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Corrosion Inhibition of Aluminum in 1M HCl Using Baobab Tree Pulp Extract

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Abstract

A corrosion study of Aluminum in 1M HCL was carried out using Baobab tree pulp extract as the potential corrosion inhibitor. Weight loss measurement was adopted to evaluate the inhibition efficiency of the extract, corrosion product and surface coverage. Fourier transform infrared (FT-IR) spectroscopy and scanning electron microscopy (SEM) were used for surface morphology examination. The result of the inhibition efficiency shows that extract inhibition increases with an increase in inhibitor concentration and contact time, while corrosion rate decreases with increases in contact time and extract concentration. FT-IR result of the extract corrosion product shows that some of the compounds present in the FT-IR result of the extract appear in the corrosion product, which indicates activity has taken place between the metal surface and the inhibitor, as such reduces the rate of aluminum corrosion in 1m HCL. Also SEM image of the inhibited metal coupon appears to be smooth when compared with the uninhibited one, which proved the inhibitor reduces the rate of aluminum corrosion in 1m HCL. This implies that the extract can inhibit acid corrosion of aluminum.

Keywords: Aluminum, Baobab tree pulp, corrosion inhibitor.

Introduction

Corrosion is the deterioration or destruction of metals and alloys in the presence of an environment by chemical or electrochemical means. The medium in which the metal undergoes corrosion is termed as corrosive or aggressive medium [16]. Corrosion product formed are chemical compounds on the metal in the oxidized form, with the exception of gold and platinum, all other metals corrode and transform themselves into substance similar to the mineral ores from which they are extracted [16]. Corrosion cost manifest in the form of premature deterioration or failure which necessitate maintenance, repair, and replacement of damage part [17]. Corrosion has a vast environmental and economic impact on all the surface of national infrastructure like highways, bridges, buildings, chemical processing unit, wastewater treatment and virtually all metallic objects in our day to day life activities [14]. Adansonia digitata which belongs to the kingdom plantae, phylum,- tracheophyta, class,- magnoliosida, order,-malveles, family,-malvaceae, Genus,-Adansonia, specie,-digitata, common name,-boabo, local name,-kuka whose leaves are commonly used in Southeast Asia as a folk medicine for the treatment of dermatitis and hepatitis [15].

This species is globally distributed from Indo-Maleisa to Australia. *Adansonia digitata* is a large, spreading tree now distributed throughout the tropics in coastal environments. The tree is tolerant of strong winds, salt spray, and moderately high salinity in the root zone. It grows principally in freely drained, well aerated, sandy soils. The species has traditionally been very important for coastal communities, providing a wide range of non-wood products and services. As a result, the purpose of this work is to look into the inhibitory and adsorption properties of ethanol extracts of *Adansonia digitata* for the corrosion of zinc in HCL medium [16]. The *Adansonia digitata* has been analyzed with some of the following major phytochemicals identified; α-farnesene (21.3%), octadedecane (11.7%), hexadecanoic acid (9.5%), dibutyl phthalate (9.1%), 1,2,3-trimethoxy-5-(2-propenyl)- benzene (6.6%), neoisothujol (5.8%), 1,2,4-trimethoxy-5-(1-propenyl)-benzene (4.5%) 6,10,14-trimethyl-2-pentadecanoic, 1-(2,3,6-trimethyl phenyl)-(E)-3-buten-2-one, geranyl acetone, hexadecanoic acid (21.0%) and 2-ethyl-3,6- dimtheylpyrazine (19.2%), (Z)-phytol (41.2%), fatty acid palmitic acid (11.0%), and the (E)-nerolidol (4.7%) [17]. Because of the presence of these phytochemicals in the molecule, it can be used as a corrosion inhibitor since they possess, (-bond, aromatic system, conjugated bond, heteroatoms and long carbon chains [17].

MATERIAL AND METHODS

MATERIAL

The sheets of zinc, A72357 type used for this study were obtained from the Novara group Limited England. The zinc specimens used had the following percentage elements of composition: Zn (99.591), Sr (0.227), Fe (0.094), Co (0.011), Ni (0.011), Si (0.021), and Zr (0.045). Each sheet was 0.4 mm thick and was manually pressed into 5 x 4 cm weight loss coupons and 2 x 3 cm electrochemical coupons. Before usage, the coupons were cleaned in 100% ethanol, dried in acetone, and stored in moisture-free desiccators (7).

