International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 6, Issue 3 [March 2017] PP: 05-10

Inhibition Effect of Combination of Vernonia Amygdalina, Piper Nigrum and Telfairia Occidentalis Extracts on Corrosion of Al-1.0wt%Zn Alloy in Acidified Environment

C. C. Ogbu[1], C. W. Onyia[2] and N. I. Amalu[3]
[1]*Dept. of Metallurgical Engineering Technology, Akanu Ibiam Federal Polytechnic, Unwana, Afikpo, Ebonyi, Nigeria.*
[2] *Dept. of Metallurgical & Materials Engineering, Enugu State University of Science and Technology, Enugu, Nigeria.*
[3]*Projects Development Institute (PRODA), Enugu, Nigeria.*

Abstract:- The inhibition effect of combination of vernonia amygdalina, piper nigrum and telfaria occidentalis extracts on the corrosion of AI-1.0wt% Zn alloy in HCl environment has been investigated. Each set of experiment consisted of pre-weighed samples of the alloy immersed in 0.5M and 1.0M HCl, each containing total volume of $100cm^3$ and $200cm^3$ of the extracts. The experiment took 28 days to complete with weekly withdrawal of samples for analysis which involved determination of the final weight loss and corrosion rate of the samples. The results showed that combination of vernonia amygdalina, piper nigrum and telfaria occidentalis extracts does not successfully inhibit the corrosion of AI-1.0wt% Zn alloy in HCl environment and follows no definite trend which is unexpected since the individual application of these extracts has been previously found to effectively inhibit corrosion of aluminium alloys in acidified environment. The reason for this is suspected to be as a result of non-compatibility in their molecular structure. As there may be some expletive polyphasic dispersion which is a very common occurrence in dispersed systems. It is therefore not advisable to use a combination of these extracts as corrosion inhibitor for AI-1.0%wt Zn alloy in HCl environment.

Keywords: *Corrosion rate, Passivation, Aluminium alloy, Vernonia amygdalina (bitter leaf), Piper nigrum (uziza), Telfairia occidentalis (ugu).*

I. INTRODUCTION

Corrosion is the destructive attack of a material by reaction with its environment. The serious consequences of the corrosion process have become a problem of worldwide significance. Many efforts have been made by researchers to find ways of combating this unwanted phenomenon, one of which is the use of corrosion inhibitors. A corrosion inhibitor is a chemical substance that, when added in small concentration to an environment, effectively decreases the corrosion rate [1]. The use of inhibitors to prevent metal dissolution and acid consumption is one of the most practical methods for protection against corrosion, especially in acidic media. Corrosion inhibitors reduce or prevent the oxidation-reduction reactions accompanying metal corrosion from taking place at anode or cathode. They are adsorbed on metal surfaces and form a barrier to oxygen and moisture by complexing with metal ions or by removing corrodent from the environment. Some of the inhibitors facilitate formation of passivation film on the metal surface [2]. Although synthetic chemicals are the most effective corrosion inhibitors, they are highly costly and toxic. They may cause reversible (temporary) or irreversible (permanent) damage to the organs of humans and animals. The toxicity of these chemicals may manifest either during the synthesis of the compound or during its applications.The safety and environmental issues of corrosion inhibition arising in industries have always been a global concern. It is necessary to find out low cost corrosion inhibitiors that are easily available and environmentally acceptable i.e eco-friendly (green) inhibitors.Natural plant extracts are easily available and also biodegradable in nature and therefore safe to the environment. These extracts contain large variety of organic compounds through which they get adsorbed on the metal surface, displacing water/solvent molecules and forming compact barrier films on the metal surface. Thus, they inhibit metal dissolution to a considerable extent [2]. Combating metal corrosion by ‘‘eco-friendly (green) inhibitors’’ shows environmental conservation awareness and concern besides cost efficacy. Attempts have been made to investigate the inhibitory propensity of vernonia amygdalina, piper nigrum and telfaria occidentalis on the acid corrosion of aluminum alloy. From literature the action of vernonia amygdalina on the acidic corrosion of 2S and 3SR aluminum alloys in 0.1M HNO_3 gave an average corrosion rates of 6.5×10^{-3} and 5.5×10^{-3} mpy for 2S and 3SR alloys respectively. In 0.1M HCI, 18.2×10^{-3} and 10.4×10^{-3} mpy were obtained for the two alloys respectively. From the results the highest inhibition efficiency for the 0.1M HCI and 0.1M HNO_3, were 49.5% and 72.5% respectively. However, the 0.2 g/l concentration gave the best result for all the samples [3].

