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Investigating the Effect of *Lasienthera africanum* Extract as Mild Steel Corrosion Inhibitor in 0.5 M HCl Solution

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ABSTRACT

The use of inorganic and synthetic organic compounds as corrosion inhibitors is becoming less prevalent due to environmental concerns. The use of environmentally friendly compounds is currently the focus of the majority of corrosion mitigation research. In this study a weight loss gravimetric technique was used to analyse the inhibitive effect of leaf extract from Lasienthera africanum against mild steel corrosion in hydrochloric acid solution. The inhibitor concentrations used were 20, 40, 60, 80 and 100 ppm in hydrochloric acid concentration of 0.5 M. The extract was shown to have a 98.6% inhibitory effectiveness in inhibiting the corrosion of mild steel coupons in acid environments, making it an excellent corrosion inhibitor against steel dissolution. It was revealed that the inhibitor efficiency increased as the inhibitor concentration increased, It was also shown that the weight loss decreased with an increase in inhibitor concentration. Scanning electron microscopy showed that as the concentration of Lasienthera africanum extract increased, the corroding system maintained a surface morphology generally devoid of micro-cracks on the test materials. Therefore, Lasienthera africanum leaf extract, with an inhibition efficiency of 98.6% on mild steel can be recommended for use in high acidic environment.

1. INTRODUCTION

Mild steel is applied in a broad range of applications, including the manufacturing, automotive, and oil and gas industry. Some of the reasons for the extensive utilization of these materials include their ductility, durability and excellent weldability, and low cost (Ahmad, 2006). One drawback of mild steel is that it is prone to corrosion, which causes aesthetic faults and loss of its mechanical properties (Okuma et al., 2021).

Metal corrosion is a disruptive and reactive electrochemical process. Metal corrosion management has received considerable attention in recent years (Aslam et al., 2020; Okuma et al., 2020). General corrosion is the most damaging cause of mild steel degradation; as a result, the steel requires ongoing maintenance, repairs, and replacement, resulting in massive overhead and operational cost (Aminu, 2015). In the industry, hydrochloric acid is the most commonly used acid for pickling, cleaning, and descaling (Fernando *et al.,* 2014*)*. This acid solution is also utilized in acidification process in the oil and gas industry.

There are varieties of corrosion control techniques in widespread usage, comprising material selection, modifications in design philosophy, and the employment of various preventive measures. The addition of inhibitors to processing liquids to reduce the rate of metal corrosion is relatively common in many industrial activities. The compounds present in the extract, according to Alvarez et al. (2018), are capable of removing scales, dirt, and mild rust from metal surfaces. To prevent metal surfaces from corrosion, inorganic inhibitors have been widely used (Zhang et al., 2012; Markhali et al., 2013). However, these inhibitors are harmful, costly, and have environmental effects (Goni and Mazumder, 2019). Alternative sources, such as natural products, plant extracts, and other environmentally friendly organic sources, have been widely reported (Sharma et al., 2015).

Previous research has revealed that plant extracts have excellent compounds for suppressing metal electrolyte reactions (El-Etre, 1998, 2003, 2006; Ebenso et al., 2004; Ibrahim *et al*., 2012; Zhang *et al*., 2012; Mourya *et al*., 2014). Several plant extracts, including *Carica papaya, Rosmarinus officinalis, Damsissa, Murrayakoenigii, cashew, mango, Uncariagambir*, and *Fiscusycomorus* extracts, have been studied (Ebenso and Ekpe, 1996; Kliskic et al., 2000; Abdel-Graber et al., 2006; Ashish and Quraishi, 2010; Da Rocha et al., 2010; Hussain and Kassim, 2011; Ogwo et al., 2017; Ogunleye et al., 2018; Okuma and Onyekwere, 2022). According to Helen et al. (2014), these plants have sufficient cyclic organic phytochemicals, nitrogen, sulfur, and oxygen atoms, which are responsible for their inhibitory characteristics. Many difficulties exist in the large-scale synthesis of diverse natural plant extracts. The most important of them is the extraction of certain plant extract components having inhibitory properties. Nonetheless, numerous natural plant extracts have been shown to be effective corrosion inhibitors (Ji et al., 2011; Kamal and Sethuraman, 2012; Yaro et al., 2013).

