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Corrosion Control of Aluminium Alloys Using Teak Tree Leaf Extract

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ABSTRACT

Corrosion inhibition of aluminium alloy by teak tree leaf extract was studied to investigate the effect on corrosion using Gravimetric experiment in 0.5M HCl. The teak tree leaves were obtained from nearby locality, washed and dried, after which they were ground to micro size. Reflux method was use to obtain 25g of leaf extract. Aluminium alloy coupons were dipped into the solutions and were removed at two hours interval. The concentration of the leaf extract was studied using weight loss measurement and the result showed that teak tree leaf extract is good inhibitor. The gravimetric measurement results showed that teak tree leaf extract increased corrosion rate at the beginning of the control experiment and subsequently corrosion rate reduced uniformly over 8 hours of exposure time. These findings showed that the inhibitor has the capacity to protect the metal surface by forming passive film. The inhibition efficiencies obtained varies from 75.33% after 8 hours of exposure to 99.80% after 2 hours of exposure of immersion, both at the 0.4 concentration of the inhibitor in the corrosive media.

KEYWORDS: Alloy weight loss, Corrosion inhibition, Gravimetric analysis, Inhibition efficiency, Leaf extract, Reflux method.

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1.0 INTRODUCTION

Aluminium is also another significant metal with enormous potential. The useful properties of aluminium and its alloys are clear decisive features for metallurgists, engineers, producers and designers to apply them in different environments. These experts are constantly on the watch for superior materials and state-of-the-art processes. Aluminium has a density of 2700 kg/m^3 and the least weight amongst all ordinary metals. It is estimated to be nearly three times as radiance as steel (steel density is about 8700 kg/m^3) (Mahanta *et al.,* 2017). The decrease of weight is a valuable answer to issues of superior energy productivity, reduced carbon footprint and business productivity on account of reduced overheads on materials handling in the workshop. Other advantages attributed to aluminium and its alloys are outstanding thermal and electrical conductivity; better corrosion resistance in atmospheric/industrial/marine environments; applicability for surface treatments and ease of recyclability without any difficult outcome on its basic and important features and the added advantage of compact energy cost in the processing.

The various qualities of aluminium and its alloys also enlighten the reason for its increasing operation in automated applications. Manufacturers of apparatus with rotating or moving mechanism, like robots, are making use of a growing amount of aluminium components to decrease inertia or sluggishness. The thermal conductivity of aluminium is a major factor in heat exchange considerations in electronics, seawater desalination, hydraulic ventilation and air conditioning (HVAC) exchangers and plastics industry where the utilization of aluminium alloy moulds with distinct mechanical properties can reduce fabrication cycles by about one-third (Hartley, 2016). The ever-increasing applications to which aluminium and its alloy can be put have put pressure on meeting demands. Demands for aluminium products have been increasing over the years - there is a doubling in the demand since 1990 (Omotosho, 2016). universal energy cost has been on the increase, this has negatively affected the processing of aluminium. Even though it is easily recycled with attendant energy cost reduction during processing, it is essential that critical steps are taken to protect and control the corrosion of aluminium alloys in hostile industrial service environments.

The use of green inhibitors offers a flexible means of controlling the corrosion of aluminium and its alloys. These steps will extend the time for replacement of parts and lessen the pressure on demand. These will also have the added advantage of reducing power needs thereby decreasing the carbon footprints (Omotosho, 2016).

Organic inhibitors in general have heteroatoms. Oxygen, Nitrogen, and Sulphur are found to have advanced basicity and electron concentration and thus act as corrosion inhibitor (Amitha *et al.,* 2011). Oxygen, Nitrogen, and Sulphur are the major cause of film formation on a metal surface.

The utilization of organic compounds comprising of oxygen, sulphur, and mostly nitrogen to decrease corrosion extent on steel has been widely studied. Base on the data obtained, most organic inhibitors are adsorbed on the surface of the metal through the displacing of water molecules on the surface thereby causing a compacted barrier. unluckily the use of a quantity of chemical inhibitors has been reduced due to high cost of synthesizing them and how deadly and unsafe they are to humans (Halambek *et al.*, 2010). Therefore, eco-friendly corrosion is considered as the option to replace the main chemical inhibitor to foster sustainable ingenuousness to the environment.

