The Inhibitive Effect of Occimum Gratissmum and Terminlia Chebula Extracts on Corrosion of Iron and Steel

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Abstract

The leaves extract of Occimum gratissimum (OG) and Terminlia chebula (TC) were investigated as alternative environmentally friendly corrosion inhibitor for possible anticorrosion additives to reduce the rate of corrosion of mild steel in 1 M HCl and 0.5 M H_2SO_4 environments. Gravimetric and potentiodynamic polarization techniques were used in the investigation. The obtained results showed that both OG extract and TC extract reduced the rate of the corrosion reaction considerably. For OG extract, maximum corrosion inhibition efficiency was 94.1% (in 1M HCl) and 90.1% (in 1 M H_2SO_4) while the TC extract showed maximum efficiencies of 95% and 97.1% in 1 M HCl and 0.5M H_2SO_4, respectively. Cathodic and anodic polarization curves showed that OG and TC extracts functioned as a mixed-type inhibitor. This study indicates clearly that the studied environmentally friendly biomass extracts has potentials of reducing the corrosion of mild steel in the studied acidic environments.

Keywords: Corrosion, inhibitors, occimum gratissimum, reagent, biomass, electrochemical.
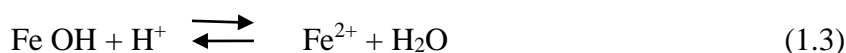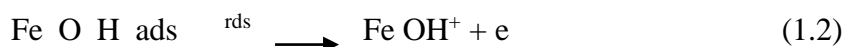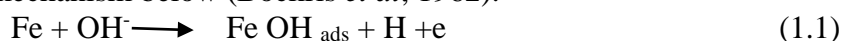
1.0. INTRODUCTION

Corrosion is the chemical degeneration and deterioration of materials usually metals as a result of their contact with water and moisture in the air, acids bases and other corrodents in their environment. Corrosion is a natural process, not only metals corrode but non-metals like plastics, rubber, ceramics are also subject to environmental degradation.

Any spontaneous reaction in the universe is associated with a lowering on the free energy of the system that is a negative free energy change. All metals except the noble ones have free energies greater than their compounds, so they lend to become the compound through the process of corrosion (Nadkarani, 2001).

As in all chemical reaction, corrosion occurs through an exchange of electrons in an electrochemical reaction. The electrons are produced by a chemical reaction in the anode. They travel through a metallic path and are consumed in the cathode. In order for electrochemical reactions to occur, four components must be present and active. These are the anode, cathode, electron path and electrolyte.

The anodic dissolution of iron in acidic solution has been reported to proceed according to the mechanism below (Bockris *et al*, 1962).

$$Fe + OH^- \longrightarrow Fe\ OH_{ads} + H + e \qquad\qquad (1.1)$$

$$Fe\ O\ H\ ads \xrightarrow{rds} Fe\ OH^+ + e \qquad\qquad (1.2)$$

$$Fe\ OH + H^+ \rightleftarrows Fe^{2+} + H_2O \qquad\qquad (1.3)$$

As a consequence of these reactions, including the high solubility of the corrosion products the metal loses weight in solution.

In acid solutions electrons can react with hydrogen ions, adsorbed on the metal surface from the solution to produce hydrogen gas (Oguzie *et al*, 2007). This is the cathode reaction.

$$2H^+_{adsorbed} + 2e^- \longrightarrow H_{2(g)} \qquad\qquad (1.4)$$
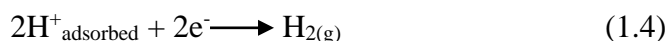
For steel in contact with water at lower (pH), the cathode reaction is

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \qquad\qquad (1.5)$$

In controlling corrosion, iron and its alloys are widely used in many applications, which have resulted in research into the corrosion resistance in various aggressive environments (Oguzie, 2004). In efforts to reduce electrochemical corrosion the primary strategy is to isolate the metal from corrosive agents.

The effect of corrosion is often explained in economic terms. Financial losses have been assessed in several studies which concluded that premature materials degradation costs industrialized nations approximately three (3) percent (%) of their gross domestic product (GDP). Corrosion also causes adverse environmental effect; this affects human beings and the aquatic life. This is cause by leakages from oil pipelines, and storage tanks. Furthermore, the uses of synthetic inhibitors like chromates etc. are very expensive and toxic. This affects the environment and living organism, hence there's need to develop alternative inhibitors that are inexpensive and environmentally friendly.

