Green Inhibitor for Corrosion of Aluminium Alloy AA8011A in Acidic Environment

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ABSTRACT – *In this study, a green inhibitor, Terminalia ivorensis was used to inhibit the corrosion of Aluminium alloy, AA8011A in 0.5 M HCl environment using gravimetric method and studying the adsorption isotherm. Results obtained revealed that Terminalia ivorensis inhibits corrosion of aluminium alloy AA8011A with a peak of 89.56% at 0.5g/L concentration of the extract in the environment. The efficiency increased with increasing concentration. Adsorption studies showed that there was a mix in the adsorption isotherms implying that both the chemisorption and physiosorption adsorption reactions took place.*

Keywords: Adsorption isotherms, Aluminium alloy AA8011A, Green inhibitors, *Terminalia ivorensis*.

INTRODUCTION:

Wear and tear of equipment is caused majorly by the corrosion of the metals that make up the equipment. It increases downtime and at the same time reduces the life of the equipment. Accidents could also arise as a product of corrosion of metals. Aluminium and its alloys are very reactive metals, being greatly prone to corrosion as they are being used as vessels, in pipes, machinery, and chemical batteries. Hydrochloric acid (HCl) solutions are used for pickling, chemical and electrochemical etching of aluminum. It is very important to add corrosion inhibitors to prevent metal dissolution and minimize acid consumption [1]. Aluminum relies on the formation of a compact, strongly adherent and continuous passive oxide film is developed on aluminum upon exposure to the atmosphere or aqueous solutions. This is responsible for the corrosion resistance of aluminum in most environments [2-3]. The surface film formed is amphoteric, dissolving substantially when the metal is exposed to high concentration of acids or basis. When the oxide film increases above and below the pH 4-9 range, corrosion inhibitors are needed to stop the corrosion of aluminium (El-Etre, 2003). There are many methods to minimize corrosion. Cathodic protection, use of inhibitors, use of anticorrosive coatings is different methods recorded by researchers for this purpose.

Although different techniques have been reported to address the degradation behavior of metals in some environments, the use of inhibitors for controlling and reducing the corrosion rate of metals have been reported to be effective in contact with aggressive medium. Inorganic substances such as phosphates, chromates, dichromate and arsenates have been found effective as inhibitors of metal corrosion, but a major disadvantage is their toxicity and as such their use has come under severe criticism [4-6]. Among the alternative corrosion inhibitors[7], organic substances containing polar functions with nitrogen, oxygen and/or sulphur atoms in a conjugated system have been reported to exhibit good inhibiting properties [4, 8-10]. The organic inhibitor presented in this research work is *Terminalia ivorensis* Chev, commonly known as Black afara.

Terminalia species are native from Africa and are now widely spread out in tropical and sub-tropical regions [11]. They have been reported to be a large genus consisting of over 200 species of very large tress that occur extensively in the tropical regions of the World. *Terminalia ivorensis* (Black afara) is a large deciduous forest tree which belongs to the family *Combretaceae* [12]. The plant height ranges from 15 – 46 meters with small buttress and sometimes fluted roots. The branches are whorled with deciduous young shoots and foliage falling a few years after initial growth, leaving sockets to mark their original position on the bole [13]. *Terminalia ivorensis* is found in China, Guinea, Ivory Coast, Liberia, Nigeria and Serra Leone [14]. It is usually found in forest and transition zones, most times used as ornamentals. Reports from [14] showed that *Terminalia ivorensis* contained Saponnin (+), Alkaloids (++), Tannins (++) and Flavonoids (++). These are compounds whose presence in extracts inhibits the corrosion of metals in acidic environment [15 – 18].

MATERIALS AND METHODS:

Aluminium alloy AA8011A was used for this research work. The spark analysis was done at First Aluminium, Port Harcourt to determine the composition as Si = 0.796%, Fe = 0.796%, Cu = 0.022%, Mn = 0.075%, Mg = 0.013%, Zn = 0.002%, Ti = 0.015%, Cr = 0.002%, Ni = 0.002%, V = 0.007%, Pb = 0.007% and the rest being Aluminium. The aluminium alloy was cut into coupons of 20 mm X 20 mm, creating a hole of 1.5 mm at the centre for suspending the metal in the acidic environment. The surface of the metal was degreased by scourging with silicon emery paper, washing in detergent and subsequently ethanol. Acetone was used to dry off the surface of the coupon just before being hanged for air-drying.