Organic corrosion inhibitor is not toxic, they are not expensive, mostly renewable and are easily extracted. They can be used as alternative corrosion inhibitors from different types of plant extract (Okafor *et al.*, 2008; Okafor *et al.*, 2010; Oguzie, 2008). The justification of the use of plant products as corrosion inhibitors is justifiable because of the phytochemical compounds present in them, they also share relatable molecular and electronic structures with the conventional organic inhibitor molecules (Oguzie *et al.*, 2010).

The use of corrosion inhibitors is a good alternative to prevent metal corrosion and to increase the durability or lifetime of metals. Another disadvantage of synthetic compounds, most especially inorganic inhibitors is that they are very toxic to both human beings and the environment, notwithstanding the point that most of them reacts as anticorrosive inhibitors (Raja & Sethuraman, 2008; Andreani *et al.,* 2016). This problem has led the several researches carried out to discover eco-friendly readily available corrosion inhibitors and there is an increased initiative to employ plant extracts as corrosion inhibitors for metals in acidic or alkaline solutions. Plants extract are exceedingly rich sources of natural chemical compounds that are ecofriendly inexpensive and easy to extract and renew (Abiola & James, 2010). Green organic compounds are efficient inhibitors because they contain different polar functional groups with S (Sulphur), O (Oxygen), and N (Nitrogen) atoms in molecules, heterocyclic compounds and π electrons. Plant extracts that contains tannic acid, polyphenols, polysaccharides, alkaloids, amino acids, and vitamins are already used as an alternative corrosion inhibitor. These compounds are well-known to penetrate into metal surfaces to form a film that blocks the reaction with the surrounding element and the metal surface thereby causing a reduction in the corrosion rate (Verma & Khan, 2016a).

Our atmosphere and surrounding is filled with a lot of chemicals. The surround is mostly the composition of several natural and synthetic chemical compounds. Some of these compounds are stable while some are unstable and unpredictable. However, they all interface with the metallic surfaces that can deteriorate the integrity of structural members, as well as effect reliability over time. The drop process includes all materials, and are not restricted to metals but also includes glass, plastic, concrete, leather and paper materials. The corrosion or degradation of plastic accompanied with discoloration, crazing, phase separation is caused by UV-light, heat, moisture or biological activities normally by physical, chemical or biological reactions (Raja *et al.*, 2016; Shah *et al.*, 2008). Atmospheric pollutants like SO2, CO2 and hydroxyl ion can cause corrosion in glass. Hydroxyl ions attack on siloxane bonds leads to extraction of silica (Franz, 1980; Melcher, 2010). Corrosion of concrete materials is also a very significant economic predicament. The preservation costs of concrete microbial corrosion (CMC) of sewer pipelines in Hamburg (Germany) in 1970s reached up to €25 million while in Los Angeles (USA), the sewer pipe of 208 km in an entire length of 1900 km had been dented by CMC, and the remedy expenses were as high as $400 million (Kong *et al.*, 2017).

Corrosion as defined by American Society for Testing and Materials (ASTM International) is the weakening of a material due to chemical reaction occurring on the surface of the material. That is, the “electrochemical and chemical reaction between a metal material and the environment that causes the deterioration of the material (ASTM G15-02., 2002). However, the most desirable and obvious is corrosion of metals which is defined by ISO (International Organization for Standardization) as the change of metal due the physiochemical reaction between the metal and the environment. It leads deterioration of the structural integrity of the metal, this can lead to massive destruction of the purpose the metal is designed to perform. This can also alter the environment, the industrial system (ISO 8044:2015). The total cost of corrosion includes “the design and construction or manufacturing includes cost of maintenance, cost of replacement of corroded metal piece, cost due to the disposal or disvalue of a corroded structural element or metallic member. Koch (2017) estimated the cost to be up to US$2.5 trillion and it represents about 3.4% of GDP globally.