2.0. METHODOLOGY

The corrosion inhibition study on the crude extracts of plants will be done by carrying out the following methods of assays.

i)   Weight loss measurements at room temperature and different extract concentrations.

ii)   Potentiodynamic polarization studies at room temperature.

2.1. Material Preparation

2.1.1 Metal specimen

In this current work, investigation of plant extracts for corrosion inhibitory effect, mostly ethanol extracts of the plants was used. Since it is only appropriate to study the efficiency of the plant extracts containing higher alkaloidal/heterocyclic content, the corrosion inhibition studies was performed on the crude plant extracts in the present work.

Mild steel (MS) specimens containing C = 0.01%, Mn = 0.34%, P = 0.08% and Fe = 99.51% was used for the study. Each sheet, which was 0.1cm in thickness, was mechanically pressed-cut into coupons of dimension 3cm x 3cm. These coupons were used as procured without further polishing, but were degreased in absolute ethanol, dried in acetone, weighed and stored in moisture free desiccators prior to use.

2.1.2. Reagents

All the reagents used were of analytical grade acquired from Sinopharm Chemical Reagent Co., Ltd. All of them were used without further purification. Distilled water was used for all solution preparations. 1 M HCl and 0.5 M H_2SO_4 solutions were employed as corrodents.

2.1.3. Preparation of Biomass

The leaves of the *Termilia chebular* and *Occimum gratissimum* used for this experiment were obtained locally at Ihiagwa. They were verified in the Department of Crop Science, FUTO. The leaves were properly washed, sun dried to a constant weight and grounded to fine powder.

2.1.4. Extraction process

10 g of the ground leaves of the plant extracts were added into 400 ml of ethanol contained in a 500 ml round-bottom flask. The resulting solution was heated under reflux for 3 hrs; allowed to cool to room temperature and then filtered. The ethanol content of the filtrate was evaporated with the aid of rotary evaporator and the obtained slurry was stored in air tight container and kept away from the sun.

Thereafter, it was used for the experiment. All experiments were carried out at $30\pm1\ ^{o}C$ and non-deaerated solutions.

For experiments involving *Termilia chebula* and *Occimum gratissimum*, the extracts were added to the blank solutions mention above to reach the final concentrations.

2.2. Corrosion Experiments

2.2.1. Gravimetric Studies

Gravimetric experiments were conducted under total immersion conditions in 200 ml of test solutions at room temperature. All tests were made in aerated solutions. Test coupons were retrieved at 24hrs intervals progressively for 120hrs, immersed in 20% NaOH solution containing 200g/L of zinc dust, this was scrubbed thoroughly with bristle brush, washed, dried with the aid of a hand dryer and reweighed. The weight loss was taken at a given time.

2.2.2. Electrochemical Studies

Electrochemical experiments were carried out in a three-electrode corrosion cell using a Potentiostat/Galvanostat-263 Electrochemical workstation, with Powersuit software. The data obtained in a three-electrode mode; graphite rod and saturated calomel electrodes were used as counter and reference electrodes. The material used for constructing the working electrode was mild steel that had the compositions mentioned earlier in Section 3.1.1. The samples were washed thoroughly with distilled water, followed with A.R Acetone, dried before insertion into the cell. Before polarization measurements the working electrode was inserted into the test solution and left for 1h in order to attain a stable open-circuit potential. Potentiodynamic polarization studies were carried out in a potential range ±250 mV versus corrosion potential, at a scan rate of 0.333mV/s. All measurements were done at 30.0 ±0.1°C in solutions open to the atmosphere under unstirred conditions. Each experiment was carried out in triplicate to test its reliability and reproducibility.

3.0. RESULT PRESENTATION

Table 1 below shows data for weight loss and corrosion inhibition efficiency for TC in 0.5 M H_2SO_4 as a function of time and also similar results in 1 M HCl environment, as well as the gravimetric and electrochemical measurements.

3.1. Electrochemical Results

It is well known that corrosion reaction is an electrochemical process and therefore, electrochemical measurements are most suitable for obtaining detailed understanding into the corrosion process. Experiments were conducted to determine the effect of various concentrations of OG and TC inhibitors on the electrochemical corrosion behavior of mild steel in HCl and H_2SO_4 solutions.

