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The Inhibitory Effect of Ethanolic Extract of *Newbouldia Laevis* Leaf on the Corrosion of High Carbon Steel in 1M Sulphuric Acid (H_2SO_4)

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***Abstract*:- Corrosion processes have been connected to several catastrophes and losses in the processing, manufacturing, and oil and gas industries. Chemical inhibitors can be used to combat failures caused by metals' inability to fulfill designed load requirements due to corrosion losses. Chemical inhibitors, despite their effectiveness, are connected with toxicity, environmental issues, litigation, and exorbitant expenses. Green inhibitors as substitutes and replacements for chemical inhibitors have grown popular as a way to protect the environment, humans and save money. The effects of ethanol extracts of Newbouldia Laevis leaf on high carbon steel samples corroded in 1M sulphuric acid solution in the absence and presence of various doses of the extracts were investigated in this study. Weight loss data was collected every 4 hours for a total of 20 hours, at inhibitor concentrations of 0.1 g/L and 0.5 g/L, respectively, the leaf extract had the lowest (0.1g/L) and maximum (0.5g/L) inhibitory efficiency, with 88 percent and 93 percent respectively at 20 hours.**

Keywords: Concentration, Ethanol, Green corrosion inhibitors, Newbouldia Laevi, Weight loss method.

1. INTRODUCTION

Sulphuric acid solution is extensively used in metalworking processes to remove unwanted scale and rust, as well as to clean boilers and heat exchangers (Adejo, Ekwenchi &, 2010a). Inhibitors are frequently used to prevent metal dissolution and acid consumption during these operations. Corrosion-induced metal depletion has become a critical technical issue. Perhaps no other source of waste is of greater concern to all than that which disrupts human life. It has been argued that the only way to cut the cost of living and boost our level of living is to eliminate corrosion-related waste and increase national efficiency. Waste removal is a comprehensive asset that has no liabilities (Ating, Umoren, Udousoro, Ebenso & Udoh, 2010; Adejo, Ekwenchi, Odiniya, Acholo, & Banke, 2010b; Adejo, Ekwenchi, & Banke, 2010c). Corrosion studies may provide insight into its dynamics, allowing for the prediction of equipment service life and showing the environmental control for which a certain metal is suitable (Oguzie, Okolue, Ebenso, Onuoha & Onuchukwu, 1994; Obot, & Obi-Egbedi, 2008).

Corrosion of materials has gotten a lot of attention in the technological world, because its effects on material structural integrity have been a hot topic for a long time. In mechanical engineering and transportation, metallic materials are still the most commonly exploited materials. Metals are also frequently used in industries such as processing, manufacturing, oil and gas, and increasingly in the construction industry. (Buchweishaija, 2009). However, corrosion, a common concern, restricts the use of metals and their alloys. As a result, since the late-eighteenth-century industrial revolution, it has been intensively explored. (Sato, 2012). Corrosion is a natural occurrence that occurs when metal surfaces corrode as a result of chemical reactions with the environment. (Buchweishaija, 2009). Corrosion may cause disaster on metal and their alloys, and on structural integrity, resulting in expensive repairs, replacements, product losses, safety concerns, and contamination of the environment. Because of these detrimental implications, corrosion is an undesirable phenomenon that should be avoided.

Scientists are relentless in their pursuit of new and more effective ways to combat metal corrosion. There are several techniques to avoid corrosion and the rates at which it may spread in order to improve the lifetime of metallic and alloy materials. (Buchweishaija, 2009). Hunag and Chen (2012) emphasize the use of corrosion-resistant metal alloys, cathodic and anodic protection, protective coatings (Stack, 2002), and the inclusion of corrosion inhibitors to the corrosion environment as methods for preventing and managing corrosion (Papavinasam, 2000). One of the most common corrosion control methods is the use of inhibitors. It is one of the established approaches for decreasing and/or preventing corrosion because of its simplicity. The majority of corrosion inhibitors are heterocyclic compounds including oxygen, sulphur, and nitrogen as heteroatoms. (Kumar et al, 2009).

