INVESTIGATION INTO THE EFFECTIVENESS OF NEEM LEAF EXTRACT AS CORROSION INHIBITOR FOR MILD STEEL IN HCL SOLUTION

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ABSTRACT

This research work presented the account of experimental investigation into the effectiveness of Neem (Azadirachta Indica) leaf extract as corrosion inhibitor for mild steel in 0.5M HCL solution. The mild steel (0.2%C) was cut and machined into twenty five (25) cylindrical corrosion coupons of 2cm diameter and 1cm height. Each of the coupons was immersed in 0.5M HCL solution containing varying inhibitor concentrations of 0, 0.1, 0.3, 0.7, and 1.0%v/v for an interval of 4 days, 8 days, 12 days, 16 days and 20 days respectively. Weight loss method was used to determine the corrosion rate and the inhibitor efficiency for each coupon within the specified period of interaction with corrosive medium. The mechanism of inhibition was adsorption where the adsorbed molecules of the inhibitor lie on the surface of the metal thereby blocking the active corrosion site on the steel against corrosion. It was found that within the experimental period, the adsorption of Neem leaf could reduce the corrosion of the steel in the 0.5M HCL solution and also the percentage inhibition increased with increase in the concentration of the inhibitor. Inhibitor with concentration of 1.0%v/v gave the lowest corrosion rate of 37.02 mils per year and the corresponding highest inhibition efficiency of 65.1%. The neem leaf extract, to some degree, was found to be effective for inhibiting corrosion in mild steel in corrosive environment.

KEYWORDS: Neem leaf; Corrosion inhibitor; Mild steel; Corrosion rate; Adsorption.

1.0 INTRODUCTION

Most engineering materials interact with large number of environments with consequent of impairing some of their mechanical and physical properties respectively. In metallic materials, especially ferrous types, the deteriorative mechanism is actual material loss either by dissolution or by the formation of non metallic scales or films on the surface (Kakani, 2004). One of the metallic ferrous materials that account for a large percentage of metals used for diverse applications in construction and other industries is mild steel. When in contact with the environment
it tends to convert to its pre-extraction state. The conversion process is faster and complex if the environment is very aggressive and contains some radicals such as sulphides, nitrides, chloride, etc. Machines and process equipment made of ferrous materials often deteriorate and ultimately strive to produce hydrated oxide known as rust as a result of corrosion (Idenyi and Nzife, 2005).

Corrosion is the gradual destruction of material, usually metals, by chemical or electrochemical reaction with its environment. The adverse effects of these reactions are enormous and include reduction in the strength, stiffness, ductility, brittleness, toughness, malleability and hardness (i.e. mechanical properties) of the material and in some cases lead to failure and total collapse of structure which may cause loss of life and capital among others.

Many structural alloys corrode merely from exposure to moisture in air, but the process can be strongly affected by exposure to certain substances such as dilute hydrochloric acid (HCl). HCL solution is extensively used for different purposes in various types of industries to clean steels, remove dirt on metal surface, for pickling operation to remove scales on steel surface and for improvement of heat transfer efficiency of equipment.

Since corrosion due to HCL in these units represent a significant portion of production cost due to loss of production and inefficient operations, it becomes imperative to exhibit the corrosion since the usage of the HCl solution on those operations cannot be ignored or changed for economic reasons.

Corrosion is usually prevented or minimized by different methods and ways. The use of inhibitors is one of the many methods especially in flow cooling system. Organic, inorganic or a mixture of both inhibitors can inhibit corrosion by either adsorption or by chemisorptions on the metal surface or reacting in the metal ions and forming a barrier-type precipitate on the surface (Al-Sehaibani, 2000). The chemicals currently used to inhibit corrosion in metals are toxic and dangerous to health in addition to their high costs. Sequel to that, there is the need to source an alternative to the traditional inorganic corrosion inhibitors such as chromates and lead for economic and health purposes.

Many researchers at different times have exhibited corrosion of metals by using the aqueous extract from different plants such as Henna (lawsonia inermis) by Al-Sehaibani (2000), date palm (Phoenix dactylifera) by Farooqi (1999) and Carica papaya by Okafor and Ebenso (2007) among others. The current study seeks to investigate the effectiveness of neem leaf extract as corrosion inhibitor for mild steel in HCL solution. The outcome of the work would no doubt add to the knowledge of corrosion inhibition processes of mild steels in acidic or moist environments and thus cushion some of the adverse effects associated with the use of traditional corrosion inhibitors.