METHODS

Sample collection and Preparation

The Baobab tree pulp was obtained from Federal University Gashua, Yobe State (Lat. 11^0.44.820'N, Long. $011^0$58.153' E) in North-East Nigeria. The samples were washed in distilled water, dried in the shade, ground, and steeped in an ethanol solution for 48 hours. The material was filtered after 48 hours. Evaporation of the filtrate at 338K (65 ^{0}C) was used to guarantee that the sample was free of ethanol (8)

The acid (HNO_3) concentration utilized in the study was 0.1 M, whereas the inhibitor Baobab tree pulp) concentrations were 0.1, 0.2, 0.3, 0.4, and 0.5 g. (per liter of the acid solution). These were dissolved in 1liter solution containing 0.1 M of HNO_3 respectively (8).

The preparation of acid was done using equation:

Stock concentration (C_1)

3.1

Where:

% purity of HNO_3 acid=70 %

Density of HNO_3=1.42 g/cm^3

Molar mass of acid= 63 g/mol

Thus, the concentration of stock from which the 0.1 M HNO_3 solution was prepared from is 15.8 M.

The quantity (volume) of the stock needed is then estimated by using the relation:

$C_1V_1 = C_2V_2$……..3.2

Where:

C1 = Concentration of the stock,

C2 = the required molarity of the acid (0.1 M),

V1 = Volume of stock solution needed to prepare the 0.1 M acid and

V2 = Volume of acid required (1000 cm^3)

3.3

Therefore, approximately 6.3 cm^3 of the stock was made up to 1000 cm^3 in a 1 L standard flask to obtain the 0.1 M concentration of nitric acid solution (9).

CORROSION MONITORING

Weight Loss Method

$$V_1 = \frac{C_2 V_2}{V_1}$$

A previously weighed metal (zinc sheet) was completely immersed in 250 mL of the test solution (different concentrations of acid, inhibitor as described in section 3.2) in an open beaker. The beaker was inserted into a water bath maintained at a temperature of 303 K. Similar experiments were repeated at 313 K, 323 K and 333 K. In each case, the weight of the sample before immersion was measured using Scaltec high precision balance (Model SPB31). Prior to measurement, each coupon was washed in 5 % chromic acid solution (containing 1% silver nitrate) and rinsed in de-ionised water (7). The difference in weight for a period of 168 hours was taken as total weight loss. The inhibition efficiency (% I) for each inhibitor was calculated using equation 3.4 (Ameh, 2015). Where W_1 and W_2 are the weight losses (g/L) for zinc in the presence and absence of inhibitor in HNO_3 solution, respectively. The degree of surface coverage θ is given by the equation 3.5. The corrosion rates for zinc corrosion in different concentrations of the acid and other media have been determined for 168h immersion period from weight loss using Equation 3.6 (Yurt *et al.*, 2005).

where CR is the corrosion rate of zinc, A is the surface area of the zinc coupon in cm^2 and t is the period of immersion in hours.

The Fourier Transform Infrared Analysis

FTIR analyses of the gums were carried out using Cary-630 Agilent Fourier Transform Infra-red Spectrophotometer. Each coupon was separately dipped in 250 mL of 1.0 M (HNO_3) of acid-inhibitor concentration for 7 days to form an adsorbed layer after which they were removed, dried and scraped with a sharp razor blade taken for analysis. The sample for FT-IR studies were prepared by finely mixing the scrapped corrosion product with spectroscopically and then pressed by using a die so as to get a fine transparent pellet. The spectrum was recorded by scanning the sample through a wave number range of 650 to 4000 cm^{-1} (10).

Scanning Electron Microscopy Studies

Surface morphologies of the zinc coupons before and after inhibition were studied using a JSM-5600 LV scanning electron microscope of JEOL, TOKYO, Japan. 1 cm x 1 cm coupons were dipped separately in each of the following: blank solutions and 1 M of acid-inhibitor (HNO_3) solutions for 7 days. The coupons were removed, rinsed with distilled water and dried in the air. Each sample was mounted on a metal stub and sputtered with gold in order to make the sample conductive. Scanned images were taken at an accelerating voltage of at a 15 kV (14).