In order to be effective, an inhibitor must convey water away from the metal surface, interact with anodic and cathodic reaction sites to limit the oxidation and reduction corrosion process, and prevent water and corrosion-active species from being transferred onto the metal surface. (Maqsood, 2011). The acknowledged hazards of synthetic organic inhibitors (Popova et al., 2007; Li, et al., 2009), as well as a desire to develop low-cost, non-toxic, and environmentally acceptable processes, have led researchers to focus on natural compounds. (Umoren et al., 2008; Umoren & Ebenso, 2008; El-Etre, 2008). Plants have long been recognized as natural substances having a wide range of physical, chemical, and biological properties, some of which have extremely complex molecular structures (Buchweishaija, 2009). As a result, the current study was

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conducted to assess the effect of Newbouldia laevis leaf extracts on the corrosion inhibition of high carbon steel in 1M sulphuric acid solutions, with the goal of contributing to the search for other beneficial uses of plant extract. The examination was conducted using gravimetric method.

1.1 Importance of Green Inhibitors

The progressive weakening of metals and alloys caused by the action of air gases, moisture, and other chemicals is known as corrosion. When corrosion inhibitor is applied to a little amount of water, the rate at which it spreads enhances the life of metallic materials, effectively extending the life of the metal exposed to that water. Different plant extracts, often known as green corrosion inhibitors, can be employed as corrosion inhibitors to prevent metal from corroding. Naturally produced chemicals can be found in plants.

The majority of naturally occurring substances are used because they are environmentally friendly, cost effective, and readily available. Some have complicated molecular structures, as well as chemical, biological, and physical properties. Inhibitors are added to corrosive media in low concentrations to postpone the reaction between the metal and the corrosive ingredients in the medium.

Corrosion inhibitors must have the following properties:

1. Ability to reduce corrosion rate
2. The corrosion inhibitor's active principle must come into touch with the metal.
3. There must be no negative side effects.

1.2 Review of Related Work

Steel and its alloys are used in the process, manufacturing, oil and gas. They corrode due to their surroundings and are affected by a variety of elements such as metal composition, temperature, and the presence of corrosive gases such as sulphur dioxide, hydrogen chloride, chlorine, and other corrosive gases. Some investigations have been undertaken on the corrosion inhibitor potentials of various plant extracts, also known as "green inhibitors." To reduce the rate of metal corrosion in a chemical environment, it is advised to use a green corrosion inhibitor, the presence of heteroatoms such as N, O, P, and S can improve the adsorption of an inhibitor. Following the disruption of the protective barrier, corrosion processes occur quickly and are accompanied by a number of reactions that alter the composition and properties of both the metal surface and the surrounding environment, such as the formation of oxides, metal diffusion into the coating matrix, local pH changes, and electrochemical potential.

The study of carbon steel corrosion is a topic of great theoretical and practical relevance, and as a result, it has generated a lot of interest. Acid solutions, which are commonly employed in industrial acid cleaning, acid descaling, acid pickling, and oil well acidizing, necessitate the addition of corrosion inhibitors to prevent corrosion of metallic components.

In light of numerous green corrosion inhibitors, the current study is pursuing the following goals:

1. To see how effective *Newbouldia Laevis* leaf extracts are as corrosion inhibitor.
2. The creation of a protective coating on the metal surface.

Various pieces of literature based on these concerns were researched in order to conduct this investigation. There are a number of worldwide and national publications on this issue, and after reviewing the journals, several corrosion concerns were uncovered. A rundown of some literatures connected to this topic is included in the following text.

