IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 17, Issue 2 Ser. 1 (Mar. – Apr. 2025), PP 48-55
www.Iosrjournals.Org

Evaluation Of The Corrosion Inhibition Characteristics Of Heinsia Crinita (Atama) Leaf Extract On Mild Steel In Acidic Environment

Okporie Ndifreke Brown[1,2]*, Patrick Akata Nwofe[2,3], Nweke Friday Ukpai[1]
Department Of Industrial And Medical Physics, Faculty Of Natural Sciences, David Umahi Federal University Of Health Sciences, Uburu, P.M.B. 211, Ebonyi State, Nigeria
Department Of Industrial Physics, Faculty Of Science, Ebonyi State University, P.M.B. 53, Abakaliki, Ebonyi State, Nigeria
Department Of Physics And Astronomy, Faculty Of Science, Ebonyi State University Of Aeronautics And Aerospace Engineering, Ezza, P.M.B. 035, Ebonyi State, Nigeria.

Abstract
In this work, the potentials of leaf extracts of Heinsia crinita (atama) was investigated for use as a green inhibitor for the control of corrosion of mild steel in an acidic environment. The experiment was conducted in an acidic environment and in a control environment under different concentrations of the green inhibitors and with different exposure times. The concentration of the acidic environment was maintained at 0.5 M. Further, the concentration of the green inhibitor was changed between 0 g/mol (control) to 50 g/mol. The incremental change in the concentration of the leaf extracts of Heinsia crinita were retained at 10 g/mol. The exposure times were varied between 72 hours to 144 hours, and the experiments were all performed at room temperature. The weight loss technique was employed for analysis in all the measurements. This resulted in the extraction of the corrosion rate-CR (mpy), surface coverage (θ), and inhibition efficiency (%). The coupons were further subjected to varying characterisation procedures such as X-ray diffractometry (XRD) to investigate the structural properties, Scanning Electron Microscopy (SEM) to study the morphology, and Fourier Transform Infrared Spectroscopy (FTIR) to study the optical properties as well as the functional groups. The findings indicated that the leaf extracts of Heinsia crinita (atama) exhibited excellent corrosion inhibition characteristics under the test conditions. The higher concentration of the leaf extracts of Heinsia crinita exhibited best corrosion inhibition performance irrespective of the different exposure times. To date, this is a pioneering report on the use of leaf extracts of Heinsia crinita (atama) for corrosion inhibition of mild steel in an acidic environment.

Date of Submission: 01-03-2025 | Date of Acceptance: 11-03-2025

I. Introduction

Corrosion is a cankerworm that has been ravaging different industries such as petrochemical, metallurgical, chemical, oil and gas, including mild steel over the years. Research on how to reduce the negative impact of corrosion has been ongoing and is almost as old as corrosion itself. Although several inorganic inhibitors of corrosion has been established, it has been observed that inorganic corrosion inhibitors are not only less affordable economically, but also pose serious threat to the environment. It is in this viewpoint that emphasis has been shifted toward increased research on organic materials that will solve the problem of corrosion in mild steel at more affordable cost and also be friendly to the environment. These organic materials are termed green inhibitors because they are sourced from plants. Green inhibitors for mild steel or other materials in acidic, alkaline, or in other environments, are usually plant extracts, which contains compounds like alkaloids, flavonoids, and phenols. These products behaves as natural corrosion inhibitors in different media, and thus offer a sustainable and environmentally friendly option to the traditional and inorganic corrosion inhibitors. Typical examples of green inhibitors include extracts from turmeric (Umoren et al., 2024), ginger (Yadav et al., 2024), tamarind (Abdo et al., 2015), Musa paradisiaca peels, Moringa oleifera leaves, and Carica papaya peels (Agarry et al., 2019), psidium guavaja (guava) and moringa oleifera leaves extract (Idenyi et al., 2015), Peronema canescens leaves extract (Maigoda et al., 2022), Citrus macroptera Montruz (Nongalleima et al., 2017), Crocus Sativa (Mir et al., 2016), soybean leaves (Pepe et al., 2024), Citrus paradise (Roghini & Vijayalakshmi, 2018), Robinia pseudoacacia leaves extract (Yüce, 2020), and various other leaves, with their applicability in corrosion inhibition typically evaluated through different techniques. In general, inhibitors are usually grouped into organic or inorganic groups based on their composition and source of origin. The current research and commercial change from use of inorganic and non-degradable products for corrosion inhibition to utilising green inhibitors of plant extracts which are organic, bioactive and biodegradable is as a result of their friendliness to the environment (Agarry et al., 2019; Zeng *et al.*, 2021). Different research groups (Umoren *et al.*, 2024; Agarry *et al*., 2019; El-Hashemy & Almehmadi, 2025) have shown that the potentials of the various parts of plants, including the extracts of leaves will exhibit high potency for corrosion inhibition due to their presence of phytochemicals content (Jabbar *et al.*, 2023).