This research seeks to evaluate the use of *Lasienthera africanum* extracts for corrosion prevention and control by evaluating its corrosion preventive characteristics on mild steel in 0.5 M HCl solution. *Lasienthera africanum* is a low erect or subscandent, vigorous shrub with stout recurved prickles and a strong odour of black currants. This plant is found primarily in the humid tropical forest regions of Central African Republic, Cameroon, Gabon It is typically found in Nigeria's southern regions (Cross River and Akwa Ibom) and is employed in the preparation of particular specialties (editan soup).This plant is a very common, available and priceless plant in Southern Nigeria. In the present work, *Lasienthera africanum plant* (LA) was first extracted and then evaluated as a corrosion inhibitor for mild steel in HCl.

2. MATERIALS AND METHODS

2.1. Materials Collection and Preparation

A mild steel sheet was cut into rectangular pieces with approximate length, width, and thickness dimensions of 1.8 cm, 0.9 cm, and 0.3 cm, respectively. It had a chemical composition (wt.%) of 0.05% S, 0.04% P, 0.8% Mn, 0.16% C, and 98.95% Fe. For the weight loss investigation, a mild steel specimen of the requisite size was employed. The strips were manually polished with emery sheets rated 220, 320, 400, 600, 800, and 1000 before being completely cleaned with distilled water, degreased with acetone, and dried in air before immersion in the corrosive solution. The *Lasienthera africanum* leaves were sourced from Effurun market in Delta State, Nigeria. The leaves were washed, oven dried at 90 °C for 4 hours, then crushed using an electric blender. The powdered leaves were weighed and steeped in 250 ml of ethanol for 48 hours. The solution was then filtered to get the extract. To eliminate extra ethanol, the filtrates were treated in saucepan to evaporation at 352 K. The extract was made at volumetric concentrations of 20, 40, 60, 80, and 100 ppm per 200 ml of acid solution. The corrosion test medium was a 0.5 M HCl solution of analytical grade.

2.2. Coupon Measurement

Samples were immersed in 200 ml of 0.5M HCl solution and weighed every 48 hours for total period of 288 hours .Equation (1) was used to calculate the corrosion rate (C) (mm/y).

$$C = \frac{87.6w}{DAt} \quad (1)$$

where w represents weight loss (g), D represents density (g/cm^3), A represents visible surface area of mild steel specimen (cm^2), 87.6 represents corrosion rate constant, and t represents duration of the experiment in (hr).Inhibition efficiency η (%) was obtained from Equation (2).

$$\acute{\eta} = \frac{W1-W2}{W1}\times 100 \quad (2)$$

where w_1 and w_2 represents weight loss of samples at predetermined *Lasienthera africanum* concentrations.

2.3. Characterization Tests

2.3.1. Phytochemical screening

The quantitative tests were carried out using standard methods of analysis of alkaloids, flavonoids, tannins and saponins (Olawale, 2007).

Test for alkaloids: 1 cm^3 of 1% HCl was added to 3 cl of the extract in a test tube. Each extract was treated with few drops of Meyer's reagent. The appearance of a creamy white precipitate was taken as an indication of the presence of alkaloids.

Test for flavonoids: 2 cm^3 of the extract was heated with 10 cm^3 of ethyl acetate in a water bath and cooled. The layers where allowed to separate. The appearance of a red-coloured layer was taken as an indication of the presence of flavonoids.

Test for tannins: To test for presence of tannins, about 1cm^3 of the extract was dissolved in distilled water and about 10 ml of bromine water added. Decolourization of bromine water was taken as an indication of the presence of tannins.

