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Amaranthus cordatus as a Green Corrosion Inhibitor for Mild Steel in H₂SO₄ and NaCl

Michael O. Nwankwo[1], Peter O. Offor[2], Simeon I. Neife[2], Lucky C. Oshionwu[1], Ndubuisi E. Idenyi[1]

[1]Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria
[2]Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka, Nigeria
Email: michaelnwankwo@yahoo.com, peterjoyoffor@yahoo.com, drneifes@gmail.com, edennaidenyi@yahoo.com

Abstract

This work studies the use of *Amaranthus cordatus* as the corrosion inhibitor for conventional mild steel in 0.5 M and 1.0 M of both H₂SO₄ and NaCl. The effects of different concentrations of the acid and base on the inhibition efficiency of *Amaranthus cordatus* were tested at room temperature and at different inhibitor volumes. The experiment was set for 30 days and weight-loss corrosion technique was employed in obtaining the corrosion penetration rate using the standard equation: $cpr = \dfrac{87.6 \Delta w}{\rho A t}$. The result shows that the rates of corrosion of the mild steel increased with an increase in concentration of the acid or base and also decreased with increasing volume of *Amaranthus cordatus*. Expectedly, the inhibition efficiency was found to be greater in sodium chloride than in tetraoxosulphate VI acid. Also inhibition efficiency was found to increase with increase in extracts volume and decrease in concentration of the acid or base. These findings strongly suggest that *Amaranthus cordatus* can be used as the inhibitor for preventing the corrosion of mild steel.

Keywords

Corrosion, Inhibition Efficiency, *Amaranthus cordatus*, Mild Steel, Tetraoxosulphate (VI) Acid, Sodium Chloride

1. Introduction

Corrosion of a metal is said to be due to chemical or electrochemical reactions when it comes in contact with matters present in its environment. However, corrosion can be controlled by suitably modifying the environment

which stifles the anodic or cathodic reaction or both, and this is achieved by the use of inhibitors [1].

Mild steel has been extensively used under different conditions in chemical and allied industries in handling alkaline, acid and salt solution. One way of protecting mild steel from corrosion is the use of organic inhibitors [2]. The known hazardous effects of most synthetic corrosion inhibitors are the motivation for the use of some natural products. The exploration of natural products as the corrosion inhibitor is becoming the subject of extensive investigation due to low cost and eco-friendliness of these products and their biodegradability. This method is fast replacing the synthetic and expensive hazardous organic inhibitors [3]. The yield of these compounds as well as their corrosion inhibition abilities varies widely depending on the part of the plant and its location [4]. The extracts from the leaves, seeds heartwood, bark, root and fruit of plant have been reported to inhibit metallic corrosion in acidic media. Researchers have reported the use of local plant such as Italian Vernonia *amygdalina* as the corrosion inhibitor for aluminium [5] [6]. In line with this, *Allamanda blanchetii* has been reported as the effective inhibitor for mild steel in citric acid and sulphuric acid [7].

Veawab, Totinwachuthikul & Chakma [8] noted that ferrous materials, especially mild steel, are largely used in acidic media in most industries including oil/gas exploration and ancillary activities. They stated that during such activities, inhibited sulphuric acid is widely used in pickling, descaling and stimulation of oil wells in order to increase oil and gas flow [8].

Inhibitors currently employed in corrosion works are varied and some have been found to be hazardous to health and the environment at large. Thus efforts are now directed towards formulation of modern environmentally safe inhibitors in which plants extracts have become important because they are eco-friendly; are economically cheap; are readily available; and are renewable sources of effective corrosion inhibitors [9].

Therefore, the present investigation is directed at the evaluation of extracts from *Amaranthus cordatus* as inhibitors for fighting the corrosion of mild steel in H_2SO_4 and NaCl media employing weight loss technique.

2. Experimental Techniques

2.1. Materials/Experiment

The materials and equipment used for the work include 10 mm diameter mild steel rods sourced from a local steel stockist in Enugu, Nigeria, beakers, digital weighing balance, tetraoxosulphate (VI) acid, leaves of *Amaranthus cordatus*, acetone, nylon strings, emery cloth, distilled water, hacksaw, vernier calliper, measuring cylinder, and volumetric flask.

2.2. Materials Preparation

The mild steel rods were cut to sizes, each averaging 94.5 cm^2 in surface area. They were thoroughly brushed with emery cloth to reveal the metal surface. Thereafter, they were washed with distilled water and swabbed in acetone. They were weighed after drying to note the initial weight. The tetraoxosulphate (VI) acid and Sodium Chloride were prepared to 0.5 M and 1.0 M concentration using standard procedures. The *Amaranthus cordatus* leaves were washed with cold tap water, dried under room temperature; after which they were subjected to soxhlet extraction process in ethanol for about 80 hours to obtain the extract.