Corrosion has been generally seen as the process by which metals or mild steel undergo deterioration, degradation, or any form of reduction in value, upon its chemical or electrochemical interaction with its surrounding environment (Jabbar *et al.,* 2023). Such deterioration, degradation, or any form of reduction in value of metals or mild steel is generally influenced by some factors like acids, alkalis, humidity, pH, temperature and salts that are then induce the formation and succession of corrosion in the metals. In the process of cleaning, descaling and pickling of metal surface using acids, the metallic parts undergo mass loss as a result of corrosion. Mild steel have been known to corrode easily in everyday occurences because they are very reactive and mostly oxidises to iron oxide (rust) in the presence of water, oxygen, and free ions (Kadhim *et al.,* 2021). The ability of mild steel to oxidize on slight exposure to the environment imply that that it should be offered serious protection in order to stop self-oxidation and thus retain its aesthetic, structure, quality and design integrity. This is major industrial issue globally. The application of plant extract as corrosion inhibitors is gaining popularity recently because of its cost-effective, eco-friendly, plentiful availability and simplified production techniques. Different plant extracts along with constituent molecules are presented so as to provide insight on their mechanism to prevent the corrosion of mild steel in acid media by different research groups (Idu et al., 2016; Jabbar *et al.,* 2023; Okungbowa *et al.,* 2017; Peter & Sharma, 2017; El-Hashemy & Almehmadi, 2025).

The major aim of this study is to investigate the potentials of extracts of the leaves of *Heinsia crinita* (atama) for corrosion inhibition of mild steel in an acidic medium.

II. Materials And Methods

Materials

For this study, the mild steel was obtained from Scientific Equipment Development Centre (SEDI), Enugu, Nigeria. The composition percentage by weight of the mild steel is: Iron-Fe (98.82), Carbon-C (0.1041), Silicon-Si (0.0441), Manganese-Mn (0.2553), Phosphorus-P (0.0078), Sulphur-S (0.0332), Copper-Cu (0.0482), Cobalt-Co (0.0313), Nickel-Ni (0.2202), Chromium-Cr (0.0518), Molybdenum-Mo (0.0351), Tungsten-W (0.0420), and Titanium-Ti (0.000). The 0.5 M H_2SO_4 electrolyte solution was prepared with 95% analytical grade sulfuric acid (BDH Chemicals) with double distilled water. The leaves of *Heinsia crinita* (atama) was obtained from local forests in Ebonyi State, Nigeria and standard methods was used to get the extracts.

Methodology

The preparation of the green inhibitor from the leaves of *Heinsia crinita* (atama) was done as follows. The leaves of *Heinsia crinita* (atama) was obtained and cleaning was carefully done to remove dust and other unneeded particles. The leaves were further dried in a shadowy area for seven (7) days. Finally, it was crushed into a fine powdered form. A 15 g powder of each of *Heinsia crinita* (atama) was extracted by use of ethanol as a solvent, with a soxhlet apparatus. The experimental set-up was allowed for twenty four hours.

Mild steel sample preparation

The Mild steel coupons were cut into dimensions of 1.55mm x 1.99mm. Polishing of the coupons was done through a sandpaper that contained different grit sizes in order to obtain a smooth surfaced mild steel coupon. Abrasion of the coupons were further done mechanically and in sequential pattern with silicon carbide papers. This helped to get rid of fine metal or dust particles deposited on the surface. The major aim of getting all the coupons abraded are to: i) ensure that the surface of the mild steel coupons are uniform, ii) ensure that weight of the coupons are relatively the same, and iii) limit the influence of rough surfaces on the corrosion monitoring process during the procedure. Following the abrasion process, each sample was degreased one after the other in methanol, further rinsed with acetone, dried in air, and stored at room temperature in the desiccators in order to stop the mild steel coupons from oxidising before the start of the experiment.

Weight Loss Measurements

The leaf extracts of the *Heinsia crinita* (atama) was prepared by changing the concentrations from 10 g/mol to 50 g/mol, where 0 g/mol was used as the control (no inhibitor). To measure the weight loss of the Mild steel coupons, the exposure time was varied between 72 hours to 144 hours. The pre-cleaned and dried Mild steel coupons were weighed before and after being immersed with or without the *Heinsia crinita* (atama) leaf extract at the various concentrations in 0.5 M H_2SO_4 and for the varying immersion times. Different grades of Silicon carbide papers were used to polish the individual mild steel coupons. This was followed with successive washing with distilled water and acetone. Furthermore, the coupons were dried in a moisture-free desiccators. According to the literature (Idenyi *et al.,* 2015), the weight loss data was deduced by using the equations given hereunder.