Test for saponins: 1 cm^3 solution of extract was diluted with distilled water to 20 ml and shaken in a graduated cylinder for 15 minutes. Frothing was taken as an indication of the presence of saponins.

2.3.2. SEM analysis

Scanning electron microscope analysis was used to evaluate the morphology of the surface of the uninhibited and inhibited sample of mild steel using Jeol JSM-7600F UHR Analytical FEG SEM machine.

3. RESULTS AND DISCUSSION

3.1. Phytochemical Screening of *Lasienthera africanum* Leaves

The phytochemical screening of extract of *Lasienthera africanum leaves* is presented in Table 1. The result obtained shows that alkaloids, tannins, saponins and flavonoids were present in the extract of *Lasienthera africanum.*

Table 1: Qualitative phytochemical analysis in *Lasienthera africanum* extract

Phytochemical	Occurrence
Alkaloids	++
Tannins	++
Flavonoids	++
Sapnnins	++

++ = Present in appreciable quantity

3.2. Effects of *Lasienthera africanum* Extract on Mild Steel Corrosion

Figure 1 shows the variations in weight loss with time for mild steel in 0.5 M hydrochloric acid solution (with and without) *Lasienthera africanum* extract. Weight losses for systems using *Lasienthera africanum* extract were observed to decrease compared to systems containing no inhibitor. The Figure shows that the rate of weight loss for sample increases drastically when no inhibitor was use between the first 50 to 148 hrs. Also, the Figure shows that weight losses decreased as the extract concentration increased. This might be attributed to the fact that the strength of the bond between the inhibitor molecules and the metal surface increased thereby providing a better inhibition efficiency (Adam et al., 2016).

Figure 2 shows the inhibitory efficiency of the extract for mild steel at different concentrations. The plot shows that inhibition effectiveness increased with increasing concentration of extract but decreased slightly with increasing exposure time. At the optimal concentration of 100 ppm, the inhibition efficiency was 98.6% demonstrating *Lasienthera africanum*'s inhibitive properties in mitigating the effect of mild steel corrosion in HCl medium. As a result, increasing the inhibitor concentrations enhanced the adsorption of the inhibitor molecules on the metal surface, hence slowing the weight loss of mild steel coupons. Okuma and Onyekwere, (2022) observed the same trend in their evaluation of the corrosion inhibitive properties of *Irvingia gabonensis* extract.

The effect of exposure time on the corrosion of mild at different concentrations of *Lasienthera africanum* extract is shown in Figure 3. The plot indicates that corrosion rate increased with increase in exposure time but decreased with increasing concentrations of the inhibitor. However, throughout the exposure period, corrosion rate was higher for uninhibited mild steel than the inhibited ones. The decrease in corrosion rate for inhibited acid solutions compared to the uninhibited suggests retarding effect of *Lasienthera africanum* extract on the corrosion of mild steel (Onyeka and Nwambekwe, 2007). The findings in this study reaffirm the earlier investigation carried out by Akinfaloye, (2021).