The recent practice has shown that the use of various corrosion control procedures and practice, involving the use of organic corrosion inhibitors can lead to a saving of 15–35% of the cost of corrosion. The variation of the cost of corrosion is because of the difference types of industries but its dominant in the transportation and chemical industry. In 2014 china, cost of corrosion in transportation was estimated to be 268.72 billion RMB which is 23.97% of the total costs of corrosion realized (Hou *et al.*, 2017). Corrosion is an ever-present phenomenon that can’t be completely eradicated or prevent it. The solution being established can do as much as slow down the reaction with the surface of the metal. However, change in our climate and environment characteristics has caused the process of controlling it a nightmare. Also, pollution and order environmental factors has made corrosion control very costly. Only the increase of global temperature by 2^oC originates an escalation of corrosion rates by up to 15% (Stewart *et al.*, 2012).

2.0 MATERIALS AND METHODS

The aluminium (Al) plate was obtained from the aluminium company within. For weight loss study, the Al plate was prepared with size 2 x 2 x 1cm for polarization measurements (Prithiba & Rajalakshmi, 2016)

2.1 Equipment and Apparatus

An electronic FAJA weighing balance of model FA2004b and weighing capacity of 0.0001g – 200g was used for all forms of gravimetric analysis during the course of work. Other apparatus used were:

i. Measuring cylinders, flat bottom flask, beaker and other glass wares
ii. Retort stand/clamps
iii. Volumetric flask
iv. Reflux apparatus

2.2 Miscellaneous Materials

Other materials used without specifications are:

i. Cotton wool (for cleaning the metal surface)
ii. Thread and sticks (for suspending the coupons)
iii. Bowl (for washing the coupon)
iv. Scissors (for cutting the suspending thread)
v. Brush (for polishing the coupon during washing)
vi. Medium glass container (for immersion and retention of corrodents,)
vii. Paper Tape (for labelling)

2.3 Preparation of Plant Extract (Inhibitor)

Adapting the method from Prithiba (2016), *Tectona grandis* leaf shall be collected from the nearby locality and shade dried. 25g of the dried flowers shall be refluxed with 500ml of 1M HCl for 3 hours and kept overnight. The cooled extract shall be filtered and diluted up to 500ml (5% extract) to obtain the stock solution. Further dilutions shall be done from stock solution to obtain the desired concentration (Prithiba & Rajalakshmi, 2016). The extract was used to prepare a stock solution of the following concentrations; 0.1mg/l, 0.2mg/l, 0.3mg/l, 0.4mg/l, 0.5mg/l, using the formula below.

$$C_1V_1 = C_2V_2 \quad (1)$$

$$V_{extract} = \frac{C_{dil}V_{500ml}}{C_{extract}} \quad (2)$$

where:

$C_1 = C_{extract}$
$V_1 = V_{extract}$
$C_2 = C_{dil}$
$V_2 = V_{500}$

2.4 Gravimetric Experiments

Adapting the method from Mejeha (2012), glass hook and rod was used to suspend a pre-cleaned and weighed coupons of dimension $2 \times 2 \times 1\ cm$ inside beakers. The sample was totally immersed in a 300mL still and unstirred test solutions. The time of Immersion varied from 1 to 8 days in 1M HCl. To conclude on the weight loss with respect to time, retrieved coupon from the test solution was properly cleaned, dried and weighed. The weight loss was calculated by subtracting the weight after immersion from the weight before immersion with respect to the time. The effect of temperature on Al corrosion and corrosion inhibition was investigated by performing experiments in 0.5M HCl for 2-h immersion period. All

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tests run in triplicate for good data reproducibility (Mejeha *et al.*, 2012).
The weight loss, corrosion rate and the Inhibition efficiency ($\eta_{gravimetric}$ 0/0) was calculated by equations:

$$\Delta W = W_1 - W_2 \quad (3)$$

Where W_1 and W_2 are samples weight before and after immersion,
Corrosion rate was estimated as

$$CR = \frac{K\Delta W}{At\rho} \quad (4)$$

3.0 RESULTS AND DISCUSSION

3.1 Weight loss measurements

MS plates were washed and weighed before being immersed in 1M HCl having an extract concentration extracts ranging from 0 to 450 ppm for 3 h at 298 (±2) K. Then, the distilled water was used to rinse the MS plates. Later the MS plates were air-dried before measuring the final weight. The data obtained for the corrosion behaviour of Aluminium in 0.5M HCl acid solution containing leaves extract within the concentration range of 0.1-0.5g/l from weight loss measurements are presented in Figure 1 as well as Table 1.

