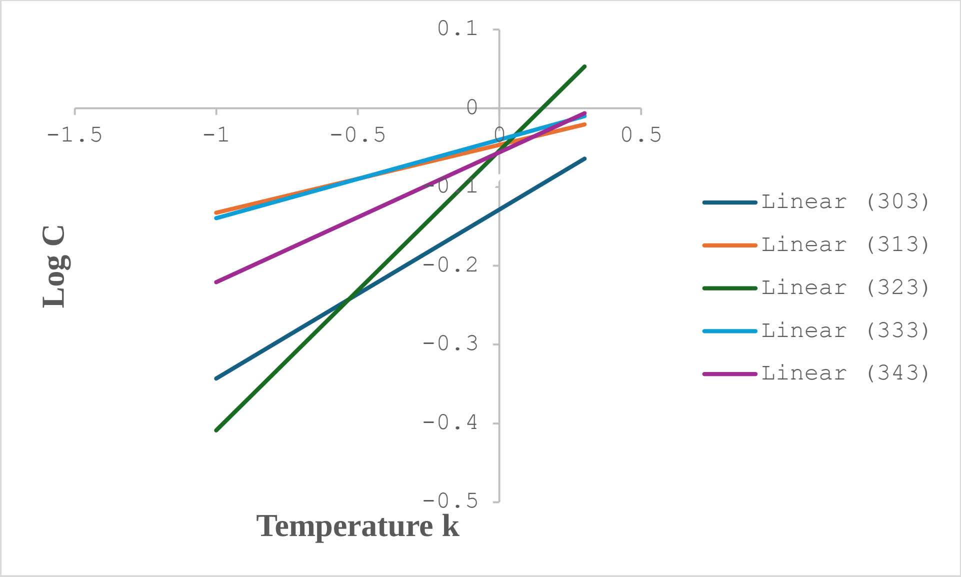

Figure 8. *Freundlich plots of mild steel in 1N HCl solution without and with different concentrations of ACP*

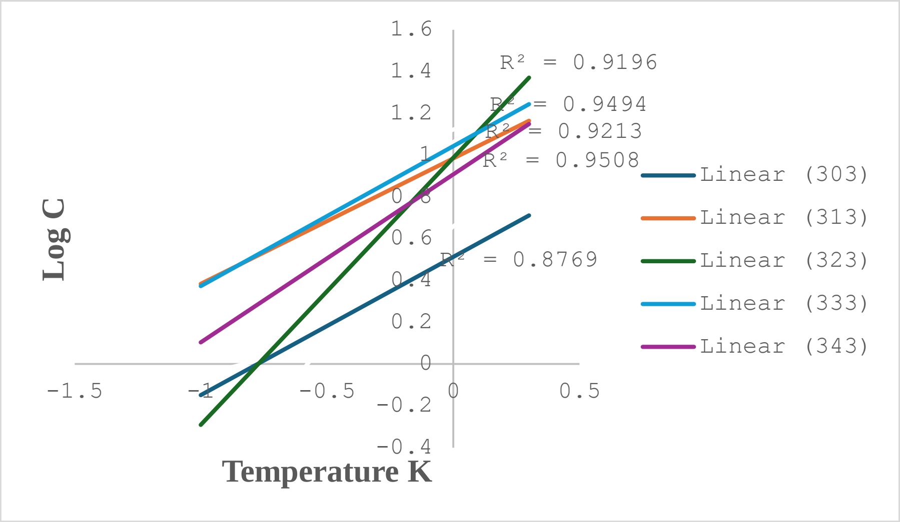

Figure 9. *El - Awady plots of mild steel in 1N HCl solution without and with different concentrations of ACP*

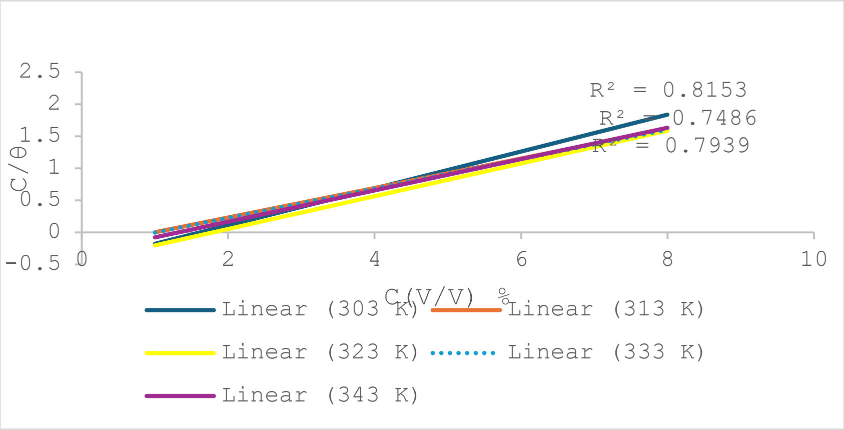

Figure 10. *Langmuir's adsorption plots for mild in 1N HCl containing different concentration of ACP*