Neem tree is remarkable both for its chemical and for its biological properties. It is one of the richest sources of secondary metabolites in nature. To date, more than 300 natural products have been identified from different parts of neem tree with new compounds added to the list every year. A number of them have been shown to have insect antifeedant, insect growth regulatory, antifungal, antimalarial and antiviral properties. Neem trees are popularly called “Dalbejiya” or “Dogonyaro” by Hausa speaking people of Nigeria. The trees are found in many parts of the world, but in Nigeria mostly in the northern part of the country where they abundantly grow all year round. It costs very little to get the leaves from the trees or collect those that fall on the ground under the trees.

The primary step in the action of inhibitors in acid solutions is generally adsorption onto the metal surface, which is usually oxide-free in acid solutions. The adsorbed inhibitor retards the cathodic and/or anodic electrochemical corrosion processes (Fontana, 1987). The production of the adsorbed chemical is faster and more when the concentration of the inhibitor and time of the
exposure are increased respectively. The adsorbed inhibitor shielded the corroded surface from further corrosion attack thereby depressing the rate of corrosion (Kuznetsov, 2004). Also the adsorbed molecules of the inhibitor on the metal surface contains tannin which acts as a physical barrier to restrict the diffusion of ions to and from the metal and prevent its atoms from participating in further anodic or cathodic reactions and thus decrease the corrosion rate in the medium (Loto, 2003).

The corrosion of metals in acid solutions can be inhibited by a wide range of methods and substances. This research work was centered on investigating the effectiveness of neem leaf extract as corrosion inhibitor for hypoeutectoid steel in HCL solution.

2.0 MATERIALS AND METHODS

2.1 Materials
The materials, equipment and machine tool used to carry out the work include: Neem leaves, Mild steel (0.2%C), Dilute hydrochloric acid (HCL), Ethanol, Emery paper, Glass breaker, Setra electronic digital weighing balance model BL-410S, Measuring cylinder, Lathe machine and Hack saw.

2.2 Methods
2.2.1 Preparation of Neem Leaf Extract:
After the collection of Neem leaves that fall under the neem tree, the needed quantity was kept in the sun for five days to dry to taste as shown in Plate 1.

![Plate 1: Dried Neem Leaves ready for use](image)

2.2.2 Extraction of the Aqueous Extract of the Neem Leaf: The aqueous extract of the neem leaf was obtained by soaking 2.0 grams of the dried neem leaves in 60 ml distilled water at room temperature for 72 hours (3 days). The resulting solution was filtered into glass beakers as shown in Plate 2 below.
2.2.3 Production of mild steel coupons: The mild steel (0.2% C), sourced from machine tool workshop, was machined into solid cylindrical shape of 2cm diameter and 1cm height using hack saw and lathe machine. Twenty five (25) pieces of the coupons were produced. Each cleaned and polished with emery paper and recleaned with tissue paper. They were later weighed using accurate analytical weighing balance. Extra effort was put to ensure that each weight of the coupon comes out to be 24.8 grams. Plate 3 below shows a sample of the coupons.

2.2.4 Experimentation: 0.5M HCl solution was added to the neem leaf extract containing the inhibitor of concentrations 0, 0.1, 0.3, 0.7, and 1.0% v/v respectively. Each of the coupons which
have been polished and thoroughly cleaned with tissue paper was immersed in each of the solutions. The weight loss of each coupon was determined at four (4) days interval for twenty (20) days. After the weight loss (W) of each coupon was calculated, the corrosion rate (i.e. corrosion penetration rate, CPR) in mils per year was calculated using the formula (Fontana, 1987):

\[
\text{Corrosion rate (mpy)} = \frac{534W}{\rho AT} \quad \ldots \quad (1)
\]

Where: mpy = mils per year; W= weight loss in mg; \(\rho\) = density of the materials in g/cc; T = time of exposure in hours; and A = surface area in inches square (in\(^2\)) of the coupon.

In the current study: Diameter = 2 cm; height (h) =1cm; Density of mild steel = 7.86g/cc; HCL concentration = 0.5m; Surface area (A) of ample =\(2\pi (r + h) = 2 \times 3.142 \times 1 (1+1) = 12.57\text{cm}^2\)

Total surface area (A) of sample in inch square = (12.57 x 0.153) = 1.95 in\(^2\).

The inhibitor efficiency was calculated using the formula:

\[
\text{Inhibitor efficiency} = \frac{w_o - w}{w_o} \times 100\% \quad \ldots \quad (2)
\]

Where: \(w_o\) = corrosion rate without inhibitor and \(w\) = corrosion rate with inhibitor.