(1)

(2)

(3)

where $W_0 - W_i = \Delta W$ is weight loss (g), W_0 and W_i is weight loss with and without plant inhibitor, k represents the corrosion constant and was used as 87600 (Olanrewaju & Olaseinde, 2025; Ogunleye *et al*., 2020), D represents the density of coupon (g cm^{-3}), A is the Mild Steel coupon total area (cm^2), θ is the surface coverage and T represents corrosion exposure time (hours).

III. Results And Discussion

Weight Loss Studies

For the different exposure times and different concentration of the *Heinsia crinita* leaves extract on the mild steel coupon in the acidic medium, the Corrosion rate (CR), Surface coverage (θ) and Inhibition efficiency (%) against varying Concentration of *Heinsia crinita leaves extracts* (g/mol) for the respective exposure times are shown as Figure 1 (exposure time of 72 hours) and Figure 2 (exposure time of 144 hours) respectively. The research findings are indicative that there was a tremendous corrosive attack of the mild steel coupon in the acidic environment because the weight loss was maximum when there was no inhibitor (0 g/mol). In a more specific terms, the corrosion rate of the mild steel coupon was 4.2 x 10^{-1} mpy when there was no inhibitor in the medium. Conversely, when the concentration of the green leaves extracts of the *Heinsia crinita was* increased, the corrosion rate, changed drastically to lower values. The reduction in values of the corrosion rate was an indication of the ability of the extracts from the *Heinsia crinita* leaves to prevent the mild steel coupons from corroding. The decrement in the corrosion rate of the mild steel coupon exhibited highest values at the highest concentration of *Heinsia crinita leaves extract*, changing to a very low value of 1.35 x 10^{-1} mpy. The relative gradual and uniform decrement in the Corrosion rate values of the mild steel coupon could be linked to the possible deterioration of the bioactive compounds in the acidic medium over time, especially when the fact that the *Heinsia crinita* leaves extracts inhibitor biological and acidic nature were taken into consideration. Therefore at an exposure time of 72 hours, the corrosion rate decreased with an increase in the concentration of the *Heinsia crinita leaves extracts.* The findings observed herein, is in agreement with the findings on decrease of corrosion rate of mild steel in acidic environment, with increasing concentration of extracts of green leaves as reported by other authors in the literature (El-Hashemy & Almehmadi, 2025).

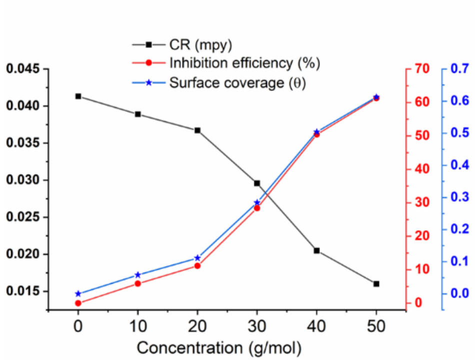

Figure 1. Corrosion Rate (CR), Surface Coverage (Θ) And Inhibition Efficiency (%) Against Varying Concentration Of Heinsia Crinita Leaves Extracts (G/Mol) In 72 Hrs.

Figure 2 gives the plots of the different concentration of the *Heinsia crinita* leaves extract on the mild steel coupon in the acidic medium, indicating the changes in the the Corrosion rate (CR), Surface coverage (θ) and Inhibition efficiency (%) against varying Concentration of *Heinsia crinita leaves extracts* (g/mol). As observed in Figure 1 earlier, the highest value of the corrosion rate was recorded when the *Heinsia crinita leaves extracts* was not included the medium. The corrosion rate was maximum at that test condition with a value of 2.5 x 10^{-2} mpy. As the Concentration of *Heinsia crinita leaves extracts* was increased to 10 g/mol, the corrosion rate was 2.4 x 10^{-2} mpy. When the Concentration of *Heinsia crinita leaves extracts* was increased to 20 g/mol, the corrosion rate was 2.25 x 10^{-2} mpy. Further increase of the Concentration of *Heinsia crinita leaves extracts* to 30 g/mol resulted in a larger decrement of the corrosion rate to 1.6 x 10^{-2} mpy. Additionally, when the Concentration of *Heinsia crinita leaves extracts* was increased to 40 g/mol, the corrosion rate was further reduced to 1.0 x 10^{-2} mpy. Finally, when the Concentration of *Heinsia crinita leaves extracts* was increased to 50 g/mol, the corrosion rate attained a minimum value of 5.0 x 10^{-3} mpy which corresponded to an inhibition efficiency of 50%. These research findings are indicative that the *Heinsia crinita leaves extracts* inhibitor is quite efficient in preventing the mild steel coupons from corroding in the acidic environments, especially at concentrations of 50 g/mol. The *Heinsia crinita leaves extracts* inhibitor exhibited both short-term and long-term corrosion protection potential at all the test concentrations of the *Heinsia crinita leaves extracts* inhibitor. Other authors have reported similar findings in the literature (Yadav *et al.,* 2024; Rahal *et al.,* 2024; Santhi & Sengottuvel, 2016).