2.3. Experimentation

The mild steel coupons were tied with nylon strings and then suspended in beakers containing the acid and the base as well as the hydrolysed and acidified extracts. Each beaker contained 5 coupons and the entire set up were allowed to stand for 30 days. After 6 days a coupon was withdrawn from each beaker, rinsed in distilled water and swabbed in acetone. Thereafter they were reweighed for weight loss determination, corrosion rate and inhibition efficiency calculation using the formulas:

$$cpr = \frac{87.6\Delta w}{\rho At}; \text{ and}$$

$$IE\% = \left[\frac{\Delta w_a - \Delta w_p}{\Delta w_a} \right] \times 100$$

where *cpr*, *Δw*, *ρ*, *A* and *t* are corrosion penetration rate (mm/yr), weight loss (g), density, total surface area and exposure time (hours) respectively; while W_a and W_p are the values of weight losses in absence and presence of inhibitor respectively, and *IE*% depicts Inhibition Efficiency in percentages. The pH value of the *Amaranthus cordatus* extract was evaluated and noted.

3. Results

Table 1 and **Table 2** show the inhibition efficiency of the plant extract in controlling corrosion of mild steel at different extract volumes; while **Figures 1-4** show the effect of *Amaranthus cordatus* on corrosion penetration rate of mild steel at room temperature.

4. Discussion

A look at **Figures 1-4** shows that the corrosion rates obtained were typical of those of passivating metals. This is usually associated with an initial steep rise in corrosion rate, then peaking at a maximum and subsequently de-
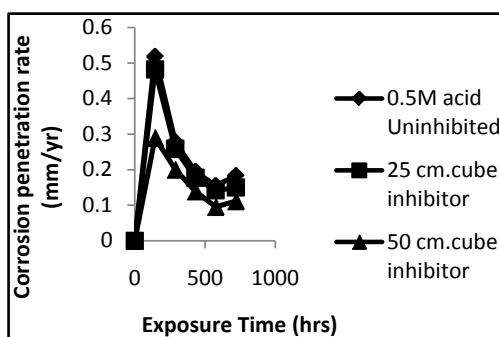

Figure 1. Effect of plant extract on corrosion penetration rate of mild steel in 0.5 M H_2SO_4 at room temperature.

Table 1. Inhibition efficiency of mild steel in H_2SO_4 in presence and absence of *Amaranthus cordatus*.

Time (hours)	0.5 M H_2SO_4		1.0 M H_2SO_4		
	25 cm³ inhibitor	50 cm³ inhibitor	25 cm³ inhibitor	50 cm³ inhibitor	
144	24.1270	44.1270	32.4125	46.1326	Inhibition Efficiency (%)
288	26.0740	27.8519	40.9266	45.4826	
432	26.6197	28.4507	40.000	42.7376	
576	25.4328	27.8296	43.9590	44.5051	
720	39.6040	47.7948	43.9375	43.8750	

Table 2. Inhibition efficiency of mild steel in NaCl in presence and absence of *Amaranthus cordatus*.

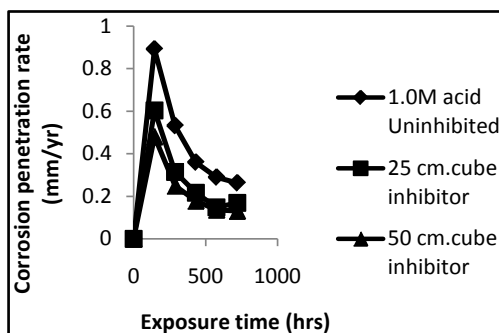| Time (hours)	0.5 M NaCl		1.0 M NaCl		
	25 cm³ inhibitor	50 cm³ inhibitor	25 cm³ inhibitor	50 cm³ inhibitor	
144	98.1188	99.5050	93.3333	90.6667	Inhibition Efficiency (%)
288	98.7850	99.0654	98.5075	99.1905	
432	97.7707	98.9172	98.2456	98.5965	
576	97.8109	98.9055	98.2659	98.5549	
720	97.2603	98.6301	98.0723	97.8313	

Figure 2. Effect of plant extract on corrosion penetration rate of mild steel in 1.0 M H_2SO_4 at room temperature.
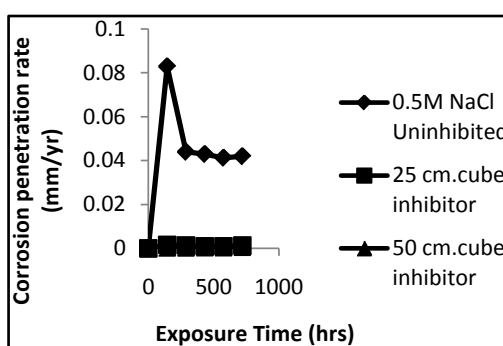