The inhibitory propensity of the piper nigrum linn seeds extracts towards acid corrosion for aluminum alloy (AA110) was investigated by employing weight loss method. It was found that the inhibition efficiency of these extracts increased with an increase in their concentration [4]. Some other researchers studied the corrosion suspectibility of Al-1.0% Zn alloy in acidified vernonia amygdalina, piper nigrum and telfaria occidentalis and reported that the individual application of these extracts gave excellent corrosion inhibition in the following order: telfaria occidentalis>piper nigrum>vernonia amygdalina [5].In line with the increasing interest in the use of plant extracts in corrosion control systems, this work is aimed at investigating the inhibition effect of combined application of vernonia amygdalina, piper nigrum and telfaria occidentalis extracts on corrosion of Al-1.0wt%Zn alloy in acidified environment.

II. EXPERIMENTAL PROCEDURE

2.1 Preparation of Test Coupons and Environment

The materials used for this experiment were rolls of aluminum wire (99% pure Al), pure granulated zinc, leaves of vernonia amygdalina, piper nigrum and telfaria occidentalis. The other materials were acetone, hydrochloric acid, distilled water, laboratory beakers, measuring cylinders, etc.The equipment used were: lathe machine, drilling machine, surface crucible furnace and analytic digital weighing balance.The charge materials consisted of aluminum wires and granulated zinc. The aluminum wires were thoroughly cleaned and charged into the crucible furnace. The composition of the aluminum was carefully worked out using appropriate charge calculations [6]. After melting of the aluminum wires at 660^oC, the temperature of the furnace was reduced to 419^oC followed by the addition of calculated quantity of granulated zinc to the molten aluminum. The molten AI-1.0wt%Zn alloy was cast into rods and machined to 2.97cm x 1.5cm coupon samples and initial specific area of 27.8516cm^2. Each sample coupon was drilled with a 10mm drill bit to provide hole for the suspension of the strings and the surface of each thoroughly polished.The corrosion tests were carried out in acidic media of two concentrations (0.5M and 1.0M) made from stock solution of hydrochloric acid (36.5% purity assay) using standard procedure [7]. The technique adopted for this research is the weight loss technique.The leaves were plucked directly from the plants. The fresh leaves were ground immediately after plucking using a manual grinding machine after washing in clean water. The ground fresh leaves were soaked in 250mIs of distilled water for about 35 minutes (soaking process). After soaking, a sieve cloth was used to squeeze out extract laden solution into a container. This extracted solution served as the inhibitor solution from which measured volumes were introduced into the acid solutions for this experiment.

2.2 Experimentation

To three different beakers of 0.5M HCI, 50cm^3 of telfaria occidentalis and 50cm^3 of vernonia amygdalina, 50cm^3 of telfaria occidentalis and 50cm^3 of piper nigrum, 50cm^3 of vernonia amygdalina and 50cm^3 of piper nigrum extracts were added respectively. Same volumes of the extracts were also added to three different beakers of 1.0M HCI respectively. Also to three different beakers of 0.5M HCI, 100cm^3 of telfaria occidentalis and 100cm^3 of vernonia amygdalina, 100cm^3 of telfaria occidentalis and 100cm^3 of piper nigrum, 100cm^3 of vernonia amygdalina and 100cm^3 of piper nigrum extracts were added respectively. Same volumes of the extracts were also added to three different beakers of 1.0M HCI respectively. Each beaker of the HCI solution consisted of combination of two different extracts. A total of twelve beakers were used for the test and in each of the beakers four (4) pre-weighed sample coupons of the alloy were suspended and the test set-up was allowed to stand for 28 days (672 hours). A sample coupon was then withdrawn from each beaker every 7 days (168 hourly), washed with distilled water, cleaned with acetone, dried in open air and weighed to determine the final weight loss using a digital weighing balance.

Corrosion rate of the samples were determined using the following equation for corrosion penetration rate, *CPR* [8]:

$$CPR = \frac{K\Delta\omega}{\rho A t} \quad (1)$$

where $\Delta\omega$ is the weight loss after exposure time t, ρ and A are density and exposed specimen total surface area respectively, K is a constant whose magnitude depends on the system of unit used. When *CPR* is in mm/yr, then K = 87.6 and $\Delta\omega$, t, ρ and A are expressed in mg, hrs, g/cm^3 and cm^2 respectively. For most applications, a corrosion penetration rate less than about 0.50 mm/yr is acceptable [8].