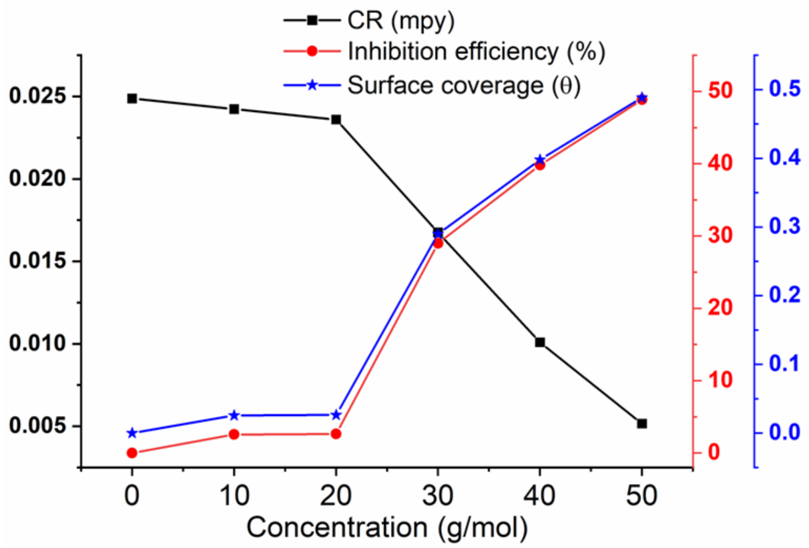

Figure 2. Corrosion Rate (CR), Surface Coverage (Θ) And Inhibition Efficiency (%) Against Varying Concentration Of Heinsia Crinita Leaves Extracts (G/Mol) In 144 Hrs.

Scanning Electron Microscopy Studies

Figure 3 gives a typical SEM micrograph at 50 g/mol Concentration of *Heinsia crinita leaves extracts* (g/mol) in exposure time of 72 hrs. Generally speaking, SEM analysis contributes to better explanation and to understanding of the surface morphology of mild steel coupons under different test environments. A close scrutiny of the SEM micrograph indicates bolder formation with emerging star-like features that are indicative molecular rearrangement during the physical and chemisorptions mechanism.

Figure 4 show the SEM micrograph at 50 g/mol Concentration of *Heinsia crinita leaves extracts* (g/mol) in exposure time of 72 hours show a clear uniform film formation, arising from the increase in the exposure time. The increasing exposure time induced more uniform formation of thin film on the surface of the mild steel coupons thereby offering maximum protection to corrosion on the mild steel coupons. This findings agrees with reports of Bhardwaj, Jaiswal & Kaushik (2024) and that of Maigoda et al (2022) on their studies on the evaluation of Peronema canescens leaves extract: Fourier transform infrared analysis, total phenolic and flavonoid content, antioxidant capacity, and radical scavenger activity. This also agrees with the report of Peter & Sharma, (2017) on the use of Azadirachta indica (AZI) as green corrosion inhibitor against mild steel in acidic medium: Anti-corrosive efficacy and adsorptive behaviour. Additionally, the research of work of Pepe et al (2024) on green corrosion inhibitor for mild steel extracted from soybean leaves also lends credence to the findings in the present investigation.