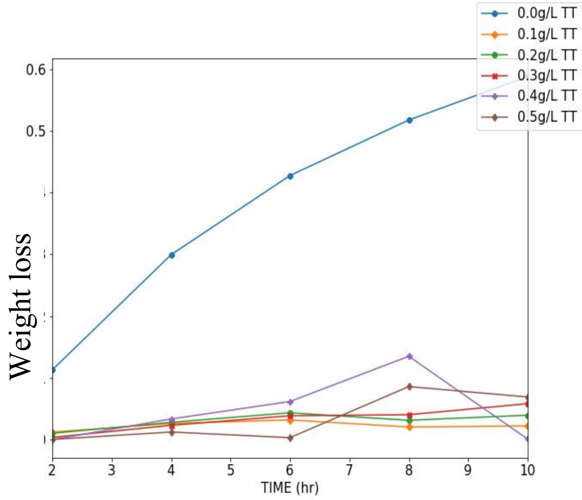

Figure 1: Weight loss measurement for aluminium alloy in 0.5M HCl in the absence (control) and presence of different concentrations of teak tree leaves extracts

Figure.1 shows the weight loss-time curves for aluminium in 0.5mHcl without and with different concentrations of teak tree leaves extract. It is seen from the plots that the amount of the material loss (g/L) decreases significantly in the presence of the extracts compare to the blank acid solution and was also found to be dependent on the concentration of the extracts. This indicates that additives inhibit the corrosion of aluminium in 0.5M HCl.

Table 1: Weight loss parameters calculated from the initial and the final weight measurement.

S/N	Exposure time hrs.	Control 0.0g/2	Weight Loss at Different Concentration				
			0.1g/l	0.2g/l	0.3g/l	0.4g/l	0.5/
1	2	0.1131	0.0126	0.0106	0.0039	0.0002	0.0007
2	4	0.2995	0.0265	0.0283	0.0235	0.0338	0.0127
3	6	0.4276	0.0322	0.0438	0.0390	0.0620	0.0035
4	8	0.5175	0.0208	0.0316	0.0407	0.1352	0.0862
5	10	0.5877	0.0225	0.0399	0.0585	0.0013	0.0693

Table 2: Calculated values of Corrosion rate for aluminium alloy of 0.5MHCl acid in the absence and presence of teak tree extract

S/N	Exposure time hrs.	Control 0.0g/2	Corrosion rate for control experiment and different concentration of teak tree leaf extract in corrosive media.				
			0.1g/l	**0.2g/l**	**0.3g/l**	**0.4g/l**	**0.5/**
1	2	187.55	20.79	18..98	10.21	0.38	1.23
2	4	267.77	23.35	24.56	19.75	29.80	9.79
3	6	250.49	18.26	25.22	23.52	36.57	2.14
4	8	233.26	8.25	13.97	18.03	57.54	37.96
5	10	204.32	8.43	15.20	20.70	0.48	22.96

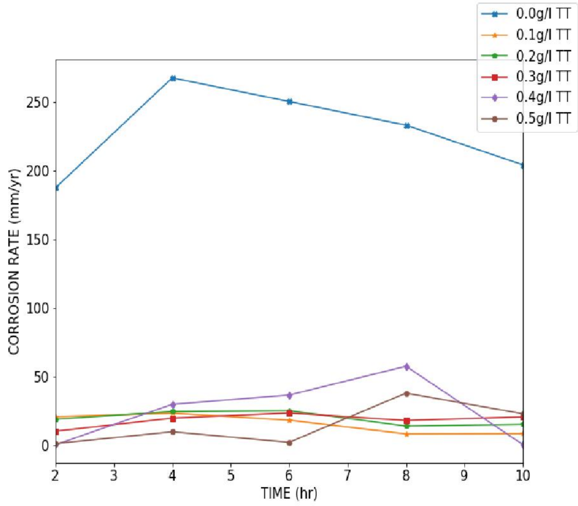

Figure 3: Corrosion rate plots of aluminium alloy in 0.5M HCl in the presence of different concentrations of teak tree leaves extracts