The stock inhibitor solution was prepared using the reflux method. *Terminalia ivorensis* leaf which had been earlier dried was pulverized and 10 g was refluxed in 0.5 M HCl solution for three hours. The stock inhibitor solution was used to prepare inhibitor test solutions of concentrations from 0.2 g/L to 0.5 g/L. The aluminium alloy AA8011A was exposed to the acid solution without the inhibitor and also to the acid solution containing the different concentrations of the inhibitor. To quench further corrosion after the time elapsed, the aluminium alloy was dipped in nitric acid, distilled water, and ethanol in succession. It was then dried in acetone. All weighing was done with electronic balance JA 1003A and all reagents used were analytical grade. Triplicate tests were run and average results reported.

RESULTS AND DISCUSSION:

Using the mathematical equation represented in equation 1, the corrosion rates of the aluminium alloy AA8011A was calculated. This was done after a gravimetric study in the presence and absence of *Terminalia ivorensis* extract in 0.5 M HCl was done for two (2) hours of exposure.

$$CR = \frac{K\Delta W}{\rho A t} \quad (1)$$

Where CR = corrosion rate in mm/yr

K = Corrosion rate constant, 87.6mm/yr

Δw = mass loss in grams (g)

ρ = Density of the aluminium alloy (g/cm^3)

A = Area of the Aluminium alloy coupon (cm^2)

t = Exposure time (yr)

Results generated from the calculation with equation 1 were plotted against concentration as shown in Figure 1. The graph shows that increasing the concentration of the inhibitor in the acidic medium decreases the corrosion rate of the aluminium alloy. Also, the graph of weight loss against the concentration of the inhibitor was plotted in Figure 2. As corrosion rate decreased, weight loss also decreased with increasing inhibitor concentration.

To calculate the inhibition efficiency, equation 2 was used. The results simulated were plotted against the concentration in Figure 3. From the modeled bar chart, an increase in the concentration of the inhibitor in the acidic environment increased the efficiency of the inhibitor to the corrosion of aluminium alloy AA8011A.

$$\mathrm{I}(\%) = \left(1 - \frac{\rho_{\mathrm{inh}}}{\rho_{\mathrm{blank}}}\right) \times 100 \quad (2)$$

To get an understanding of the adsorption mechanism involved, a mathematical estimation of the adsorption modes of the inhibitor was done. The adsorption mode predominant in the research will depend on the factors such as the composition of the extract and nature of the surface charge on the metal. If the surface charge is negative, the adsorption of cations will be favoured whereas anion adsorption is favoured in a positive surface charge. The plot of the ratio of concentration to surface coverage (C/θ) against concentration (g/L) displayed a straight line for *Terminalia ivorensis* extract in 0.5 M HCl. The plot (Figure 4) showed a linear plot with correlation of 0.97. A plot (Figure 5) of surface coverage (θ) against the natural logarithm of the concentration shows the correlation that adsorption energy decreases linearly with increase in the value of the surface coverage (θ). The Temkin isotherm is often used for the description of chemisorptions models [10, 19]. Theoretically, it is related by the equation 3.

$$\theta = \frac{1}{f}(\ln KC) \quad (3)$$

Equation 3 implies that

$$\theta = \frac{1}{f}\ln K + \frac{1}{f}\ln C \quad (4)$$

Values of R^2 generated from the Langmuir and Temkin isotherm reveals that there was a higher surface adsorption process but the chemisorption mechanism wasn't left behind as it was also prevalent.

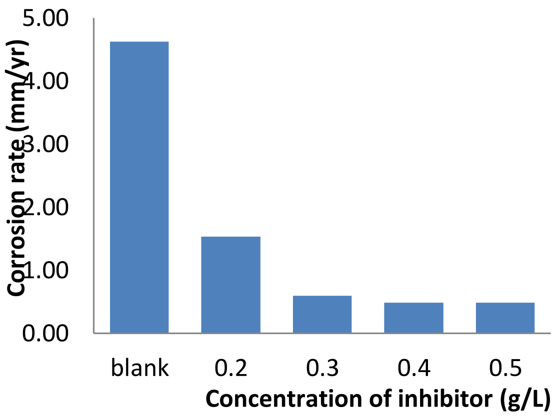

Figure 1: A plot of Corrosion rate of various concentrations of *Terminalia ivorensis* in 0.5 M HCl on mild steel

