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EFFICIENT USE OF LOCAL VEGETABLE EXTRACTS AS VERITABLE ALTERNATIVE CORROSION INHIBITORS (A Case Study of *Ocimum basilicum* and *Amaranthus cordatus*)

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ABSTRACT

A study of the efficient use of local vegetable extracts as veritable alternative corrosion inhibitors in controlling the corrosion of conventional engineering mild steel has been undertaken. The work studies the use of *Ocimum basilicum* and *Amaranthus cordatus* as corrosion inhibitors for conventional mild steel in 0.5M, 1.0M of both H_2SO_4 and NaCl. Weight-loss corrosion technique was employed in obtaining the corrosion penetration rate using the equation: Cpr = $\frac{87.6\,\Delta w}{\rho A t}$. The experiment was carried out for 30 days and the result showed that corrosion of the mild steel was found to increase with increase in concentration of the base or acid and also decreased with increase in the volume of the extracts of these local vegetables. Expectedly, the inhibition efficiency was found to be greater in Sodium Chloride than in tetraoxosulphate (VI) acid because the acid contain more corrosion enhanced species. It was concluded then that *Amaranthus cordatus* and *Ocimum basilicum* can be used as good alternatives to replace most of the costly synthetic corrosion inhibitors currently being used. The finding ultimately will boost the economic development of Nigeria.

Keywords: **Corrosion, Inhibition, *Ocimum basilicum, Amaranthus cordatus,* Mild Steel, Acid and Base.**

INTRODUCTION

Corrosion can be defined as the environmentally induced degradation of a material that involves a chemical reaction (Duquette *et al.,* 2011). Degradation implies deterioration of physical properties of the material. This can be a weakening of the material due to a loss of cross-sectional area, it can be the shattering of a metal due to hydrogen embrittlement, or it can be the cracking of a polymer due to sunlight exposure.

Most authors insist that the definition of corrosion should be restricted to metals, but more often than not, corrosion engineers must consider both metals and non-metals for solution of a given problem. Accordingly, polymers (plastics, rubbers, etc.), ceramics (concrete, brick, etc.) or composites (mechanical mixtures of two or more materials with different properties) and other non-metallic materials are generally included as materials that can corrode (Fontana, 2005).

Some of the deleterious effects of corrosion are known to include among others poor outward appearance of material surfaces, high maintenance and operating costs, frequent plant shutdowns, contamination of end products, loss of valuable products, hazardous effects on safety and reliability and burdensome product liabilities. Consequent upon these, huge financial losses have always been recorded as resulting from corrosion damage. For instance, estimates of the annual cost of corrosion in the United States alone is said to be around $276 billion but is realistically put at $30 billion as at 1998 (Fontana, 2005). By March 2013, it was evaluated to be $993 billion with a project figure of $1 billion by June 2013 (G2MT Lab., 2011).

Even with the proper selection of base metals and well-designed systems or structures, there is no absolute way to eliminate all corrosion. Therefore, corrosion protection methods are used to additionally mitigate and control the effects of corrosion. Corrosion protection can be in a number of different forms or strategies with perhaps multiple methods applied in severe environments (Craig, Lane & Rose, 2006). The various forms of corrosion protection include among others the use of inhibitors, surface treatments, coatings and sealants, cathodic protection and anodic protection.

With such staggering financial loss values earlier stated, the need to find cost-effective and environmentally friendly corrosion control measures becomes dire. In this respect, the use of natural plants as corrosion inhibitors has in recent times become the centrifuge of most research activities. Inhibitors themselves are chemicals that react with the surface of a material decreasing the material's corrosion rate, or interact with the operating environment to reduce its corrosivity. They can be added into the corrosion medium as solutions or dispersions to form a protective film, or as additives in coating products, or further still into waters used for washing vehicle, system or component. When added, they interact with the metal, thus slowing the corrosion process by shifting the corrosion potential of the metal's surface toward either the cathodic or anodic end; preventing permeation of ions into the metal; or increasing the electrical resistance of the surface (Craig *et al.,* 2006).

In Africa, and particularly Nigeria, a vast number of natural plants are continuously been investigated as profitable alternatives to synthetic inhibitors because of their ready availability, biodegradability, non-toxicity, non-pollutancy and eco-friendliness (Boxer and Back, 1980; Duke, 1985). These formed the choice of *Ocimum basilicum* and *Amaranthus cordatus* for this work.

EXPERIMENTAL TECHNIQUES

Materials / Experiment

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

Materials Preparation

The mild steel rods were cut to sizes, each averaging 94.5cm^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 0.5M and 1.0M concentration using standard procedures. The *Amaranthus cordatus* and *Ocimum basilicum* leaves were washed with cold tap water, dried under room temperature and after which they were differently subjected to soxhlet extraction process in ethanol for about 80 hours to obtain the extract.