3.8 Arrhenius Kinetic Study

Table 3. Activation energies (E_a) of different concentrations of ACP extract in 1N HCl

Concentration of ACP extract (% v/v)	**Ea (KJ/mol)**
Blank	50866.27
0.1	47683.47
0.25	41569.96
0.50	36040.64
0.75	36189.82
1	33553.10
2	34930.10

The Arrhenius plot indicates an endothermic adsorption process, with activation energy (E_a) determining the inhibitor's adsorption type and thermal stability.

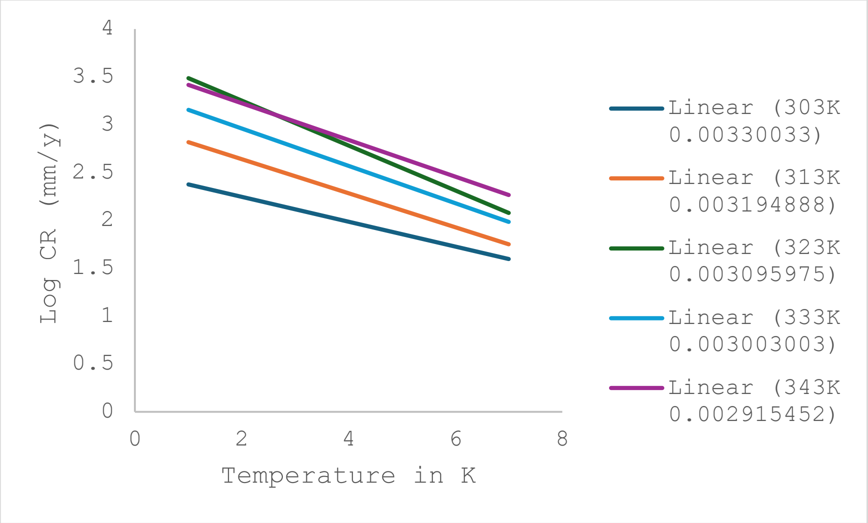

Figure 11. *Arrhenius plots of mild steel in 1N HCl solution without and with different concentrations of ACP*

4. Conclusion

The present study revealed that *Agalenoma commutam* serves to be an effective green corrosion inhibitor meeting our goal to develop solutions to attain sustainability. The extract of *Agalenoma commutam* was well characterized for the presence of phytoconstituents present and supported by UV – Vis and IR analysis. The inhibition efficiency of various concentrations of *Agalenoma commutam* for the corrosion of mild steel in 1N HCl was monitored through Weight loss method. The effect of temperature on the corrosion rate and inhibition efficiency was also well exploited. The surface morphology of the samples exposed to the acidic media and 2% concentration of *Agalenoma commutam* further supported to our study. The adsorption isotherms well fitted demonstrating the stable interaction of the inhibitor facilitated by the presence of heteroatoms, and delocalization of π- electrons with the adsorbent.

