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Determination of Corrosion Inhibiting Efficiency of Gmelina Leave on Mild Steel with Respect to Exposure Time

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ABSTRACT

Corrosion of mild steel in acidic environments poses significant challenges in various industries, leading to material failure and economic losses. This study investigates the corrosion inhibiting efficiency of Gmelina arborea leaf extract on mild steel in an acidic environment over varying immersion periods. The research measured the corrosion rates at exposure times of 200, 250, 300, 350, and 400 hours. In the absence of the inhibitor, corrosion rates were observed to be 1.081 mm/yr, 1.100 mm/yr, 1.598 mm/yr, 1.819 mm/yr, and 1.954 mm/yr, respectively. However, in the presence of the Gmelina arborea extract, the corrosion rates were significantly reduced to 0.142 mm/yr, 0.192 mm/yr, 0.289 mm/yr, 0.497 mm/yr, and 0.686 mm/yr, respectively. These findings underscore the extract's potential as an effective green corrosion inhibitor, demonstrating its capability to mitigate steel degradation over prolonged exposure periods. This study contributes to the development of sustainable and environmentally friendly corrosion prevention strategies.

Keywords: Gmelina, Inhibiting Efficiency, Corrosion, Mild Steel, Exposure time.

INTRODUCTION

Corrosion is a significant challenge in industries utilizing metallic materials, particularly in aggressive environments such as acidic solutions. The search for environmentally friendly and cost-effective corrosion inhibitors has gained momentum in recent years. Green inhibitors derived from plant extracts, such as Gmelina arborea, have shown potential as sustainable alternatives to synthetic inhibitors due to their abundance, biodegradability, and non-toxic nature. Gmelina arborea contains phytochemicals like tannins, flavonoids, and alkaloids, which can adsorb onto metal surfaces to mitigate corrosion (Sharma et al., 2020). Several researchers has studied on the effect of plant extracts on metal alloy. Oguzie, 2008 investigated the inhibitive properties of plant extracts on mild steel in acidic media and reported that their effectiveness is attributed to the presence of organic compounds with heteroatoms like oxygen, nitrogen, and sulfur. He explored plant extracts as potential corrosion inhibitors for mild steel in acidic solutions. Extracts showed significant inhibition efficiency, attributed to adsorption of organic compounds containing heteroatoms. Umoren, et al., 2011 highlighted the use of natural polymers and plant-based materials as sustainable corrosion inhibitors for metals in aggressive environments. The result signifies that green inhibitors formed protective barriers on metal surfaces, reducing corrosion rates. Okafor, et al., 2008 explored the inhibition efficiency of plant extracts, emphasizing the importance of flavonoids and

alkaloids in corrosion prevention. They evaluated the inhibition efficiency of different plant extracts on mild steel, and discovered that these extracts demonstrated high efficiency in reducing corrosion. Sharma, et al., 2020 conducted a review on green inhibitors and highlighted Gmelina arborea's potential due to its high content of bioactive compounds. These analysis highlighted Gmelina arborea for its bioactive compounds like tannins and flavonoids, which contributed to effective corrosion inhibition. Ekpe, et al., 1994 demonstrated the effectiveness of leaves and seeds of plants in reducing corrosion rates of metals in acidic solutions. Metal specimens and aqueous plant extract solutions were used and the result showed that plant-based inhibitors reduced corrosion rates in acidic solutions, demonstrating environmental compatibility. Abiola, et al., 2007 studied the adsorption characteristics of plant extracts on metal surfaces and their impact on corrosion inhibition efficiency. Adsorption was consistent with Langmuir isotherms, forming a protective film on the metal. Soltani, et al., 2013 focused on the mechanisms of adsorption of green inhibitors and their role in forming protective layers on metal surfaces. Adsorption was predominantly chemisorption, leading to effective inhibition. Verma, et al., 2017 investigated corrosion inhibition by plant extracts and discussed the role of pH and concentration on inhibition efficiency. Corrosion inhibition increased with extract concentration but decreased in highly acidic environments. Mejeha, et al., 2010 examined the synergistic effects of plant-based inhibitors when combined with other substances in controlling corrosion. Synergistic combinations enhanced inhibition efficiency significantly. El-Etre, 1998 pioneered the study of natural honey as a corrosion inhibitor, which paved the way for further research into plant-based alternatives. Honey effectively reduced corrosion rates, opening avenues for plant-based inhibitor research. This study therefore evaluates the corrosion inhibiting efficiency of Gmelina arborea leaf extract on mild steel at varying immersion periods in acidic media, contributing to the growing body of research on green corrosion inhibitors.