Experimentation

The mild steel coupons were tied with nylon strings and then suspended in different beakers containing the acid and the base as well as the basified 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:

$$\text{Cpr} = \frac{87.6\ \Delta w}{\rho A t}$$

$$IE\% = \left[\frac{W_0 - W_2}{W_i}\right]$$

Where cpr, Δ w, ρ, A and t are corrosion penetration grate (mm/yr), weight loss (g), density, total surface area and exposure time (hours) respectively while W_o and W_i are the values of weight losses in absence and presence of inhibitor respectively and IE is inhibition efficiency. The pH value of the *Amaranthus cordatus* and *Ocimum basilicum* extract was evaluated and noted.

RESULTS

Tables 1 – 4 shows the inhibition efficiency of the plant extract in controlling corrosion of mild steel at different extract volumes; while figures 1-4 shows the effect *Amaranthus cordatus and Ocimum basilicum* extract in corrosion penetration rate of mild steel at room temperature.

Table 1: Inhibition Efficiency of *Amaranthus cordatus* in Protecting Mild Steel in H_2S0_4 Environments

TIME	0.5M H_2S0_4		1.0M H_2S0_4		
(HOURS)	25CM^3	50CM^3	25CM^3	50CM^3	Inhibition Efficiency (%)
144	24.1270	44.1270	32.4125	46.1326	
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 *Amaranthus cordatus* Extract in Protecting Mild Steel in NaCl Environments

TIME	0.5M NaCl		1.0M NaCl		
(HOURS)	25CM^3	50CM^3	25CM^3	50CM^3	Inhibition Efficiency (%)
144	98.1188	99.5050	93.3333	90.6667	
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	

Table 3: Inhibition Efficiency of *Ocimum basilicum* Extract in Protecting Mild Steel in H_2SO_4 Environments

Time (Hours)	0.5M H_2SO_4		1.0 H_2SO_4		
	$25CM^3$	$50CM^3$	$25CM^3$	$50CM^3$	Inhibition Efficiency (%)
144	3.1746	11.7460	14.4567	12.0626	
288	3.2593	8.2963	19.9228	22.4710	
432	7.6056	11.2676	12.0152	14.2205	
576	7.5899	5.7257	16.5870	17.3379	
720	18.0918	9.9910	11.8750	12.4375	

Table 4: Inhibition Efficiency of *Ocimum basilicum* Extracts in Protecting Mild Steel in NaCl Environments.

Time (Hours)	0.5M NaCl		1.0M NaCl		
	$25CM^3$	$50CM^3$	$25CM^3$	$50CM^3$	Inhibition Efficiency (%)
144	99.0100	99.0000	86.6667	86.6667	
288	97.1963	95.3271	97.5124	98.5075	
432	95.5414	91.7197	97.0175	98.2456	
576	95.0249	91.0448	95.6647	97.3988	
720	94.8630	90.4110	28.6747	98.3133	

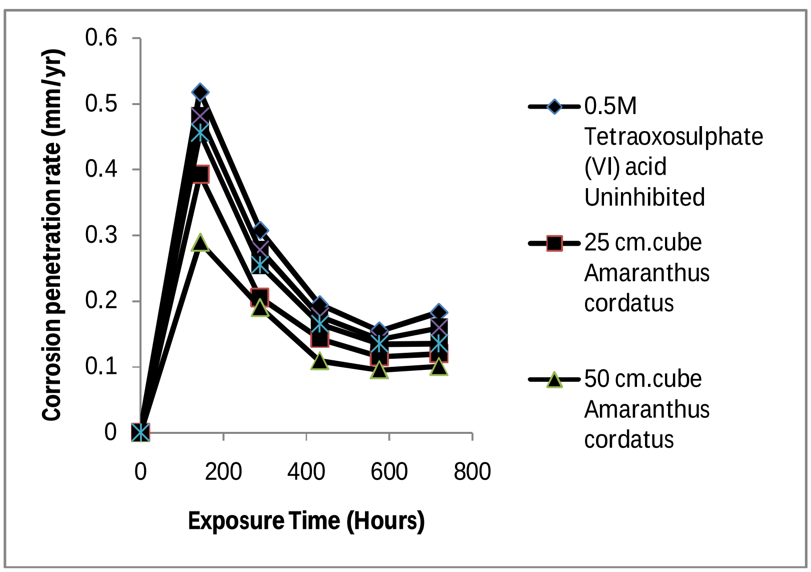

Fig. 1: Effect of Plant Extracts on Corrosion Penetration Rate of Mild Steel in 0.5m H_2SO_4 at Room Temperature