Zinc Weight (g)

The zinc metal obtained were also measure in grams using an electronic weighing balance.

RESULT

This chapter presents results from experimental weight loss analysis informed by tables and figures, discussed using cited relevant literature.

EXPERIMENTAL RESULT

This section highlights various results obtained from laboratory experiment

Weight Loss Analysis: The results obtained from weight loss measurement include; inhibition efficiency (IE%), corrosion rate and surface coverage which are presented in Table and Figure 1, 2, & 3.

TABLE 1: Variation of Inhibition efficiency (%IE) with time

TIME(h)	%Inhibition Efficiency		
	0.2g/l	0.4g/l	0.6g/l
1.00	7.14	14.28	27.27
2.00	12.50	18.75	33.33
3.00	18.18	22.72	36.36
4.00	20.00	24.00	40.00

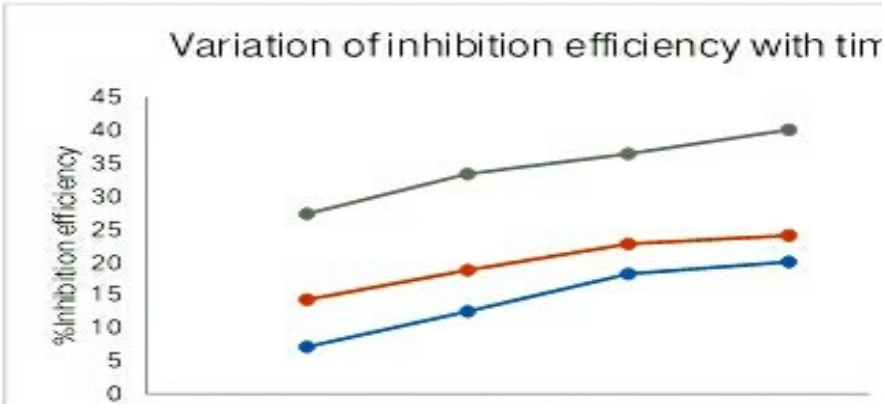

Figure 1: Variation of Inhibition efficiency with time

TABLE 2: Variation of weight loss with time

TIME(h)	Weight loss			
	Blank	0.2g/l	0.4g/l	0.6g/l
1.00	0.14	0.13	0.12	0.11
2.00	0.16	0.14	0.13	0.12
3.00	0.22	0.18	0.17	0.14
4.00	0.25	0.20	0.19	0.15

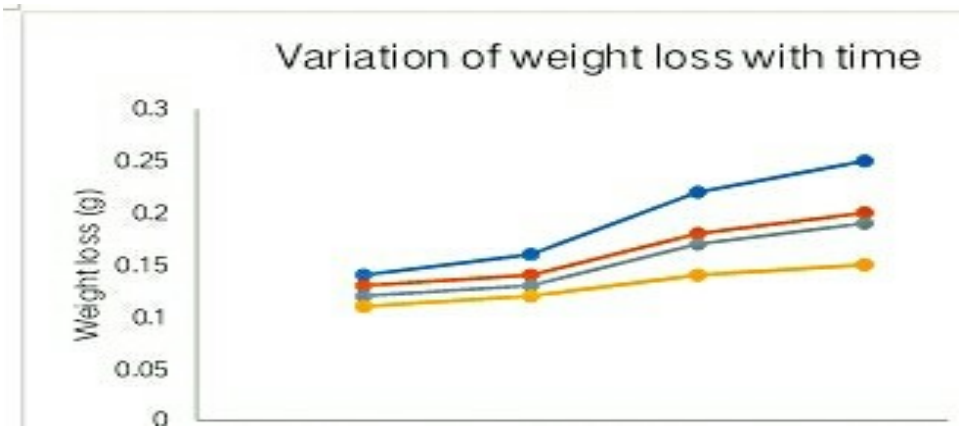

Figure 2: Variation of weight loss with time

TABLE 3: Variation of corrosion rate with time

TIME(h)	Corrosion rate ($gcm^{-1}h^{-1}$)			
	Blank	0.2g/l	0.4g/l	0.6g/l
1.00	0.035	0.035	0.03	0.027
2.00	0.02	0.017	0.016	0.015
3.00	0.018	0.015	0.014	0.012
4.00	0.016	0.013	0.012	0.009