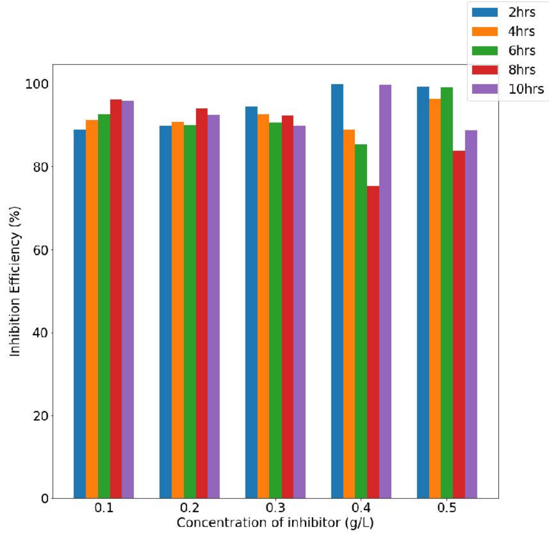

Figure 2: Inhibition efficiency plots of aluminium alloy in 0.5M HCl in the presence of Teak tree leaves extract

The values of corrosion rate in the absence and presence of teak tree leave extract at different concentration are listed in Table 2 and the values from the Table was used to plot Figure 2. The result from the Table 2 as well as Figure 2 indicate that the extracts act as good corrosion inhibitor for aluminium 0.5m HCl solution given that the corrosion rate was reduced in the presence of the extracts compare to their absence. Further inspection of the table and Figure 2 reveals that corrosion rate increases with increase in concentration with the highest value obtained at the 0.4g/L for all the systems investigated.

Table 3: Calculated inhibition Efficiencies (%) at various exposure time (t) for gravimetric method

Conc	Efficiencies at various exposure time				
	2hrs	4hrs	6hrs	8hrs	10hrs
0.1	88.91	91.28	92.72	96.25	95.87
0.2	89.88	90.83	89.93	94.01	92.56
0.3	94.56	92.63	90.61	92.27	89.87
0.4	99.80	88.87	85.40	75.33	99.77
0.5	99.35	96.34	99.15	83.73	88.76

3.2 Gravimetric Measurements

This method is widely used to study corrosion of metals (Mejeha *et al.,* 2012; Nnanna *et al.,* 2011; Nnanna *et al.*, 2013). The corrosion rate and inhibition efficiency were calculated and plotted for the acidic corrosion and inhibition of aluminum alloy AA8011. The plots are given in Figure 1 to Figure 3. The results showed that there was increase in corrosion rate at the beginning of the control experiment and subsequently corrosion rate reduced uniformly over the rest 8 hours of exposure. However, on addition of plant extract and increase in concentration of the plant extract remarkably showed that the metals were protected by the inhibitor compared to that of the control experiment. These findings show that the inhibitor has the capacity to protecting the surface by forming a passive film. The inhibition efficiencies obtained varied from 75.33% after 8 hours of exposure and 99.80% at the $2^{\text{-hour}}$ immersion, both at the 0.4 concentration of the inhibitor in the corrosive media.

4.0 CONCLUSION

The result obtained in this research show that the teak tree leave extract inhibit the corrosion of aluminum alloy in 0.5MHCl solutions to an extent. Inhibition efficiency varies at various concentration, generally it was observed that the maximum and the minimum inhibition efficiency of the extract was found to be 99.80% and 75.33% at 2hrs and 8hrs of 0.4 concentration. Teak tree leave extract normally have organic compounds containing hetero atoms (N, S, O) with lone pair of electrons, is selected as the best green inhibitor.

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