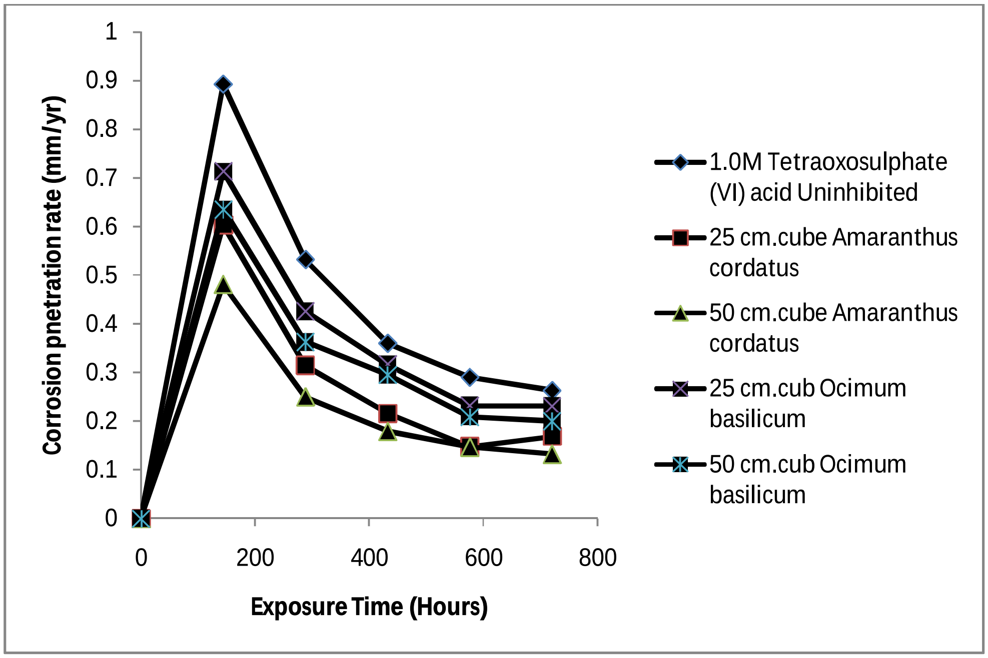

Fig. 2: Effect of Plant Extracts on Corrosion Penetration Rate of Mild Steel in 1.0M H_2SO_4 at Room Temperature

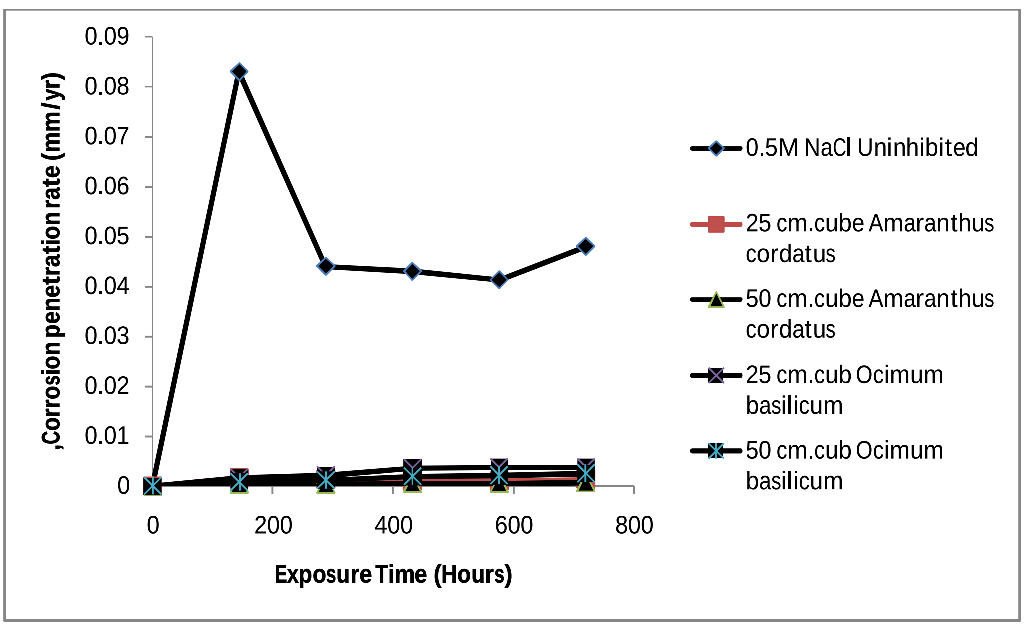

Fig. 3 Effect of Plant Extracts on Corrosion Penetration Rate of Mild Steel in 0.5M NaCl at Room Temperature