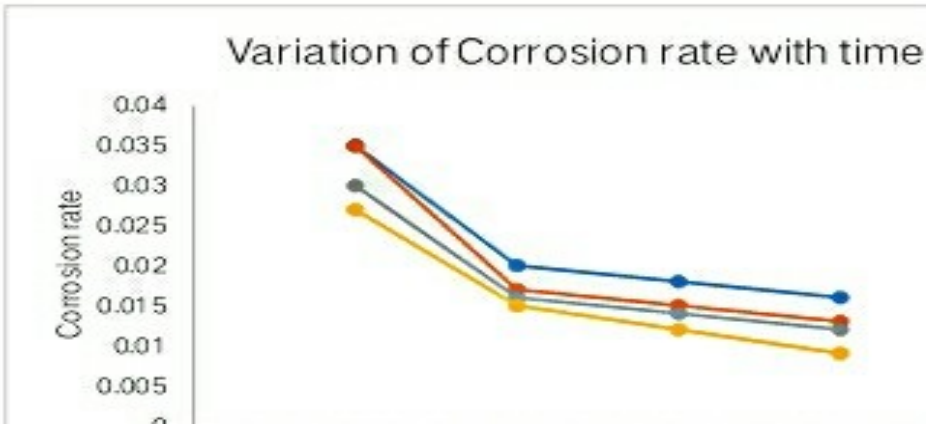

Figure 3: Variation of corrosion rate with time

FOURIER TRANSFORM INFRARED (FT-IR) ANALYSIS

The FT-IR analysis was carried out on baobab tree pulp extract, corrosion product of uninhibited aluminum and inhibited aluminum in 1M HCl/0.60 g/l extract solution after an immersion time of 4hrs determine the structural organization of *Calotropis procera* extract under study and corrosion product [12]. The result analysis is present in Figures 4, 5 and 6 for baobab tree pulp extract, uninhibited corrosion product of aluminum in 1M HCl and that of inhibited aluminum in 0.6g/l respectively.

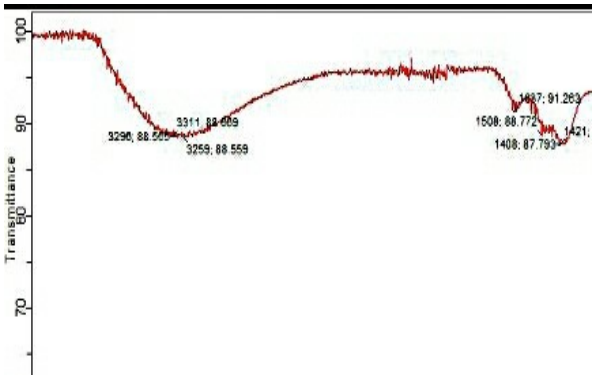

Figure 4: FT-IR spectrum of the inhibited solution

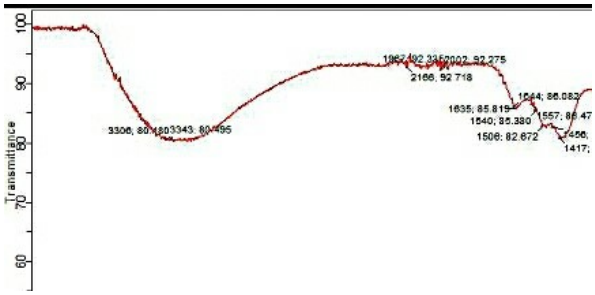

Figure 5: FT-IR spectrum of blank aluminum sample

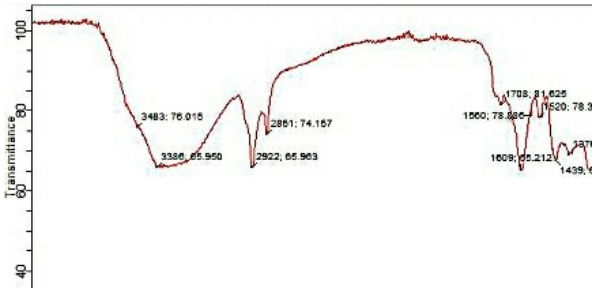

Figure 6: FT-IR spectrum of the boabao tree pulp extract

SCANNING ELECTRON MICROSCOPY (SEM) ANALYSIS

The surface examination of unreacted aluminum samples in both uninhibited and inhibited samples with calotropis *procera*

extract was examined with scanning electron microscopy (SEM) analyzed and the results are presented in plates 1, 2 and 3, respectively.