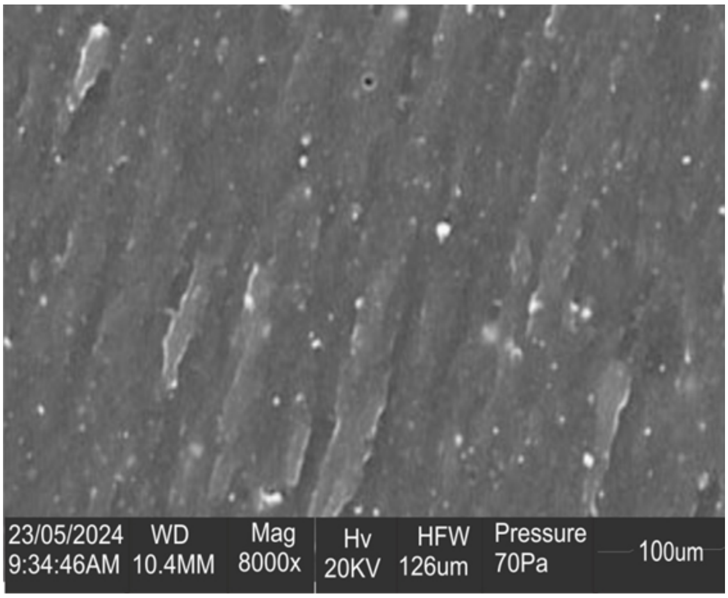

Figure 3. Typical SEM Micrograph At 50 G/Mol Concentration Of Heinsia Crinita Leaves Extracts In 72 Hrs.

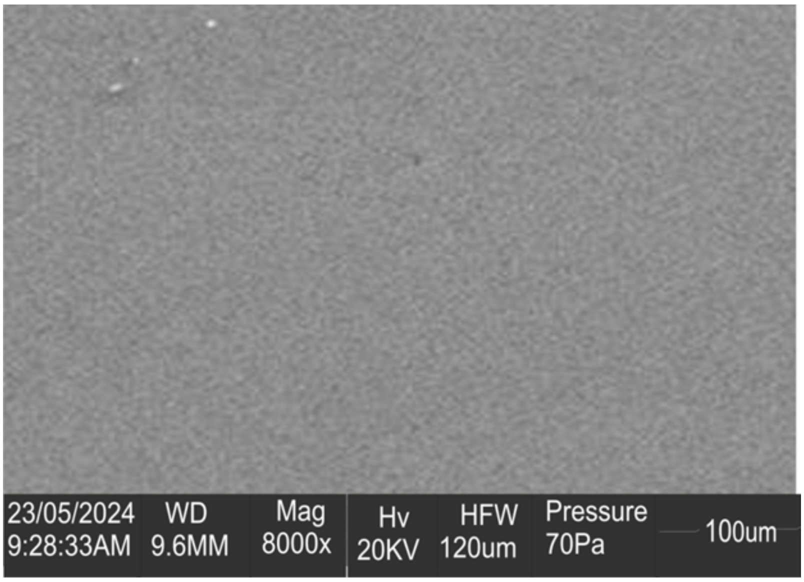

Figure 4. Typical SEM Micrograph At 50 G/Mol Concentration Of Heinsia Crinita Leaves Extracts In 144 Hrs.

X-ray Diffractometry Studies

X-ray diffractometry studies offer a comprehensive and thorough understanding of the structural properties of the material under study. In particular, the phases present in the materials are made manifest through XRD studies. Additionally, the crystallinity, polycrystalline nature or whether the films are amorphous are clearly revealed from the XRD diffractograms. Figure 5 show the XRD diffractogram at 50 g/mol Concentration of *Heinsia crinita leaves extracts* (g/mol) in exposure time of 72 hours while Figure 6 show the XRD diffractogram at 50 g/mol Concentration of *Heinsia crinita leaves extracts* (g/mol) in exposure time of 144 hours. The figures (5 and 6) depicts a near polycrystalline film formation which increased with an increase in the exposure time as indicated in Figure 6. With the increase in the exposure time, the films become more crystalline due to better crystal ordering on the films that formed on the surface of the mild steel coupon and thus acted as a strong barrier to corrosion in the test condition (acidic environment). This resulted to better corrosion rate and improved inhibition efficiency as indicated in Figure 2. Generally speaking, extracts from green plants typically undergo reaction mechanisms such as adsorption to prevent the corrosion of mild steel in any corrosive environment such ac acid, alkaline, water, and salts. Therefore the adsorbed inhibitor molecules from the Concentration of *Heinsia crinita leaves extracts* replaced adsorbed water molecules and other corrosive agents on the surface of the mild steel coupons. To elucidate further, the inhibition mechanism observed in the study was influenced by a number of variables such as the metallic surface charges and the state of natural and/or synthetic organic molecules that emanated from the *Heinsia crinita leaves extracts* which are now present in the acidic medium. The consequences are that the major reaction pathway will be dominated by an adsorption mechanism. The surface of the mild steel coupon in the hydrogen tetraoxosulphate (vi) acid environment is positively charged, and anions (sulphate ions) selectively. This could trigger the formation of excess electron density on the surface of the mild steel coupons due to the contributions of the different adsorbents. This will pave way for cationic particles to be adsorbed on the surface of the mild steel coupons through physical adsorption, resulting to better demonstration of corrosion inhibition capacity by the *Heinsia crinita leaves extracts*. The findings obtained in this study is in line with the reports of other authors including Ogunleye et al (2020), Rahal et al (2024), Olanrewaju & Olaseinde (2025), Salman et al., 2019, Santhi & Sengottuvel (2016), and Zeng et al (2021).