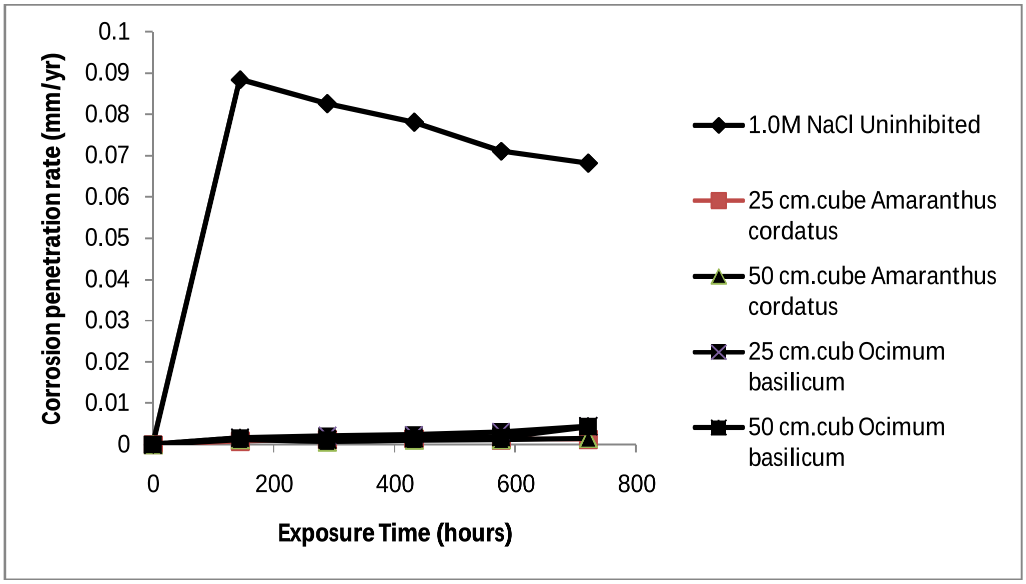

Fig. 4: Effect of Plant Extracts on Corrosion Penetration Rate of Mild Steel in 1.0M NaCl at Room Temperature

DISCUSSION

A cursory 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 decreasing 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 a barrier, thereby preventing further reactions (Callister, 1997).

Molar Concentration of Acids

The corrosion rates during six days the experiment lasted were all below the acceptable minimum (put at 0.5mm/yr for most metals) in the entire media (although in varying proportions). The lowest corrosion rate of 0.10mm/yr was achieved at $50cm^3$ of the plant extract in 0.5M H_2SO_4 while the lowest corrosion rate of 0.0004mm/yr was achieved at $50cm^3$ of the extract in 0.5M 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 (Oguzie, Onuchukwu & Ebenso, 2006; Oguzie, 2006).

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.

Volumetric Concentration of the Extract

It has been established that corrosion decreases as the concentration of plant extracts increases (Onuegbu *et al.*, 2013; Oguzie, 2006). 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 (Olusegun *et al.*, 2004). Hence, it shows that *Amaranthus cordatus and Ocimum basilicum* are 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.

Inhibition Efficiency of *Amaranthus cordatus and Ocimum basilicum*

From the tables the maximum inhibition efficiency of the extracts of *Amaranthus cordatus* and *Ocimum basilicum* at the end of the 30 days of the experiment were 47.80% in 0.5M H_2SO_4, 99.51% in 0.5M NaCl and 36.47% in 0.5M H_2SO_4, 99.01% in 0.5 NaCl respectively. This is because the attack from acids main reacting agent (hydrogen ion) is severe and is evolved without replacement, thus leaving the reaction system insufficient of its major component. This reduces the rate of the oxidation of the mild steel by increasing the efficiency of the plant extracts to inhibit corrosion while NaCl has less attack on the reaction system; hence inhibition efficiency increases more 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 (Gunase and Chanhan, 2004).

Comparison of Plant Extracts Inhibitory Action

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

CONCLUSION

Based on the results presented in this paper and the foregoing discussions, it is concluded and accurately too that *Amaranthus cordatus and Ocimum basilicum* inhibits the corrosion of mild steel in H_2SO_4 and NaCl solution to an appreciable extent. Hence, is a good inhibitor which could cause passivation, since its pH value falls within the region in which passivation occurs in the pourbaix diagram (Ijomah, 2001). Again, the increase in inhibitors efficiency with increase in volumetric values of the plant extract and decrease in concentration of the acid at room temperature shows that the plant is physically absorbed on the mild steel coupon. Therefore, the extract of *Amaranthus cordatus and Ocimum basilicum* can be considered as a source of non – toxic, environmentally friendly and effectively green corrosion inhibitor in acid and base media for mild steel. It was concluded then that aqueous extracts of *Amaranthus cordatus* and *Ocimum basilicum* can be used as a good alternatives to replace most costly synthetic inhibitors currently being used.

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