III. RESULTS AND DISCUSSION

Figs. 1-6 are the plots of weight loss against time for AI-1.0wt%Zn immersed in 0.5M and 1.0M HCI containing 100cm^3 and 200cm^3 of the different vegetable extracts of telfairia occidentalis/vernonia amygdalina, telfairia occidentalis/piper nigrum and vernonia amygdalina/piper nigrum respectively. It is observed that the curves for the weight loss against time for Al-1.0wt%Zn in the HCI media containing the extracts in their combined forms did not follow a definite trend as was observed for the individual application of these extracts, which followed a typical path of a passivating metal [5], rather there were fluctuations in the curves.It is evident from Tables 1 and 2 that the corrosion rates of the Al-1.0wt%Zn alloy were generally high for all the combinations of the vegetable extracts in HCl environment. The corrosion rates obtained were all too high to be acceptable since for most applications, it is a corrosion penetration rate less than about 0.50 mm/yr that is acceptable [8].From the results obtained, it is observed that the variation of either the volume concentrations of the different plant extracts at a constant acid molarity, or the variation of the acid molarity at a constant volume concentration did not generally result in very low and acceptable corrosion rate of AI-1.0wt%Zn immersed in 0.5M and 1.0M HCI acid containing 100cm^3 and 200cm^3 of telfairia occidentalis/vernonia amygdalina extracts, telfairia occidentalis/piper nigrum extracts and vernonia amygdalina/piper nigrum extracts respectively, as can be observed in the cases of their separate applications [5].

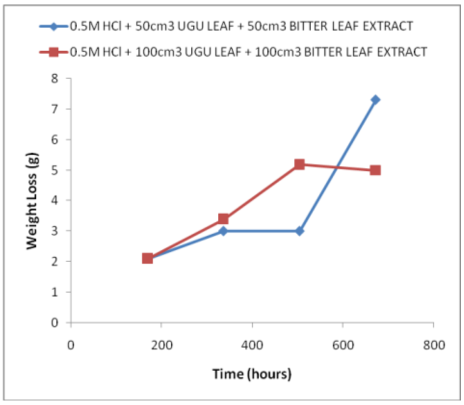

Figure 1: Plots of weight loss against time for AI-1.0wt%Zn immersed in 100cm^3 and 200cm^3 of telfaria occidentalis/vernonia amygdalina extract + 0.5M HCI

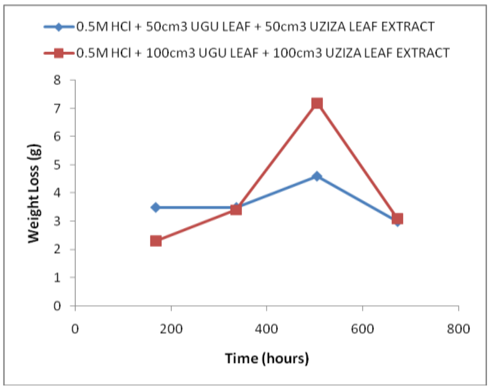

Figure 2: Plots of weight loss against time for AI-1.0wt% Zn immersed in 100cm^3 and 200cm^3 telfaria occidentalis/piper nigrum extract + 0.5M HCI

Figure 3: Plots of weight loss against time for AI-1.0wt%Zn immersed in 100cm^3 and 200cm^3 of vernonia amygdalina/piper nigrum extract + 0.5M HCI

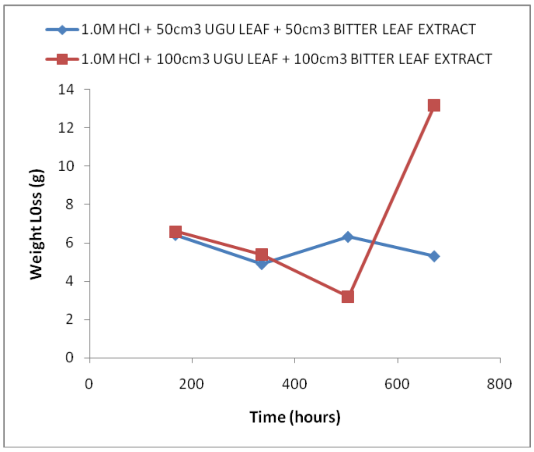

Figure 4: Plots of weight loss against time for AI-1.0wt%Zn immersed in 100cm^3 and 200cm^3 of telfariaoccidentalis/vernoniaamygdalina extract + 1.0M HCI