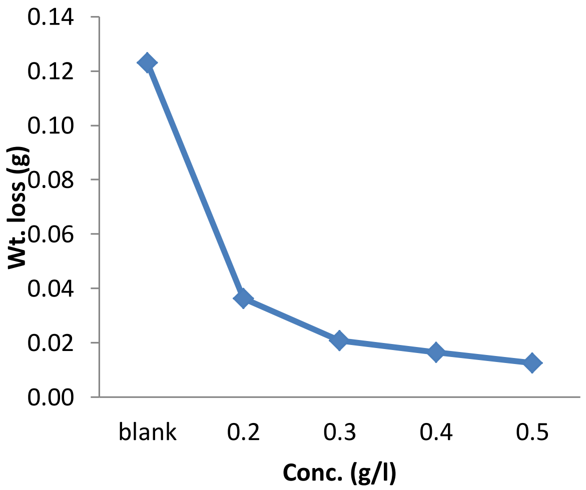

Figure 2: A plot of weight loss (g) of various concentrations of *Terminalia ivorensis* in 0.5 M HCl on mild steel

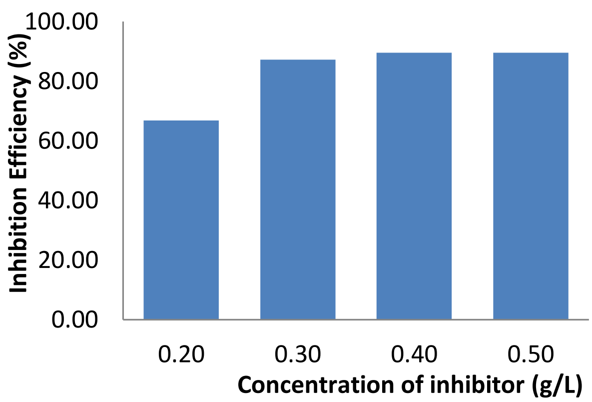

Figure 3: Inhibition efficiencies of different concentrations of *Terminalia ivorensis* in 0.5 M HCl

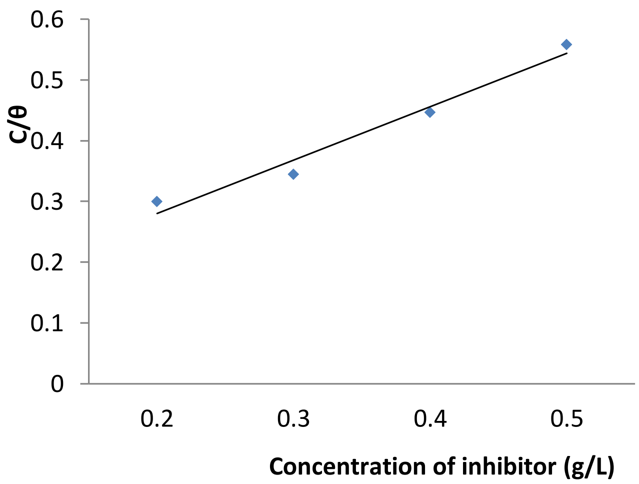

Figure 4: Langmuir isotherm for *Terminalia ivorensis* adsorption on Aluminium alloy AA8011A in 0.5 M HCl

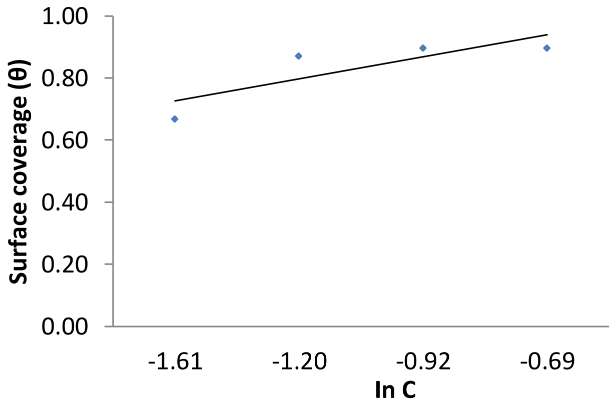

Figure 5: Temkin isotherm for *Terminalia ivorensis* adsorption on Aluminium alloy AA8011A in 0.5 M HCl

CONCLUSION:

From the present research and study, it is found that the extract of *Terminalia ivorensis* Chev can be used as an inhibitor for the corrosion of aluminium alloy AA8011A in acidic medium. The inhibitor acts by adsorbing itself on the surface of the aluminium alloy according to the studies done using the adsorption models – Langmuir and Temkin isotherm models. Both chemisorptions and physical adsorptions take place in the inhibitive action of the leaf extract on aluminium alloy, also the inhibitive action of *Terminalia ivorensis* is dependent on the concentration of the inhibitor in the medium – the higher the concentration of the inhibitor, the higher the inhibition efficiency.

REFERENCES:

[1] M. Abdallah, "Guar Gum as Corrosion Inhibitor for Carbon Steel in Sulphuric Acid Solution". Port. Electrochim. Acta., 2004, vol. 22: 161-175.