From Table 1 below, it was obvious that TC extract reduced the corrosion rate of mild steel in 0.5 M H_2SO_4 environment in a concentration dependent manner, showing its efficacy, that TC extract at low concentrations (50 mg/L and 100 mg/L) gave higher corrosion rate values than the uninhibited solution, hence the obtained negative values, low concentrations of TC (50 mg/L and 100 mg/L) The rate of corrosion values was higher now than in the uninhibited solution, hence the obtained negative values, TC maintained its inhibition behavior though, the rate of inhibition efficiency is gradually reducing with time, the rate of corrosion was higher in the presence of low concentrations TC than in the uninhibited solution, hence the observed negative values, TC extract reduced the corrosion rate of mild steel in 1 M HCl environment in a concentration dependent manner, also, higher inhibition efficiency values even at low concentrations (50 mg/L and 100 mg/L) was observed, TC extract maintained its inhibitive property, reducing the corrosion rate of mild steel at all concentrations, inhibitive effects of TC extract was almost stable at all concentrations especially at 600 mg/L, TC extract still maintained its inhibitive effect, reducing the corrosion rate of mild steel at all concentrations, TC extract maintained its inhibitory action, reducing the corrosion rate of mild steel at all concentrations, though the inhibition efficiency is gradually reducing with time compared the

obtained values in the same Table 1, OG extract reduced the corrosion rate of mild steel in 0.5 M H_2SO_4 environment in a concentration dependent manner, showing its efficacy, OG extract at low concentrations (50 mg/L and 100 mg/L) catalyzed the rate of corrosion compared to the uninhibited environment. However, at higher concentration the inhibitive effect was observed, OG extract reduced the corrosion rate of mild steel in 0.5 M H_2SO_4 environment at concentrations higher than 200 mg/L, OG extract also reduced the corrosion rate effectively and the inhibition efficiency increased with an increase in concentration, OG extract maintained its efficacy at all concentrations, the inhibition efficiency values increased with an increase in concentration, that from Table 1 for M HCl for OG, it was clear that inhibition efficiency decreased with time, however OG extract maintained its efficacy at all concentrations.

Table 1: Weight loss and inhibition efficiency values for mild steel corrosion in 0.5 M H_2SO_4 and 1 M HCl without and with ethanol extract of TC and OG after 24hours – 120hours.

System (mg/L)		Inhibition Efficiency (IE) %									
		0.5 M H_2SO_4 for TC					M HCl for TC				
		24hrs	48hrs	72hrs	96hrs	120hrs	24hrs	48hrs	72hrs	96hrs	120hrs
Blank	A B										
50	A B	15.8	-29.3	-56.5	-68.5	-69.7	80.9	70	64.3	58.1	52.8
100	A B	30.2	-8.6	-35	-55.1	-67.4	84.5	77.9	74.3	70.7	69.5
200	A B	69.5	50.9	29.8	13.3	2.48	87.5	82.4	78.9	75.4	72.3
400	A B	82.1	70.7	56.7	46.1	37.7	92.3	89.9	87.7	85.7	83.4
600	A B	93.4	92.6	91.1	89.9	88.7	90.4	84.8	81.2	77.9	76.5
800	A B	95	93.2	91.9	90.5	89.1	94.1	91.4	90	88.5	88.5
		0.5 M H_2SO_4 for OG					M HCl for OG				
		24hrs	48hrs	72hrs	96hrs	120hrs	24hrs	48hrs	72hrs	96hrs	120hrs
50	A B	32.3	-10.4	-36.5	-50.7	-50.7	75.9	59.3	46.2	34.4	25.4
100	A B	28.5	-16.3	-43.5	-48.2	-51.2	77.8	64.8	56.3	51.6	43.6
200	A	52.4	18.8	-12.6	-33.4	-50	80.7	70.2	64.3	58.3	53.1

	B									
400	A	59.6	32.2	4.7	-18.2	-34.7	85.7	77.1	72.3	68	63.7
	B									
600	A	69.9	45.3	16.9	-5.6	-22.4	87.2	80.1	76.3	71.6	67.8
	B									
800	A	83.3	79.1	74.3	68.4	68.8	89.2	83.7	81	79.4	78.1
	B									

Source: *Researchers' Fieldwork*

4.0.   DISCUSSION

4.1. Inhibition efficiency

The calculated values for inhibition efficiency are given in Table 1. Inhibition efficiency of OG in 0.5 M H_2SO_4 and 1 M HCl are compared at various levels of concentration, our results showed that inhibition efficiency increased with increase in concentration. Because of this more inhibitor molecules were adsorbed on the metal surface at higher concentration, leading to greater surface coverage. A maximum of 83.3% inhibition efficiency was observed in 0.5 M H_2SO_4 and 89.2% in 1 M HCl.