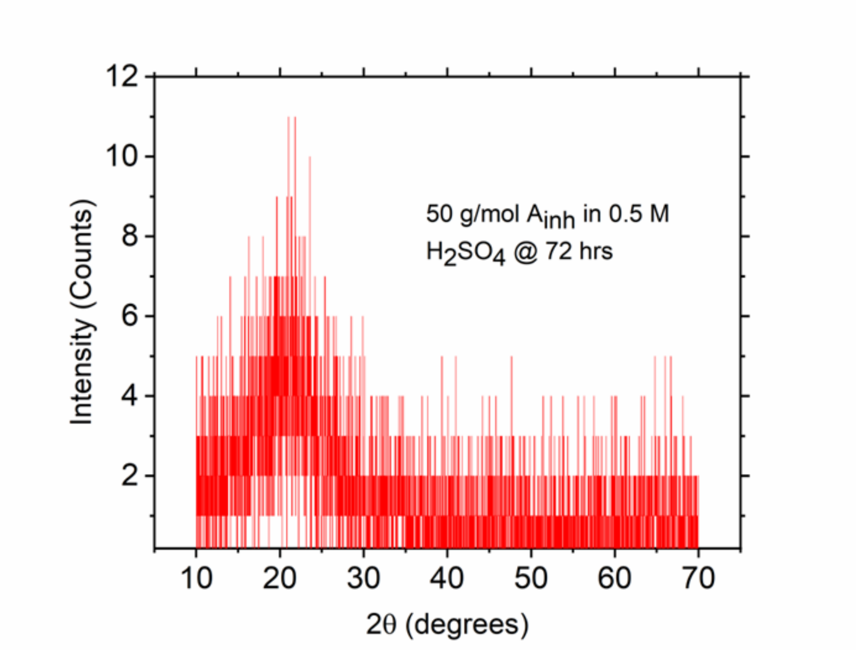

Figure 5. Typical XRD Diffractogram At 50 G/Mol Concentration Of Heinsia Crinita Leaves Extracts In 72 Hrs.

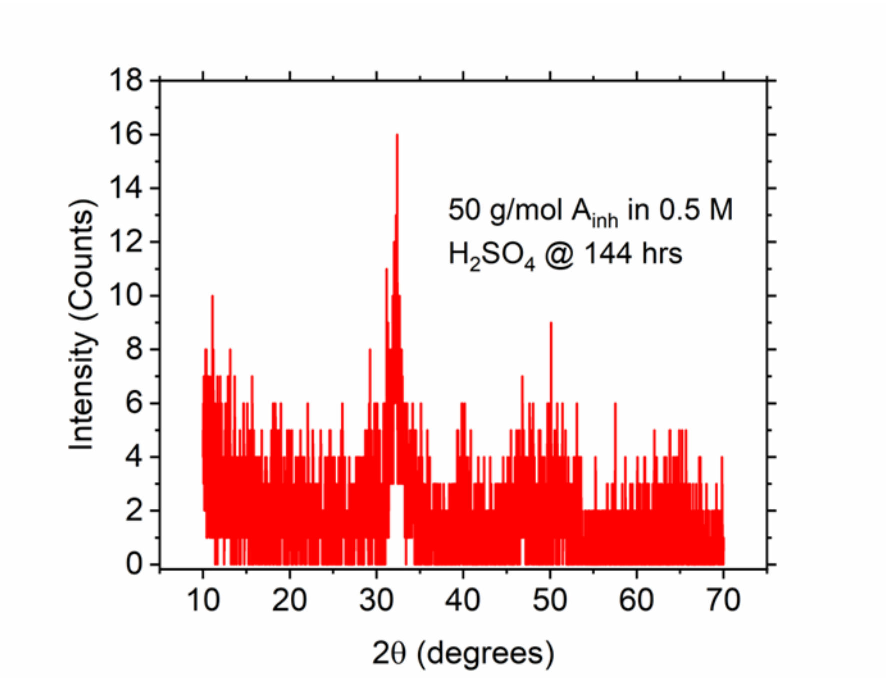

Figure 6. Typical XRD Diffractogram At 50 G/Mol Concentration Of Heinsia Crinita Leaves Extracts In 144 Hrs.