Figure 3. Effect of plant extract on corrosion penetration rate of mild steel in 0.5 M NaCl at room temperature.
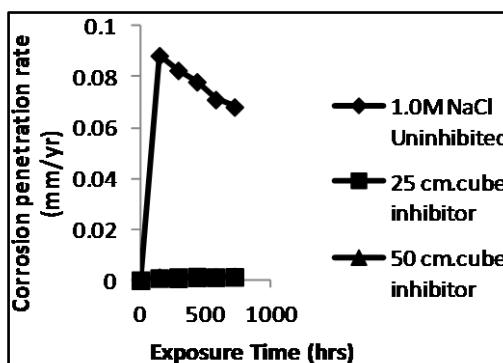

Figure 4. Effect of plant extract on corrosion penetration rate of mild steel in 1.0 M NaCl at room temperature.

creasing as exposure time increased. It can also be seen that the rate of corrosion of mild steel decreased with increase in volumetric values of the extracts and the highest corrosion recorded was without inhibitor. The metal surface on interaction with the corrosion medium normally reacts swiftly with the medium forming an oxide that coats the entire surface and acts as a barrier, thereby preventing further reactions [10].

4.1. Molar Concentration of Acids

The corrosion rates during six days the experiment lasted were all below the acceptable minimum (put at 0.5 mm/yr for most metals) in the entire media (although in varying proportions). The lowest corrosion rate of 0.10

mm/yr was achieved at 50 cm^3 of the plant extract in 0.5 M H_2SO_4 while the lowest corrosion rate of 0.0004 mm/yr was achieved at 50 cm^3 of the extract in 0.5 M NaCl. This implies that the molarity of the acid or base had a significant effect on the corrosion rate, agreeing with the works of previous researchers [11] [12]. However, the values obtained for the two molar concentrations of the acid and base showed that at higher molarities, the corrosion rates were higher comparatively, and although most of the corrosion penetration rate values fell well below the permissible limits, the trend indicated a decrease in corrosion rate as exposure time increased.

4.2. Volumetric Concentration of the Extract

It has been established that corrosion decreases as the concentration of plant extracts increases [12] [13]. In a similar fashion, the corrosion penetration rates decreased as the volumetric values of the extract increased. This can be attributed to the increase in the amount of plant extract adsorbed on the metal surface, thus reducing the available sites for either acid or base attack [14]. Hence, it shows that *Amaranthus cordatus* is a good inhibitor. The inhibition efficiencies however varied with the concentration of the acid or base such that corrosion rate values were higher at higher acid or base concentrations.

4.3. Inhibition Efficiency of *Amaranthus cordatus*

From the tables the maximum inhibition efficiency of the plant extract at the end of the 30 days of the experiment was 47.80% in 0.5 M H_2SO_4 and 99.51% in 0.5 M NaCl. This is because the attack of the acids main reacting agent (hydrogen ion) is severe as it is being evolved without replacement thus leaving the reaction system insufficient of the major component of the reaction. This reduces the rate of the oxidation of the mild steel, thus increases the efficiency of the plant extract to inhibit its corrosion while NaCl has less attack on the reaction system, hence inhibition efficiency increases as the extract volumes increase. The rate of inhibition is appreciable at lower concentration than higher concentration of the acid or base. The maximum inhibition efficiency recorded at the end of 30 days was due to the adsorption of constituents of the plant extract on the mild steel passivating it from further corrosion. This is also in line with the established fact that mechanism of adsorption of the plant extract on the surface of mild steel is a physical adsorption [15].

4.4. Comparison of *Amaranthus cordatus* Inhibitory Action

It was observed that the inhibitory character of the plant extract is more pronounced in **Figure 3** and **Figure 4** than in **Figure 1** and **Figure 2**. This shows that inhibitor strength decreased more in H_2SO_4 than in NaCl. The gap between uninhibited and inhibited samples shows that the plant extract is inhibiting the corrosion of mild steel. The plant extract has been proven in this work to have good inhibitory behaviour in the field of corrosion. Hence, *Amaranthus cordatus* in both H_2SO_4 and NaCl show good inhibitory character. So inhibition efficiency of *Amaranthus cordatus* increased tremendously in NaCl when compared to H_2SO_4 at room temperature.

5. Conclusion

Based on the results obtained and the foregoing discussion, an inference is drawn to the fact that *Amaranthus cordatus* inhibits the corrosion of mild steel in H_2SO_4 and NaCl solution to an appreciable extent. Hence, it is a good inhibitor which could cause passivation, since its pH value of 8.1 falls within the region in which passivation occurs in the pourbaix diagram [16]. Again, the increase in inhibition efficiency with increase in volumetric values of the plant extract and decrease in concentration of the acid at room temperature show that the plant extract is physically adsorbed on the mild steel coupon. Therefore, the extract of *Amaranthus cordatus* can be considered as a source of non-toxic, environmentally friendly and effectively green corrosion inhibitors in acid and base media for mild steel.

Acknowledgements

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