The characterization of the free corrosion of mild steel in the presence of the inhibitor/corrodent solution was performed by an assessment of the inhibition efficiency (I %) defined by:

$$I\% = \left(1 - \frac{W_1}{W_2}\right) x\ 100$$

(1)

Where W_1 and W_2 are the corrosion rates in uninhibited and inhibited corrodent. The calculated values are presented in Table 1. Inhibition efficiency of TC in 0.5 M H_2SO_4 and 1 M HCl are compared at various levels of concentration, our results revealed that inhibition efficiency increased with an increase in TC concentration up to a critical point (400 mg/L) in 1 M HCl environment, while in 0.5 M H_2SO_4 solution inhibition efficiency increased with an increase in concentration. This result suggests that more inhibitor molecules were adsorbed on the metal surface at higher concentration, leading to greater surface coverage. A maximum of 95% inhibition efficiency was observed in 0.5 M H_2SO_4 and 94% in 1 M HCl.

4.2. Adsorption Considerations

Surface coverage data are very useful in determining inhibitor adsorption characteristics. Such data are applied in construction of adsorption isotherms, which give detailed information on adsorption mechanism.

4.3. Corrosion inhibition by *OG* extract

OG did not inhibit corrosion at time greater than 72 hours. In 1 M HCl environment, it could be that protonated species played a vital role than unprotonated species. Weight loss decreased with increasing OG concentration. From this result it is obvious that the extent of corrosion inhibition depends on the quantity of OG species present.

4.4. Potentiodynamic Polarization Measurements

Table 1 indicate that the maximum displacement in E_{corr} value in both acidic environment are less than 85 mV, therefore, OG and TC are regarded as mixed-type inhibitors. The inhibiting effect becomes more pronounced at higher concentrations. The values of the corrosion current density in the absence($i_{corr,bl}$) and presence of inhibitor ($i_{corr,inh}$) were used to estimate the inhibition efficiency from polarization data (IEi%) as follows:

$$IE\% = \left(\frac{I_{corr(bl)} - I_{corr(inh)}}{I_{corr(bl)}}\right) x \; 100 \qquad (2)$$

where $I_{corr(bl)}$ and $I_{corr(inh)}$ represents the corrosion current density in the absence and presence of the inhibitor, respectively. The result obtained in this technique follows the same trend with the gravimetric method.

5.0. CONCLUSIONS

The results obtained from this research shows that ethanol extracts of TC and OG on mild steel corrosion in 1 M HCl and 0.5 M H_2SO_4 solution are good inhibitors of mild steel.

TC and OG actually impeded mild steel corrosion in 1 M HCl and 0.5 M H_2SO_4 solutions, in concentration dependent manner. The extract functioned by adsorption of the organic constituents on the metal surface and inhibited both the cathodic and anodic reactions. Maximum inhibition efficiencies for TC and OG are 95%, 94% and 83%, 89% in 1 M HCl and H_2SO_4, respectively. TC extract loses its effectiveness with prolonged immersion time at low concentrations in 0.5 M H_2SO_4 environment while OG loses at almost all concentrations with longer immersion.

6.0. RECOMMENDATION

The effect of plant extracts on microbial corrosion should be investigated especially in the oil and gas environment.

Work should be extended to further understudy the actual concentration of components of plant extracts and compare similar concentration with single inhibitors.

7.0. REFERENCES

Nadkarani, K. M., (2001), Indian plants and Drugs, *Asiatic Publish house New Delhi*, 233

Oguzie, E. E. (2007). Corrosion inhibition of aluminum in acidic and alkaline media by Sansevieria trifasciata extracts. Corrosion Science, 49, 1527 – 1539.

Oguzie, E. E., Onuoha, G. N., & Onuchukwu, A. I. (2004). Inhibitory Mechanism of mild steel corrosion in 2 M sulphuric acid solution by methylene blue dye. Materials Chemistry and Physics, 89, 305 – 311.