IV. Conclusion

Heinsia crinita leaves extracts was studied for their ability prevent corrosion of mild steel in an acidic environment. Weight loss measurements, SEM study and XRD studies were used for analysis. The research findings indicate that leaf extracts of *Heinsia crinita* (atama) exhibits excellent corrosion inhibition characteristics at the different concentrations of the *Heinsia crinita leaves extracts* irrespective of the exposure times. The inhibition efficiency was between greater than 50% for exposure time of 72 hours and greater than 70% for exposure times of 144 hours. The high values of the inhibition efficiencies are good indication that *Heinsia crinita leaves extracts* can serve as green inhibitor of mild steel in acidic medium and that technology could be scaled up for industrial purposes.

Acknowledgements

The authors would wish to thank the technical staff of the Department of Physics and Astronomy, University of Nigeria Nsukka for performing the characterisations.

Authors' Note

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. Authors confirmed that the data and the paper are free of plagiarism.

References

[1] Abdo, M.O, Aziz, M. & Hasnah, M.S. (2015) Turmeric And Ginger As Green Inhibitors Of Mild Steel Corrosion In Acidic Medium. Journal Of Materials And Environmental Sciences, 6(5), 1480-1487.

[2] Agarry, S. E., Oghenejoboh, K. M., Aworanti, O. A., And Arinkoola, A. O. (2019) Biocorrosion Inhibition Of Mild Steel In Crude Oil-Water Environment Using Extracts Of Musa Paradisiaca Peels, Moringa Oleifera Leaves, And Carica Papaya Peels As Biocidal-Green Inhibitors: Kinetics And Adsorption Studies. Chemical Engineering Communications, 206(1), 98-124.

[3] Bhardwaj, N., Jaiswal, P., & Kaushik, J. (2024). Qualitative And Quantitative Analysis Of The Phytochemicals In Aerva Lanata. Asian Journal Of Research In Chemistry, 17(3), 149-155.

[4] El-Hashemy, M. A., & Almehmadi, A. M. (2025). Evaluation Of Glebionis Coronaria L. Flower Extract As A Novel Green Inhibitor For Mild Steel Corrosion In Acidic Environment. Biomass Conversion And Biorefinery, 15(1), 1121-1137.

[5] Idenyi, N. E., Nwofe, P. A., Agbo, P. E., And Idu, H. K. (2015). Effects Of Psidium Guavaja (Guava) And Moringa Oleifera Leaves Extract On The Corrosion Susceptibility Of Mild Steel In An Acidic Medium. Australian Journal Of Basic And Applied Sciences, 9(35), 245-250.

[6] Idu, H. K., Nwofe, P. A., & Idenyi, N. E. (2016). Investigations On The Inhibitive Properties Of Moringa Oleifera And Psiduim Quajava Leaves Extract On The Corrosion Susceptibility Of Mild Steel. American-Eurasian Journal Of Scientific Research, 11(2), 119-124.

[7] Jabbar, A. A., Abdulrahman, K. K., Abdulsamad, P., Mojarrad, S., Mehmetçik, G., And Sardar, A. S. (2023). Phytochemical Profile, Antioxidant, Enzyme Inhibitory And Acute Toxicity Activity Of Astragalus Bruguieri. Baghdad Science Journal, 20(1), 0157-0157.

[8] Kadhim, A., Betti, N., Al-Bahrani, H. A., Al-Ghezi, M. K. S., Gaaz, T., Kadhum, A. H., & Alamiery, A. (2021). A Mini Review On Corrosion, Inhibitors And Mechanism Types Of Mild Steel Inhibition In An Acidic Environment. International Journal Of Corrosion And Scale Inhibition, 10(3), 861-884.

[9] Kale, S. (2020). Screening Of Phytochemical Components Of Leaf Extracts. Int. J. Curr. Microbiol. Appl. Sci, 9, 2394-2401.

[10] Maigoda, T., Judiono, J., Purkon, D. B., Haerussana, A. N. E. M., & Mulyo, G. P. E. (2022). Evaluation Of Peronema Canescens Leaves Extract: Fourier Transform Infrared Analysis, Total Phenolic And Flavonoid Content, Antioxidant Capacity, And Radical Scavenger Activity. Open Access Macedonian Journal Of Medical Sciences, 10(A), 117-124.

[11] Mir, M. A., Parihar, K., Tabasum, U., & Kumari, E. J. J. M. P. S. (2016). Estimation Of Alkaloid, Saponin And Flavonoid, Content In Various Extracts Of Crocus Sativa. Journal Of Medicinal Plants Studies, 4(5), 171-174.