[2] A. A. El Maghraby, "Corrosion inhibition of Aluminium in Hydrochloric acid solution using Potasium Iodate Inhibitor". The Open Corrosion Journal, 2009, vol. 2, pp. 189-196.

[3] A.Y. El-Etre, "Inhibition of aluminum corrosion using Opuntia extracts". Corrosion science, 2003, vol. 45 (11), 2485-2495

[4] E. Oguzie, "Corrosion inhibition of Aluminium in acidic and alkaline media Sansevieria trifaciata extract". Corros. Sci., 2007, vol. 49: 1527- 1539.

[5] I. B. Obot, N. O. Obi-Egbedi, S. A. Umoren, E. E. Ebenso, "Synergistic and antagonistic effects of anions and Ipomoea invulcrata as green corrosion inhibitor for aluminium dissolution in acidic medium". *Int J Electrochem Sci*, 2010; **5**(7):994–1007.

[6] D. E .Arthur, A. Jonathan, P.O. Ameh and C. Anya, "A review on the assessment of polymeric materials used as corrosion inhibitor of metals and alloys". Int J Ind Chem 2013, vol. 4: 2. https://doi.org/10.1186/2228-5547-4-2.

[7] B. E. Amitha Rani and J. B. Bharathi Bai, "Green Inhibitors for Corrosion Protection of Metals and Alloys: An Overview". International Journal of Corrosion Volume 2012 (2012), Article ID 380217.

[8] L. Nnanna, B. Onwuagba, I. Mejeha, K. Okeoma, "Inhibition effect of Some Plant Extracts on the Acid Corrosion of Aluminium Alloy". Afri. J. Pure Appl. Chem., 2010, 4(1): 011-016.

[9] A. Maayta and N. Al- Rawashdeh, "Inhibition of Acidic Corrosion of Pure Aluminium by Some Organic Compounds." Corros. Sci., 2004; 46: 112- 119.

[10] E. Oguzie, "Corrosion Inhibitive Effect and Adsorption behaviour of Hibiscus sabdariffa Extract on Mild Steel in Acidic Media". Port. Electrochim. Acta., 2008; 26: 303-314.

[11] D.J. Collins, C.A. Pilotti, F.A. Wallis, Triterpene acids from some Papua New Guinea Terminalia species. Phytochemistry, 1992, vol. 32, 881–884.

[12] N. D. Hawthorne, "Ecological Profiles of Ghanalian Forest Tress". Tropical Forestry Papers 29. Oxford Forestry Institute, Department of Plant Sciences, University of Oxford, UK. p345, 1995.

[13] C.O. Adewunmi, J.M. Agbedahunsi, A.C. Adebaja, A.J. Aladesanmi, N. Murphy, J. Inando, "Ethnomedicine: Screening of Nigerian medicinal plants for trypanocidal properties". J. Ethnopharmacol., 2001, vol. 77: 19-24.

[14] I. I. Johnny, N. J Ekong, and J. E. Okon, "Phytochemical Screening and Anti-hyperglycaemic Activity of Ethanolic Extract of Terminalia ivorensis A. Chev. Leaves on Albino Wistar Rats". Global Advanced Research Journal of Medicine and Medical Science (ISSN: 2315-5159) 2014, Vol. 3(8) pp. 186-189.

[15] C. S. Akoma, E. Osarolube, O. E. Abumere, L. A. Nnanna, W. O. John, "Corrosion Inhibition of Crown Corks of Carbonated Drinks Using Chyrsohyllym Albidium Extract". Int'l J. of Eng. Res. and Rev., 2015, Vol. 3, Issue 4, pp 67-74.

[16] P. C. Okafor, M. I. Ikpi, I. E. Uwah, E. E. Ebenso, U. J. Ekpe, S. A. Umoren, "Inhibitory action of Phyllanthus amarus on the corrosion of mild steel in acidic medium".Corros. Sci. doi:10.1016/j.corsci.2008.05.009, 2008

[17] P. C. Okafor, E. E. Ebenso, "Inhibitive action of Carica papaya extracts on the corrosion of mild steel in acidic media and their adsorption characteristics". Pigment and Resin Technol. 2007, vol. 36: 134 -140.

[18] A. Y. El-Etre, M. Abdallah, "Natural honey as corrosion inhibitor for metals and alloys. II C-steel in high saline water". Corros. Sci., 2000; 42: 731-738.

[19] P. Praus, M. Turicova, M. Valaskova, Study of Silver Adsorption on Montmorillonite. J. Braz. Chem. Soc., 2008; 19(3): 549-556.