METHODS

The experiment was conducted at Nnamdi Azikwe University's Pure and Industrial Chemistry Department Laboratory in Awka, Anambra state. To conduct this study, the following resources were used: specimens of mild steel (C 0.08 wt%, Si = 0.05 wt%, P = 1.00 wt%, Cu = 0.02 wt%, Pb = 0.02 wt%, and Fe = 98.83 wt%) with 20 x 20 x 1.5mm in size; fresh leaves of Gmelina arborea; 16 liters of distilled water, 40 beakers, a ceramic crucible, a conical flask, filter paper, suspension threads, a pH meter, plastic sticks for thread suspension, digital weighing scale, and analytical-grade hydrochloric acid and ethanol (absolute) are all required.

Preparation of Mild Steel Specimen

The specimens had dimensions of 20 x 20 x 1.5 mm and were cut from a mild steel sheet. Rough emery paper was used to clean, polish, and cut the steel samples into the appropriate sizes.

Preparation of Gmelina Leaves Extract

Gmelina leaves were gathered in the vicinity of Ogidi in Anambra state, Nigeria. The fresh gmelina leaves were harvested for their branches. They underwent crushing, drying, and washing. It was crushed and then steeped for a whole day in an ethanol solution. A filtrate was obtained by sieving the resultant solution. To eliminate ethanol from the juice extract and concentrate it, the filtrate was concentrated in a water bath set at 80°C. Before being used, the slurry extract was kept in a sterile bottle with a tight-fitting lid.

Figure 1: Gmelina leaves after crushing and soaked in ethanol.

Preparation of the Environment (Hydrochloric Acid)

Using distilled water as a diluent, analytical grade concentrated HCl was used to create HCl solutions with concentrations ranging from 0.47 to 2.39 moldm-³. The beakers that were used in this experiment were cleaned and rinsed properly.

Setting up of the Distilled Water

After measuring out 250 milliliters of the distilled water, it was added to the beakers. After that, each beaker was stored and labeled according to its weight, pH, acid concentration, and number of days.

Experimental Set-Up

There were two groups of beakers. In the first, HCL with varying initial weights was used, and in the second, 6ml of Gmelina extract was added to HCl with varying initial weights. The experiment lasted for two hundred hours. For the duration, the uniformly sized, polished, and pre-weighed mild steel specimens were suspended in their corresponding test solutions.

Measurement

Prior to the mild steel samples being submerged in the test solutions, the pH values of the solutions were measured and noted. Prior to the mild steel being submerged, the pH was 1.25; upon its removal, it was 0.46. The mild steel specimen's starting and ending weights were noted. Following the measurement of each specimen's final weight, the weight loss that was observed was computed. The specimen's appearance, geometry, and surrounding environmental changes were all closely observed. After being taken out of their various corrosive environments, the specimens were cleaned with distilled water, dried, and weighed. Weight losses that corresponded with this were measured and recorded. (Emekwisia, et al., 2024).

RESULTS AND DISCUSSION

The results of the weight loss were carefully observed and discussed below.

Weight Loss

This is the variation in weight across predetermined time periods. For convenience, the weight loss (g) of the mild steel specimen in the corrosive environment for each setup is tabulated.

$$\text{Weight loss (g)} = W_i(g) - W_f(g)$$

Where, W_i = Initial weight of the mild steel specimen.

W_f = Final weight of the mild steel specimen.

Corrosion Rate Calculation

The corrosion rate is calculated as follows:

Corrosion Rate, $C_R = \left(\frac{K\Delta W}{TPA}\right)(mm/yr)$.

Where, k = Constant = 87.6;

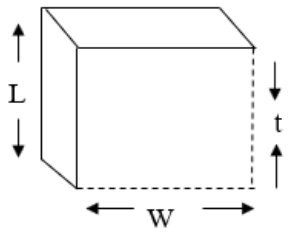
W = Weight loss = $W_{i(g)}$- $W_{f(g)}$ (Calculated below)

T = Time of Exposure (calculated below)

P = Density of mild steel = 7.85g/cm^3

K = Constant = 87.6

A = Surface Area of the mild steel sample exposed to corrosion = 2LW + 2Lt + 2Wt = 2(20 x 20) + 2(20 x 1.5) + 2(20 x 1.5) = 920mm^2



Where,
L = Length = 20mm
W = Width = 20mm
t = thickness = 1.5mm

Time of Exposure,

For T = 200 hours, (200/8760)yr.= 0.023yr.