Odiongenyi, (2015) investigated the use of the gravimetric method to study the suppression of zinc corrosion in HCl solution. The results showed that at 333 and 303 K, ethanol extract of honey (EEH) had lowest and maximum inhibitory efficiencies of 30.57 percent and 72.01 percent, respectively. In general, the extract's inhibitory efficacy increases with increasing concentration but decreases with rising temperature. The mechanism of physical adsorption was upheld for the adsorption of honey on mild steel surface based on the range of values obtained for the activation energy, the pattern of variation of the extract's inhibition efficiency with temperature, and the range of values obtained for standard free energy of adsorption.

The efficacy of an aqueous extract of Thyme leaves as a mild steel corrosion inhibitor in 2M HCl was evaluated utilizing weight loss measurements and several electrochemical techniques. The efficiency of corrosion inhibition improves with the content of Thyme leaves extract, according to the results of the experiments. In 2M HCl, 84 percent corrosion inhibition efficiency was attained. Thyme leaves extract serves as a mixed inhibitor, according to polarization experiments. The adsorption of Thyme leaves extract on the steel surface follows the Langmuir adsorption isotherm, according to the results (Ibrahim, Alayan, & Al Mowaqet, 2012).

The effect of Black tea extract (BTE) as a green inhibitor on the corrosion behavior of mild steel in 1.0M HCl, 1.0M H_2SO_4 and 35g/l NaCl was investigated using potentiodynamic polarization techniques such as open–circuit potential, linear polarization resistance, and Tafel plots polarization. It was discovered that BTE inhibits both anodic and cathodic slopes in Tafel polarization, indicating that the inhibitor used is a mixed type inhibitor. Scanning electron microscopy was also used to investigate the surface morphology of MS samples without and with the inhibitor (Mahross, 2014).

In the presence and absence of Xanthium Strumarium leaves (XSL) extracts as a friendly corrosion inhibitor, corrosion inhibition of low carbon steel in 1M HCl was examined. Weight loss was used to investigate the effects of temperature and inhibitor concentration. The findings revealed that Xanthium Strumarium leaf extracts function as a corrosion inhibitor for low carbon steel in HCl and minimize the rate of corrosion. The efficiency of inhibition was observed to rise as the inhibitor concentration and temperature were increased. At higher levels of inhibitor concentration and temperature, the inhibition efficiency was 94.82 percent. The Langmuir adsorption isotherm model was discovered to govern the adsorption of Xanthium Strumarium leaf extracts. Adsorption free energy values were greater than -20 kJ/mol, indicating a mixed

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mechanism of physical and chemical adsorption (Khadom, Abd, & Ahmed, 2018).

The aqueous extract of Aloysia citrodora leaves (Ac.L) was chosen as a mild steel (MS) inhibitor in this study against a 1 M HCl media. The results of electrochemical impedance spectroscopy (EIS) showed that in the presence of 800 ppm Ac.L extract and 2.5-hour immersion duration, MS corrosion was significantly slowed by 94 percent inhibition. Polarization tests were used to examine the kinetics of corrosion retardation, and the results revealed that the contents of Aloysia citrodora leaves extract may inhibit corrosion reactions via a cathodic/anodic (mixed) inhibitory mechanism. The results of the surface investigation revealed the usefulness of Aloysia citrodora leaf extracts in preventing MS surface damage. Along with the electrochemical/surface tests, extensive theoretical investigations using Monte Carlo (MC)/molecular dynamics (MD) and quantum chemical density functional theory (DFT) computations ensured phytochemical binding on the target metallic substrate (Dehghani, Bahlakeh, Ramezanzadeh, & Ramezanzadeh, 2020).

2 MATERIALS AND METHOD

2.1. *Newbouldia Laevis* Leaf Preparations

Newbouldia Laevis Leaves were harvested in Aba, Abia State, Nigeria's eastern region, in November of 2021. Before being utilized to manufacture the extract, the leaves were air-dried for 30 days at room temperature in the laboratory. With ethanol as the extraction solvent, the extraction was carried out using the reflux technique for 3 hours at constant heat (70 °C). The extract is then diluted into various concentrations: 0.1, 0.2, 0.3, 0.4, and 0.5 g/L using 1M H_2SO_4 solution as the corrosive media, according to Nnanna et al., (2012).