References

1. Srivastava, M. Mild Steel Corrosion Inhibition, in 4 N Sulphuric Acid, by a Green Inhibitor. *Port. Electrochim. Acta*, ***38***, 99–106 (2020).
2. Zaher, A.; Chaouiki, A.; Salghi, R.; Boukhraz, A.; Bourkhiss, B.; Ouhssine, M. Inhibition of Mild Steel Corrosion in 1M Hydrochloric Medium by the Methanolic Extract of *Ammi visnaga* L. Lam Seeds. *Int. J. Corros.,* **2020**, 1–10 (2020).
3. Dehghani, A.; Bahlakeh, G.; Ramezanzadeh, B. Green *Eucalyptus* leaf extract: A potent source of bio-active corrosion inhibitors for mild steel. *Bioelectrochemistry*, **130,** 107339 (2019).
4. Ikeuba, A.I.; Okafor, P.C. Green corrosion protection for mild steel in acidic media: Saponins and crude extracts of Gongronema latifolium. *Pigment. Resin Technol.*, **48**, 57–64 (2019).
5. Wang, X. Solanum lasiocarpum L. Extract as Green Corrosion Inhibitor for A3 Steel in 1 M HCl Solution. *Int. J. Electrochem. Sci.*, **14**, 1178–1196 (2019).
6. Koch, G.; Varney, J.; Thompson, N.; Moghissi, O.; Gould, M.; Payer, J. *International Measures of Prevention, Application, and Economics of Corrosion Technologies Study*; NACE International: Houston, TX, USA, 2016.
7. Popoola, L.T. Organic green corrosion inhibitors (OGCIs): A critical review. *Corros. Rev.*, **37**, 71–102 (2019).
8. Bouraoui, M.M.; Chettouh, S.; Chouchane, T.; Khellaf, N. Inhibition Efficiency of Cinnamon Oil as a Green Corrosion Inhibitor. *J. Bio Tribo Corros.*, **5**, 28 (2019).
9. Ogunleye, O.; Arinkoola, A.; Eletta, O.; Agbede, O.; Osho, Y.; Morakinyo, A.; Hamed, J. Green corrosion inhibition and adsorption characteristics of Luffa cylindrica leaf extract on mild steel in hydrochloric acid environment. *Heliyon*, **6**, e03205 (2020).
10. Javed, M. *Corrosion Inhibitors. Global Markets*; BCC Publishing: Wellesley, MA, USA, 2017.
11. Vorobyova, V.I.; Skiba, M.I.; Shakun, A.S.; Nahirniak, S.V. Relationship between the inhibition and antioxidant properties of the plant and biomass wastes extracts-A Review. *Int. J. Corros. Scale. Inhib.*, **8**, 150–178 (2019).
12. Haldhar, R.; Prasad, D.; Nguyen, D.L.T.; Kaya, S.; Bahadur, I.; Dagdag, O.; Kim, S.-C. Corrosion inhibition, surface adsorption and computational studies of Swertia chirata extract: A sustainable and green approach. *Mater. Chem. Phys.*, **267**, 124613 (2021).
13. Hegde, M.; Nayak, S.P. Aqueous extract of Dillenia Pentagyna Fruit as green inhibitor for mild steel corrosion in 0.5 M hydrochloric acid solution. *J. Mater. Environ. Sci.*, **2508**, 22–31 (2019).
14. Bhuvaneshwari, D.S.; Raja, B.; Durai, U. Adina Cordifolia as a corrosion inhibitor—A green approach against mild steel corrosion in 0.5 M sulphuric acid medium. *Pigment. Resin Technol.*, **49**, 63–70. (2019).
15. Şahin, E.A.; Solmaz, R.; Gecibesler, I.H.; Kardaş, G. Adsorption ability, stability and corrosion inhibition mechanism of phoenix dactylifera extrat on mild steel. *Mater. Res. Express*, **7**, 016585 (2020).
16. Dehghani, A.; Bahlakeh, G.; Ramezanzadeh, B.; Ramezanzadeh, M. A combined experimental and theoretical study of green corrosion inhibition of mild steel in HCl solution by aqueous Citrullus lanatus fruit (CLF) extract. *J. Mol. Liq.*, **279**, 603–624 (2019).
17. Bahlakeh, G.; Ramezanzadeh, B.; Dehghani, A.; Ramezanzadeh, M. Novel cost-effective and high-performance green inhibitor based on aqueous Peganum harmala seed extract for mild steel corrosion in HCl solution: Detailed experimental and electronic/atomic level computational explorations. *J. Mol. Liq.*, **283**, 174–195 (2019).
18. Anupama, K.; Ramya, K.; Joseph, A. Electrochemical and computational aspects of surface interaction and corrosion inhibition of mild steel in hydrochloric acid by Phyllanthus amarus leaf extract (PAE). *J. Mol. Liq.*, **216**, 146–155 (2016).
19. Salmasifar, A.; Edraki, M.; Alibakhshi, E.; Ramezanzadeh, B.; Bahlakeh, G. Combined electrochemical/surface investigations and computer modeling of the aquatic Artichoke extract molecules corrosion inhibition properties on the mild steel surface immersed in the acidic medium. *J. Mol. Liq.*, **327**, 114856 (2021).
20. Vidhya, K.T.; Kakkassery, J.T.; Raphael, V.P.; Ragi, K.; Johnson, R. Ixora coccinea extract as an efficient eco-friendly corrosion inhibitor in acidic media: Experimental and theoretical approach. *Curr. Chem. Lett.*, **10**, 139–150 (2021).