For T = 250 hours, (250/8760)yr.= 0.029yr.

For T = 300 hours, (300/8760)yr.= 0.034yr.

For T = 350 hours, (350/8760)yr.=0.040yr.

For T = 400 hours, (400/8760)yr.= 0.046yr.

Table 1: The weight loss and corrosion rate of mild steel specimen in HCL with variation in exposure time in the absence of Gmelina arborea inhibitor.

Exposure time in hours.	Exposure time in year	Initial weight W_i(g)	Final weight W_f (g)	Weight loss W(g)	Corrosion rate (mm/yr)
200	0.023	21.530	19.480	2.050	1.081
250	0.029	21.530	18.900	2.630	1.100
300	0.034	21.530	17.050	4.480	1.598
350	0.040	21.530	15.530	6.000	1.819
400	0.046	21.530	14.120	7.410	1.954

Table 2: The weight loss and corrosion rate of mild steel specimen in HCL with variation in exposure time in the presence of Gmelina arborea inhibitor.

Exposure time (hours)	Exposure time in year	Initial weight W_i(g)	Final weight W_f (g)	Weight loss W(g)	Corrosion rate (mm/yr)
200	0.023	21.530	21.260	0.270	0.142
250	0.029	21.530	21.070	0.460	0.192
300	0.034	21.530	20.72	0.810	0.289
350	0.040	21.530	19.89	1.640	0.497
400	0.046	21.530	18.93	2.600	0.686

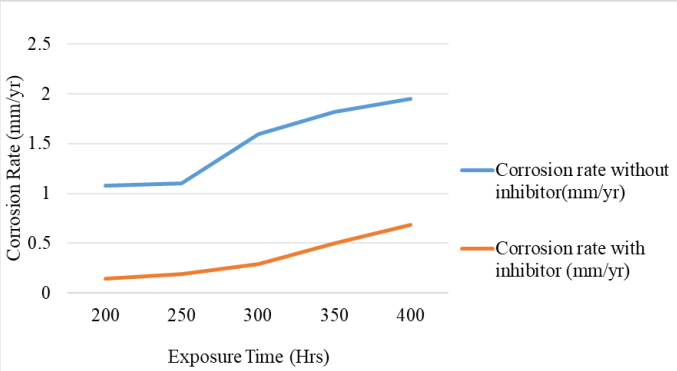


Figure 2: Graph of Corrosion Rate Against Exposure Time.

From the results obtained in table 1 and 2, and figure 2 above, the study showed the effectiveness of Gmelina arborea leaf extract as a corrosion inhibitor for mild steel in an acidic medium over different immersion periods. Without the inhibitor, the corrosion rate increases progressively with immersion time, indicating the aggressive nature of the acidic environment on the steel surface. For instance, the corrosion rate rises from 1.081 mm/yr at 200 hours to 1.954 mm/yr at 400 hours. This trend is expected due to prolonged exposure, which allows the acidic medium to attack the steel more effectively. Conversely, the presence of Gmelina arborea extract significantly reduces the corrosion rate at all exposure times. At 200 hours, the corrosion rate decreases to 0.142 mm/yr., and at 400 hours, it is 0.686 mm/yr. This reduction demonstrates the extract's effectiveness as a green inhibitor, likely due to its phytochemical constituents (such as tannins, flavonoids, and alkaloids), which adsorb onto the steel surface and form a protective barrier against corrosion.

Percentage Inhibition Efficiency

The percentage inhibition efficiency can be calculated using the formula:

$$\text{Percentage Inhibition Efficiency (IE)} = \frac{CR_{\text{without inhibitor}} - CR_{\text{with inhibitor}}}{CR_{\text{without inhibitor}}} \times 100$$

Table 3: Percentage inhibition efficiency in relation to corrosion rate.