2.2. Metal Preparations

The experiment used a high carbon steel (HCS) sample of grade (C-1345) with the following chemical composition: C = 0.85 percent, Mn = 1.71 percent, Si = 3.94 percent, Cr = 0.88 percent, Ti = 0.29 percent, Co = 0.68 percent, Cu = 0.07 percent, Mo = 0.68 percent, and Fe = 91.76 percent. The metal sheets were cut into 20 x 20 x 4mm coupons, abraded with several grades of emery paper (120, 600, and 1200), washed with soap, degreased in ethanol, and air dried before being weighed.

2.3. Gravimetric Method

Different test solutions were applied to the pre-weighed coupons. The experiment was carried out at room temperature with different concentrations of the inhibitor (*Newbouldia Laevis* Leave extracts) (0.1g/L to 0.5g/L). The coupons were retrieved after a 4 to 20 hours exposure period at interval of 4 hours, and the corrosion reaction was quenched by dipping in nitric acid, then into water to wash off the nitric acid, then into ethanol to remove the water, and finally into acetone to dry the test piece quickly so that corrosion would not begin before it could be reweighed. The weight loss was decided. The technique was repeated, and an average result was calculated.

3. RESULTS AND DISCUSSION

Below are the results of the weight loss experiment.

Table 1: Weight loss measurements for high carbon steel in 1 M sulphuric acid in the absence and presence of *Newbouldia Laevis* leaves extract.

Below are the results of the gravimetric experiment employing *Newbouldia Laevis* leaf as inhibitor for high carbon steel?

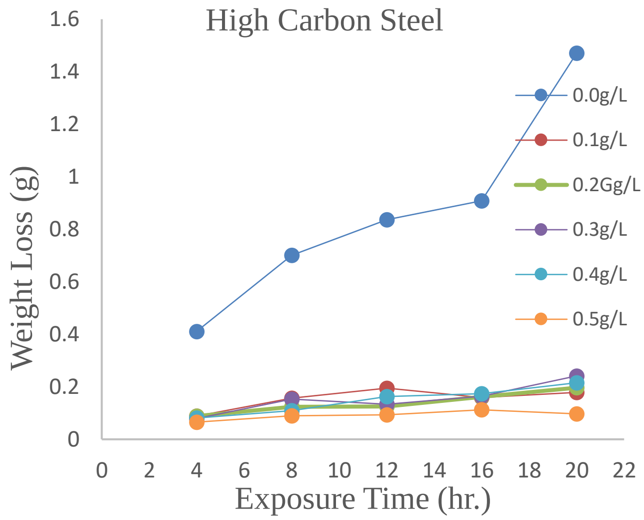

Figure 1: Plot of Weight Loss (g) versus Exposure Time (t)

Figure 1 depicts the corrosion of HCS in 1.0M H_2SO_4 in the absence and presence of various concentrations of Newbouldia Laevis leaf extract as a function of weight loss versus exposure time in the absence and presence of different concentrations of *Newbouldia Laevis* leaf extract. As seen in the graphs, the rate of weight loss in the controlled environment (1.0M H_2SO_4) increased consistently over time, although there was a substantial loss between 16 and 20 hours, indicating that the HCS was succumbing to corrosion. When the inhibitor leaf extracts were administered, weight loss dropped and stayed steady until around 16 hours, when it increased slightly, indicating that the inhibitor concentration was decreasing.