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Results

The results of all the investigations and the supporting information are presented in Table 1 and Figures 1, 2 and 3.

**Table1: Weights (g) of coupons after exposure in the inhibitors for indicated hours**

<table>
<thead>
<tr>
<th>Inhibitor Concentration (%v/v)</th>
<th>Initial weight</th>
<th>After 96 hours (4 day)</th>
<th>After 192 hours (8 days)</th>
<th>After 288 hours (12 days)</th>
<th>After 384 hours (16 days)</th>
<th>After 480 hours (20 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>24.8</td>
<td>24.508</td>
<td>23.981</td>
<td>23.937</td>
<td>23.5</td>
<td>23.4</td>
</tr>
<tr>
<td>0.1</td>
<td>24.8</td>
<td>24.571</td>
<td>24.164</td>
<td>23.98</td>
<td>23.813</td>
<td>23.788</td>
</tr>
<tr>
<td>0.3</td>
<td>24.8</td>
<td>24.643</td>
<td>24.222</td>
<td>24.035</td>
<td>23.898</td>
<td>23.826</td>
</tr>
<tr>
<td>0.7</td>
<td>24.8</td>
<td>24.653</td>
<td>24.264</td>
<td>24.189</td>
<td>24.143</td>
<td>23.958</td>
</tr>
<tr>
<td>1.0</td>
<td>24.8</td>
<td>24.698</td>
<td>24.398</td>
<td>24.34</td>
<td>24.099</td>
<td>24.27</td>
</tr>
</tbody>
</table>
Figure 1: Weight loss (mg) against time (hours) of coupons exposure in the inhibitors

Figure 2: Corrosion rate (mpy) against time (hours) of coupons exposure in the inhibitors
3.2 Discussion of Results
The results of the study were presented in section 3.1. Visual observation of the mild steel coupons in the solution with and without inhibitor after twenty days (480 hours) of exposure revealed changes in colour from initial bright silver surface to dull ones. Cracks, scales and pits were also observed which indicate severe corrosion attack on the coupons by the corrosive medium. The changes in colour and presence of cracks and scales were more conspicuous on the coupons in the solution without inhibitor and with inhibitor of 0.1%, 0.3% 0.7% concentrations respectively, while the coupons in the 1.0% inhibitor concentration have no cracks, scale or pits, only change in colour. This indicated that as the concentration of the inhibitor is increased, the corrosion rate decreased and vice-versa.

The weights (g) of coupons responses with respect to the exposure time and inhibitors concentrations were presented in Table 1 while Figure 1 illustrates the actual weight (mg) loss of coupons with respect to the exposure time and inhibitor’s concentrations. It was observed that the weights of the coupons decreased with increase in the time of the exposure. The weight decrease was much more severe in the corrosive medium without inhibitor. Also, as the concentration of the inhibitor increased, the rate at which the weights decreased became much slower. Figure 1 portrays the trends of the increase in weight loss with decrease in the concentrations of the inhibitors and increase in the time of the exposure.

The results obtained on the corrosion rate against exposure times at different inhibitor concentrations and the respective inhibitor efficiency were illustrated in Figures 2 and 3 respectively. From Figure 2, it was observed that the corrosion rates generally increase with increase in time of the exposure for the first 8 days (192 hours) and gradually decrease during the remaining 12 days of the exposure period. The general trend of the corrosion rate was that the rate of corrosion decreased with increase in the concentration of the inhibitor and the time of exposure respectively. In
the case of the inhibitor efficiency, it was observed that corrosive medium without inhibitor had zero inhibitor efficiency while the highest inhibitor efficiency of 65.1 percent was recorded from the inhibitor with highest concentration of one percent. This simply implies that the efficiency of inhibitors increase with increase in the concentration of the inhibitors. These trends of variations of the inhibitors corrosion rates and efficiencies with respect to concentrations and periods of interactions with corrosive environment are illustrated in figures 2 and 3 respectively.

4.0 CONCLUSION

Sequel to the results of the work, it can be concluded as follows:

1. The Neem Leaf extract inhibits corrosion of mild steel in 0.5m HCL solution subject to the level of inhibitor concentration.
2. The corrosion rate decrease with increase in the concentration of the inhibitor and increase with the time of interaction in the corrosive medium.
3. The inhibitor with 1.0% concentration proved to be the most effective with the lowest corrosion rate for all the time of exposure and the highest inhibitor efficiency of 65.1% in the work.
4. No cost was incurred in acquiring the neem leaf extract. This method of inhibiting corrosion is cheaper and more environment friendly than those in current use.

REFERENCES

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