Exposure Time or Immersion Period (Hours)	Corrosion Rate (mm/yr) Without Inhibitor	Corrosion Rate (mm/yr) With Inhibitor	Percentage Inhibition Efficiency (%)
200	1.081	0.142	86.87
250	1.100	0.192	82.55
300	1.598	0.289	81.91
350	1.819	0.497	72.68
400	1.954	0.686	64.91

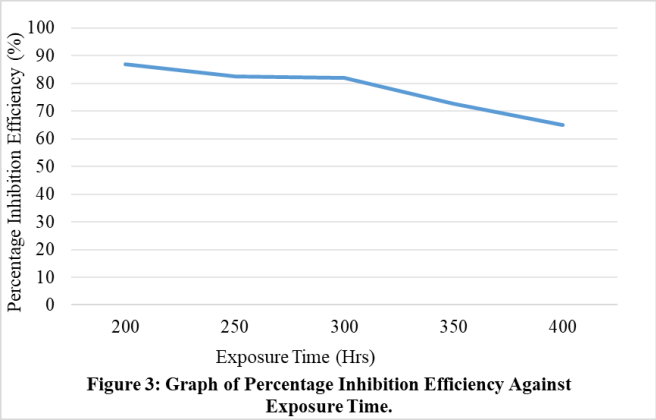


Figure 3: Graph of Percentage Inhibition Efficiency Against Exposure Time.

The inhibition efficiency shows a declining trend with increasing immersion periods, as shown in table 3 and figure 3 above. This reduction in efficiency can be attributed to desorption of the inhibitor molecules over time, degradation of the protective film, or insufficient inhibitor concentration to sustain complete surface coverage during prolonged exposure. Nevertheless, the Gmelina arborea extract remains highly effective, achieving more than 60% inhibition efficiency even at 400 hours. This therefore highlight the extract's potential as a sustainable and eco-friendly corrosion inhibitor for mild steel, making it a promising alternative to synthetic inhibitors.

Microstructural Analysis

The micrograph (figure 4) of mild steel with the highest exposure time of 400hours in the presence of gmelina inhibitor was observed. The result is shown below,

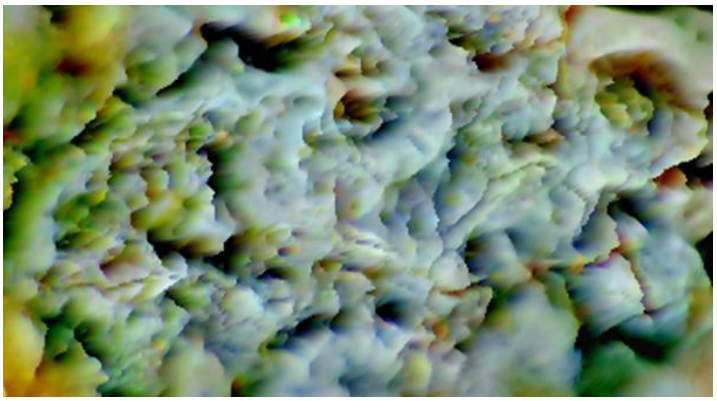


Figure 4: Mild steel at 400hours exposure time with inhibitor

CONCLUSION

The effectiveness of Gmelina arborea leaf extract as a corrosion inhibitor for mild steel in acidic environments over varying exposure time (immersion periods) was demonstrated in this study. The results revealed a significant reduction in corrosion rates when the inhibitor was present, compared to the uninhibited conditions. Without the inhibitor, the corrosion rate progressively increased with immersion time, rising from 1.081 mm/yr at 200 hours to 1.954 mm/yr at 400 hours. This trend underscores the aggressive nature of the acidic medium, which accelerates

metal degradation over time. In the presence of the Gmelina arborea extract, the corrosion rates were significantly reduced, with values ranging from 0.142 mm/yr at 200 hours to 0.686 mm/yr at 400 hours. The inhibitor's performance was quantified through inhibition efficiency, which remained above 60% across all immersion periods and peaked at 86.87% at 200 hours. The observed reduction in corrosion rates is attributed to the adsorption of bioactive compounds, such as tannins, flavonoids, and alkaloids, present in the extract. These compounds form a protective layer on the metal surface, mitigating the corrosive effects of the acidic medium. However, the inhibition efficiency exhibited a gradual decline with increasing immersion time, decreasing from 86.87% at 200 hours to 64.91% at 400 hours. This decline may result from desorption of inhibitor molecules, degradation of the protective film over time, or insufficient concentration of the inhibitor to maintain effective surface coverage during extended exposure. These findings therefore confirm that Gmelina arborea extract is a highly effective green corrosion inhibitor, providing an eco-friendly and sustainable alternative to synthetic inhibitors. It holds potential for industrial applications, particularly in environments where mild steel is exposed to acidic conditions. Future research should focus on optimizing the extract's concentration, enhancing its long-term stability, and exploring its performance in other corrosive environments to expand its applicability.

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