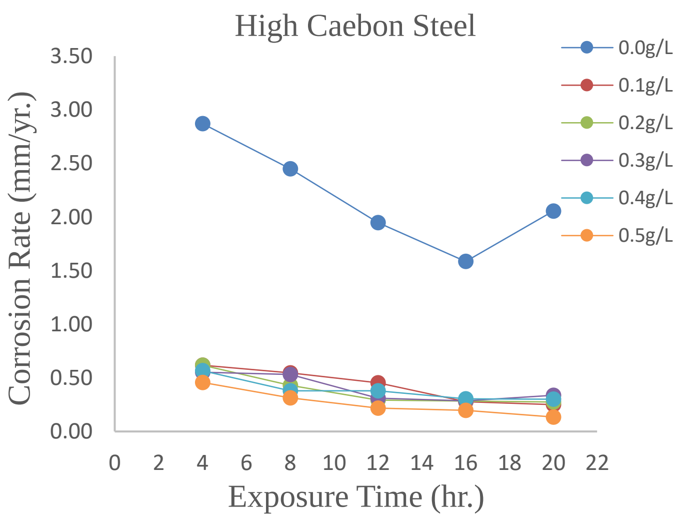

Figure 2: Plot of Corrosion Rate (mm/yr) (for control + various concentrations) versus Exposure Time (hr.)

The graph in figure 2 shows the trend of high carbon steel corrosion rate over time in the presence (control experiment) and absence (experiment) of *Newbouldia Laevis* leaf extract. The control curve shows that for the first 16 hours, there was resistance to corrosion due to the formation of a protective layer of film on the test piece's surface, which delayed the rate of corrosion. After 16 to 20 hours, the test piece succumbed to further corrosion, suggesting that the protective covering had completely gone. After the injection of various concentrations of Newbouldia Laevis Leaf extracts, the corrosion decreased dramatically and remained on a downward trend for all concentrations (0.1 to 0.5g/L), suggesting that the test piece was protected against degradation. Corrosion rates (control + various concentrations) versus exposure time are plotted.

The inhibited corrosion curves also show that the corrosion rate dropped steadily from 0 to 16 hours at a concentration of 0.1g/L, suggesting that the leaf has created a protective layer on the test piece's surface, limiting the mass transfer of charges in the corrosive environment. At 16 hours, the 0.1g/L concentration of leaf extracts had the best corrosion rate. Between 16 and 20 hours, there was a little increase, indicating that the 0.1g/L concentration is weakening and succumbing to corrosion.

The corrosion rate of 0.2g/L was gradually decreasing from 0 to 16 hours, although there was a little increase between 16 and 20 hours, indicating that the concentration of leaf extract in the corrosive media was depleting. Corrosion rate decreased from 0 to 16 hours at a concentration of 0.3g/L, but increased between 8 and 12 hours. Concentrations of 0.4g/L followed the same pattern as 0.3g/L. From 0 to 20 hours, the concentration of 0.5g/L showed a continuous declining trend, indicating that the leaf extract is still active.

The graph depicts the inhibitory impact of *Newbouldia Laevis* leaf extract on acidic corrosion of HCS.

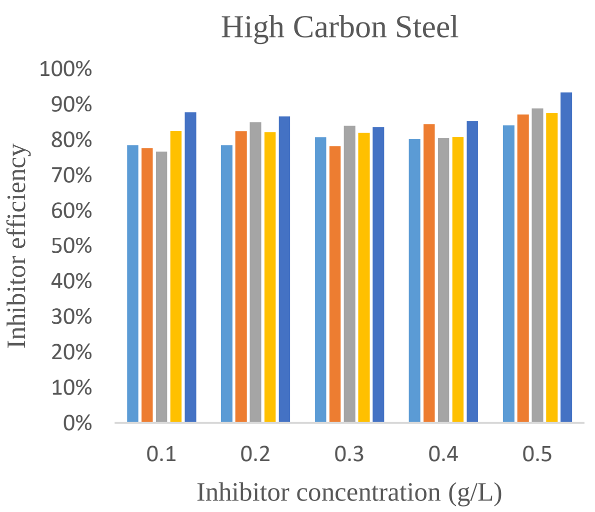

Figure 3: Efficiency (%) versus Inhibitor concentration (g/L)

In Figure 3, the inhibitory efficacy of the inhibitor is plotted against the concentration of the plant extract, demonstrating that *Newbouldia laevis* leaf extract is a potent sulphuric acid corrosion inhibitor for HCS. As the inhibitor concentration was increased, the efficiency of inhibition improved.