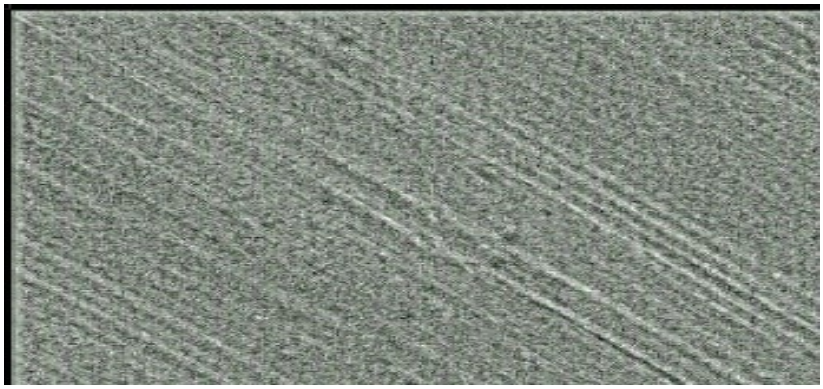

Plate 1: SEM micrograph for unreacted aluminum

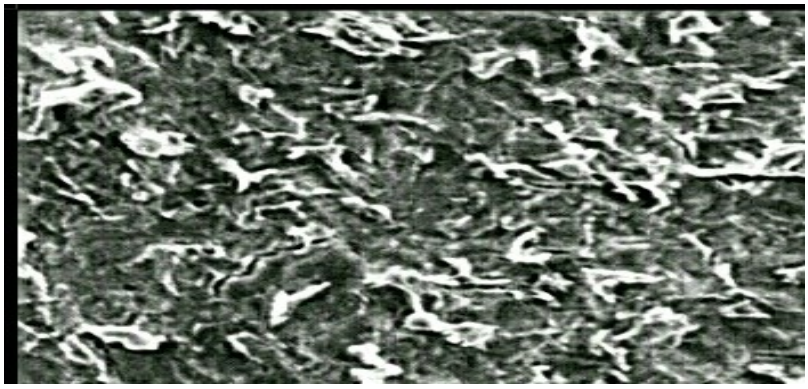

Plate 2: SEM micrograph for uninhibited aluminum in hydrochloric solution (blank)

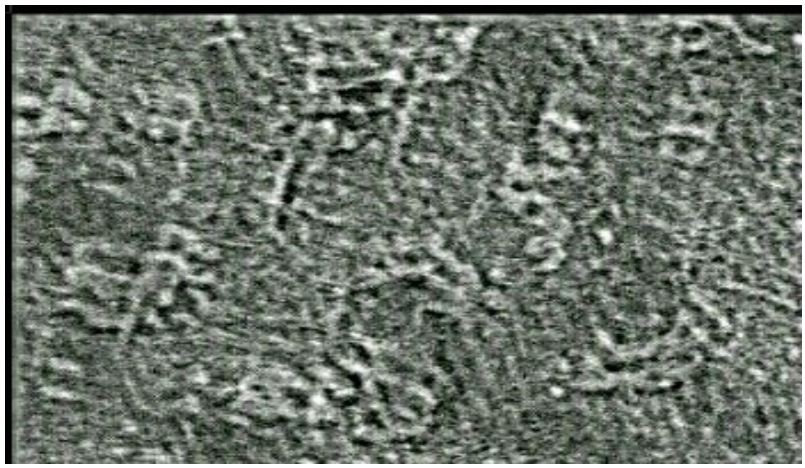

Plate 3: SEM micrograph for inhibited aluminum in hydrochloric acid solution.