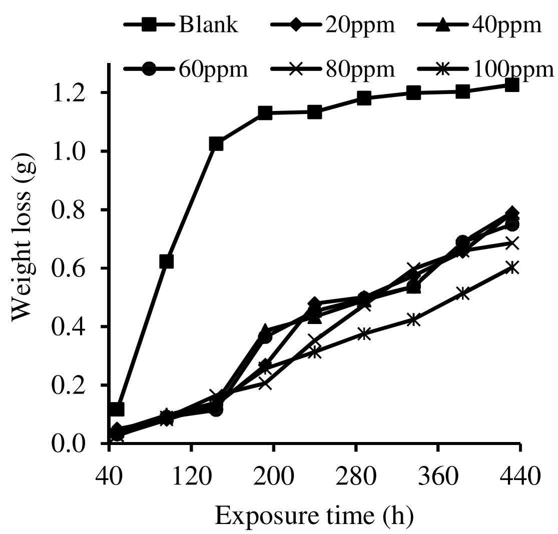

Figure 1: Plot of weight loss against time at different extract concentration

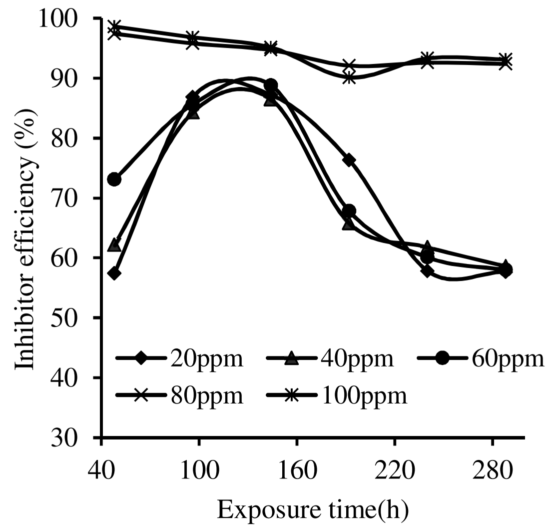

Figure 2: Plot of inhibition efficiency against time at different extract concentration

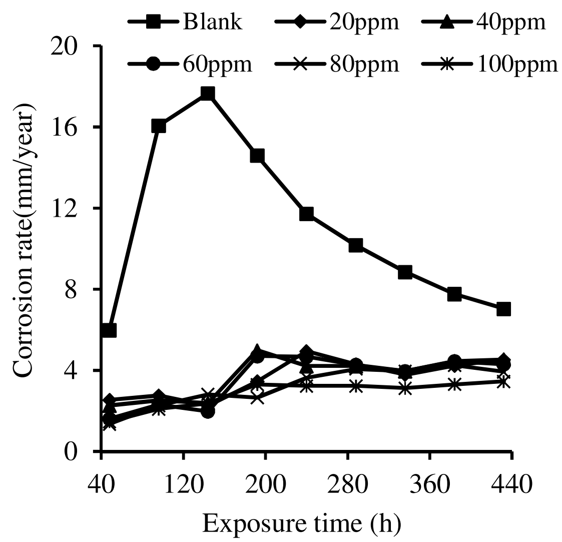

Figure 3: Plot of corrosion rate against time at different extract concentration

3.3. Optical Microscopy Analysis

Figure 4 (a-d) depicts the surface characteristics of polished mild steel immersed in 0.5 M HCl without inhibitor (blank), and the mild steel immersed in 0.5 M HCl for 12 days in the presence of 20 ppm, 60 ppm, and 100 ppm of *Lasienthera africanum* extract concentration at 60 ^{o}C. The formation of porous layers full of micro cracks was seen in the SEM image of the mild steel coupon before immersion in the 0.5 M HCl solution containing no inhibitor (Figure 4a). As a result, the chemical compounds in the extract have an easy time permeating the steel and corroding the coupon. However, in the presence of inhibitor (Figure 4b, c and d), the mild steel surface smoothness was significantly improved. It is also less porous, with relatively few micro-cracks, indicating a lower rate of corrosion. The creation of a protective layer on the metal's surface by the extract resulted in an improvement in surface morphology. As a result of the surface study, the extract

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has a significant potential to adsorb on the mild steel surface and may be considered a suitable inhibitor for mild steel corrosion in acidic medium.