The plot below shows the behavioural pattern of corrosion rates when the HCS specimen was dipped into different concentrations of *Newbouldia Laevis* leaf extract

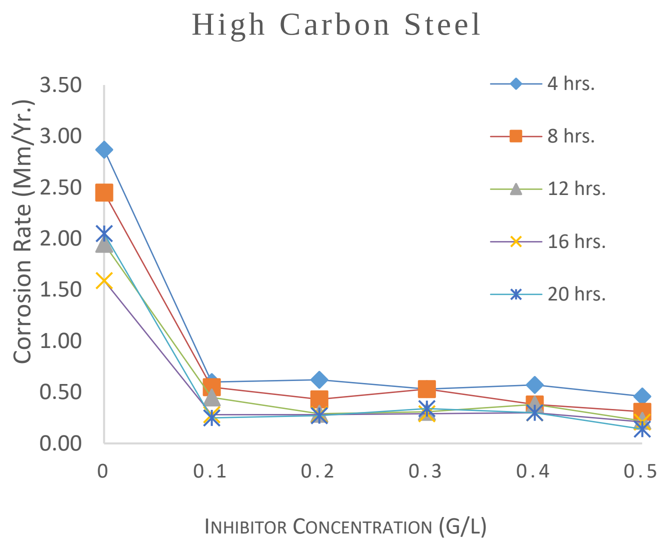

Figure 4: Plot of Corrosion Rate (mm/yr) versus Inhibition Concentration (g/L)

In Figure 4, the inhibitory efficacy of the inhibitor is plotted against the concentration of the plant extract, demonstrating that *Newbouldia laevis* leaf extract is a potent sulphuric acid corrosion inhibitor for HCS. As the inhibitor concentration was increased, the efficiency of inhibition improved.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The following conclusion may be formed based on the evidence acquired during the investigation into the inhibitive abilities of *Newbouldia laevis* Leaf extract on the Corrosion of High Carbon Steel in Sulphuric Acid:

i. Ethanolic extract of Newbouldia laevis Leaf is an eco-friendly green inhibitor for high carbon steel in 1 M H_2SO_4 solutions and can be used instead of dangerous chemicals.

ii. The gravimetric method reveals aggressive deterioration of the high carbon steel coupon immersed in the corrosive environment in the absence of *Newbouldia laevis* leaf extract in 1M of H_2SO_4 solution; the corrosion rate and weight loss increase dramatically, indicating that the active site of the test piece was bare to acid attack.

iii. The weight loss measurement revealed that adding *Newbouldia laevis* leaf extract to a 1M H_2SO_4 solution decreases the corrosion rate of high carbon steel in the acid. The efficiency of inhibition improves as the concentration of plant extracts increases; the maximum inhibition efficiency was 93 percent.

iv. When plant extracts were injected, the metal was protected from corrosion by adsorption of the extracts' component on the metal surface, providing

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a barrier for charge and mass transfer, making the metal less vulnerable to corrosion response.

v. The results reveal that *Newbouldia laevis* leaf extract is an excellent sulphuric acid (H_2SO_4) corrosion inhibitor for high carbon steel.

4.2 Recommendations

Following are some suggestions for further research based on the knowledge gathered throughout this study.

i. The researcher suggests that commercial cultivation of *Newbouldia laevis* trees be encouraged because of their great inhibitory efficacy. They can slow down corrosion by acting as inhibitors. Additionally, they are both human and environmental friendly.

ii. A study of *Newbouldia laevis* leaf extracts' inhibitory characteristics on high carbon steel in 2 moles of sodium chloride (NaCl).

iii. To see how temperature affects the effectiveness of *Newbouldia laevis* leaf extracts as a medium carbon steel corrosion inhibitor in corrosive acid conditions.

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