The SEM result shows the SEM micrograph of aluminum in inhibited solution of hydrochloric acid by boabo tree pulp extract has a smooth surface as compare to the touch and crack surface of aluminumin the inhibited solution of HCl. This is due to the adsorption of plant extract on the metal surface which reduces the level of corrosion HCL hydrochloric acid medium.

DISCUSSION

Weight loss

I. Variation of Inhibition efficiency with time

Weight loss measurement were studied for the corrosion process at different time intervals (1 hr, 2 hrs, 3 hrs and 4 hrs) at 303 K. The result of the variation of inhibition efficiency was presented in Table 1 and Figure 1 respectively. The results show the inhibition efficiency of the extract increases with an increase in contact time and extract concentration. The highest inhibition efficiency of 40% was observed at 4hrs immersion time and 0.60 g/l inhibitor concentration, while the lowest inhibition of 7.14 was observed at 1hr immersion time and 0.20 g/l. This shows that an increase in contact time between the metal surface and the inhibitor solution increases the adsorption of inhibitor molecules on the metal surface [10].

II. Variation of weight loss with time

The result of the variation of weight with time was presented in Table 2 and Figure 2 respectively. The result indicates varying the immersion time results in the decrease in weight loss. The lowest weight loss of 0.15 was observed at 4hrs immersion time and 0.60g/l extract concentration, while the highest weight loss of 0.25 was observed at 4hrs immersion in uninhibited solution. This shows that weight loss increases with an increase in immersion time in uninhibited solution while it decreases with a rise in inhibitor concentration. This means that the addition of inhibitor extract to the acid solution reduces the effect of acid attack on metal surface [8].

III. Variation of corrosion rate with time

The result of the variation of corrosion rate with time was presented in Table 3 and Figure 3 respectively [11]. The result show that corrosion rate decreases with increase in time and inhibitor concentration. The highest corrosion rate of 0.035 was observed at 1hr immersion time in blank solution while the lowest corrosion rate of 0.009 was observed at 4hrs immersion time and 0.60g/l inhibitor concentration. This indicate that the rate of corrosion decreases with increase in contact time, because the surface of the metal was gradually covered with corrosion product which provide the surface additional protection [1].

Fourier Transform Infrared Spectroscopy (FT-IR)

The FT-IR analysis of boabo tree pulp extract, uninhibited aluminum in 1M HCl and inhibited aluminum in 0.60g/l inhibitor concentration was carried out and the result was presented in Figure 4, 5 and 6 respectively [13]. It was observed that spectra of uninhibited sample are IR inactive with some minor noise from the machine. While IR spectra of inhibited sample reflect the functional groups observed in the spectra of boabo tree pulp extract. This shows that some interaction occurs between the metal surface and the inhibitor extract in a form physical adsorption. It can be suggested that the extract has some protective ability toward metal surface.

Scanning Electron Microscopy (SEM)

The SEM result shows that SEM micrograph of aluminumm in inhibited solution of hydrochloric acid by boabo tree pulp extract has a smooth surface as compare to the touch and crack surface of aluminumm in uninhibited solution of HCl. This is due to the adsorption of plant extract on the metal surface which reduce the level of corrosion hy hydrochloric acid medium.

CONCLUSION

The *Calotropis procera* extract was found to have inhibitive action toward aluminum corrosion in 1M HCl. Extract concentration plays a vital role in percentage inhibition efficiency as observed in weight loss measurement. Weight loss of aluminum and corrosion rate were both found to decrease with an increase in inhibitor concentration. The determination of corrosion of inhibitors from natural sources, such as Sodom apple (*Calotropis procera*), presents an opportunity to explore environmentally friendly alternatives to synthetic inhibitors. The present study investigates the activity of calotropis procera extract as a corrosion inhibitor of aluminum in 1M HCl solution. The result obtained from weight loss measurement reveals that *Calotropis procera* extract molecules can inhibit the corrosion of aluminum in 1M HCl solution.

The inhibition efficiency of the extract was found to increase with increase in contact time and extract concentration. The weight loss also was found to decrease with an increase in inhibitor concentration, while the corrosion rate was found to decrease with an increase in contact time and inhibitor concentration.

The FT-IR result of the corrosion product reflects the presence of molecules of the inhibitor from the FT-IR result of the extract. This shows that some activity has taken place between the metal surface and the extract.

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