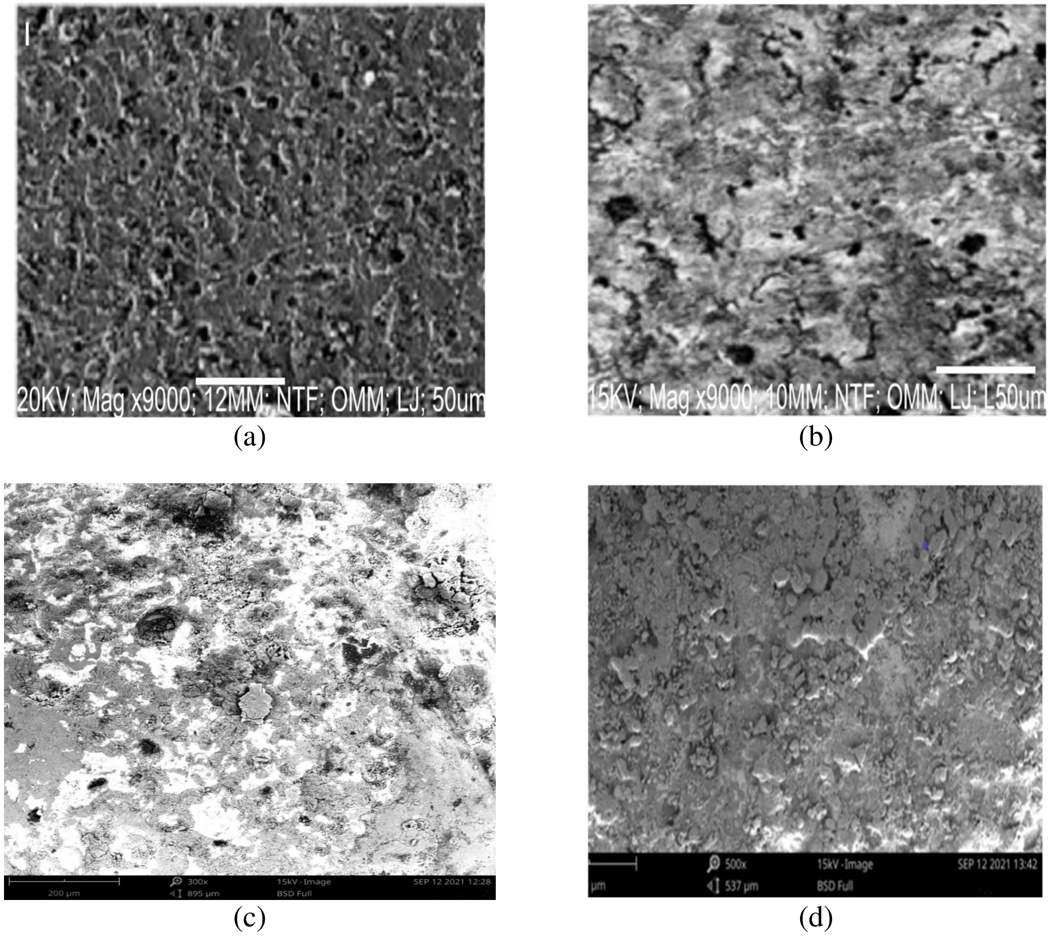

Figure 4: Surface morphology of mild steel in (a) blank 0.5 M HCl solution (b) 0.5 M HCl/20 ppm *Lasienthera africanum* extract (c) 0.5 M HCl/60ppm*Lasienthera africanum* extract and (d) 0.5 M HCl/100 ppm *Lasienthera africanum* extract

4. CONCLUSION

The weight loss and surface analyses were used to examine the potential of *Lasienthera africanum* extract as a green corrosion inhibitor in this study. According to phytochemical tests, the extract demonstrated good mild steel inhibition in 0.5 M HCl solution due to the presence of tannins, saponnins, flavonoids, and alkaloids. With higher inhibitor concentrations, the inhibition efficiency improved. The extract was shown to be a good inhibitor at a concentration of 100 ppm, with a 98.6% efficiency. The SEM examination revealed that when the concentration of *Lasienthera africanum* extract increased. The corroding system maintained a surface morphology with less micro-crack. Therefore, *Lasienthera africanum* leaf extract, with an inhibition efficiency of 98.6% on mild steel can be recommended for use in high acidic environment.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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