[12] Nongalleima, K., Ajungla, T., Singh, C. B., Chingakham, C., & Singh, B. (2017). Phytochemical, Total Phenolic, Total Flavonoid And Total Flavonols Content Estimation In Citrus Macroptera Montruz. J. Med. Plants Stud, 5(3), 114-211.

[13] Okungbowa, A. I., Okugbo, O. T., And Ezekiel-Hart, O. W. (2017). Comparative Phytochemical And In Vitro Antioxidant Analysis Of Some Indigenous Plants. BIU Journal Of Basic And Applied Sciences, 3(1), 41-51.

[14] Pepe, A., Tito, F. R., Mandri, A. D., Dommarco, R. C., & Pepe, A. (2024). Green Corrosion Inhibitor For Mild Steel Extracted From Soybean Leaves. Chemical Engineering Communications, 211(5), 697-706.

[15] Peter, A., & Sharma, S. K. (2017). Use Of Azadirachta Indica (AZI) As Green Corrosion Inhibitor Against Mild Steel In Acidic Medium: Anti-Corrosive Efficacy And Adsorptive Behaviour. International Journal Of Corrosion And Scale Inhibition, 6(2), 112-131.

[16] Roghini, R., & Vijayalakshmi, K. (2018). Phytochemical Screening, Quantitative Analysis Of Flavonoids And Minerals In Ethanolic Extract Of Citrus Paradisi. International Journal Of Pharmaceutical Sciences And Research, 9(11), 4859-4864.

[17] Olanrewaju, O. F., & Olaseinde, O. A. (2025). Biosynthesis Of Silver And Zinc Nanoparticles And Their Corrosion Inhibitory Properties On API 5 L Steels, 316 ASS, And 2101 DSS In 0.5 M H_2SO_4 And 1 M Hcl. Progress In Engineering Science, 100049.

[18] Ogunleye, O. O., Arinkoola, A. O., Alagbe, S. O., Agbede, O. O., Omodele, A. E., Morakinyo, A. F., & Osho, Y. A. (2020). Synthesis Of Green Corrosion Inhibitor For Mild Steel In Acidic Environment. Indian Chemical Engineer, 62(1), 52-66.

[19] Rahal, H. T., Abdel-Gaber, A. M., El-Rifai, M. S., & El-Housseiny, S. (2024). The Potential Of Natural Leaf Extracts As Green Inhibitors For Mild Steel Corrosion In Hydrochloric Acid Solutions. Moroccan Journal Of Chemistry, 12(4), 1554-1574.

[20] Salman, T. A., Jawad, Q. A., Hussain, M. A. M., Al-Amiery, A. A., Mohamed, L., Kadhum, A. A. H., & Takriff, M. S. (2019). Novel Ecofriendly Corrosion Inhibition Of Mild Steel In Strong Acid Environment: Adsorption Studies And Thermal Effects. International Journal Of Corrosion And Scale Inhibition, 8(4), 1123-1137.

[21] Santhi, K., & Sengottuvel, R. (2016). Qualitative And Quantitative Phytochemical Analysis Of Moringa Concanensis Nimmo. International Journal Of Current Microbiology And Applied Sciences, 5(1), 633-640.

[22] Thacker, H., & Ram, V. (2025). Green Corrosion Inhibitors Derived From Plant Extracts And Drugs For Mild Steel In Acid Media: A Review. Results In Surfaces And Interfaces, 18, 100364.

[23] Umoren, P. S., Kavaz, D., Nzila, A., Sankaran, S. S., & Umoren, S. A. (2024). Assessment Of Olive Leaf Extract–Mediated Chitosan–Silver Nanocomposites As Antibacterial And Biocorrosion Mitigation Agents. Cellulose, 31(3), 1705-1727.

[24] Yadav, O. S., Chaudhary, R., & Gupta, A. (2024). Synthesis Of Green Inhibitor For Mild Steel Corrosion In A Sulphuric Acid Medium. Portugaliae Electrochim. Acta, 42(5), 355-373.

[25] Yüce, A. O. (2020). Corrosion Inhibition Behavior Of Robinia Pseudoacacia Leaves Extract As A Eco-Friendly Inhibitor On Mild Steel In Acidic Media. Metals And Materials International, 26(4), 456-466.

[26] Zeng, X., Zheng, X., Guo, L., Xu, Q., Huang, H., & Tan, B. (2021). Three Imidazole Ionic Liquids As Green And Eco-Friendly Corrosion Inhibitors For Mild Steel In Sulfuric Acid Medium. Journal Of Molecular Liquids, 324, 115063.