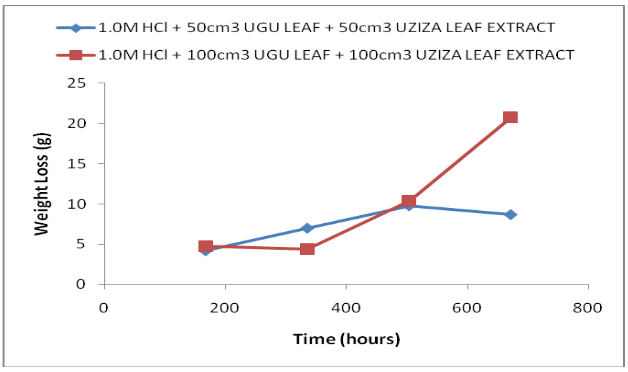

Figure 5: Plots of weight loss against time for AI-1.0wt%Zn immersed in 100cm^3 and 200cm^3 of telfaria occidentalis/piper nigrum extract +1.0M HCI

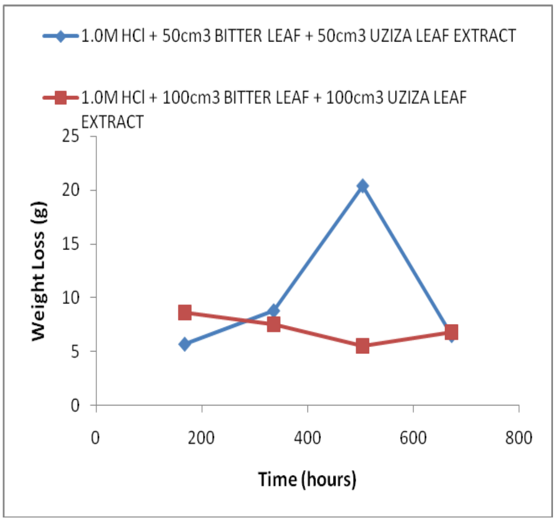

Figure 6: Plots of weight loss against time for AI-1.0wt%Zn immersed in 100cm^3 and 200cm^3 of vernonia amygdalina/piper nigrum extract +1.0M HCI

Table 1: Corrosion characteristics of Al – 1.0wt% Zn immersed in 100cm^3 of the vegetable extracts in molar concentrations of HCl.

Coupon Sample	Time (hours)	Weight loss (g)	Corrosion rate (mm/yr)
0.5M HCl + 50cm^3 UGU LEAF+50cm^3 BITTER LEAF EXTRACT			
AI-1.0%Zn	168	2.10	14.3257
AI-1.0%Zn	336	3.00	10.2327
AI-1.0%Zn	504	3.00	6.8218
AI-1.0%Zn	672	7.30	12.4497
0.5M HCl + 50cm^3 UGU LEAF+50cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	3.50	23.8762
AI-1.0%Zn	336	3.50	11.9381
AI-1.0%Zn	504	4.60	10.4601
AI-1.0%Zn	672	3.00	5.1163
0.5M HCl + 50cm^3 BITTER LEAF+50cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	4.10	27.9693
AI-1.0%Zn	336	2.70	9.2094
AI-1.0%Zn	504	6.50	14.7805
AI-1.0%Zn	672	5.70	9.7210
1.0M HCl + 50cm^3 UGU LEAF+50cm^3 BITTER LEAF EXTRACT			
AI-1.0%Zn	168	6.40	43.6593
AI-1.0%Zn	336	4.90	16.2094
AI-1.0%Zn	504	6.30	14.7805
AI-1.0%Zn	672	5.30	9.7210
1.0M HCl + 50cm^3 UGU LEAF+50cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	4.20	28.6514
AI-1.0%Zn	336	7.00	23.8762
AI-1.0%Zn	504	9.80	22.2845
AI-1.0%Zn	672	8.50	14.8373
1.0M HCl + 50cm^3 BITTER LEAF+50cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	5.70	38.8841
AI-1.0%Zn	336	8.80	30.0158
AI-1.0%Zn	504	20.40	46.3881
AI-1.0%Zn	672	6.50	11.0854

Table 2: Corrosion characteristics of Al – 1.0wt% Zn immersed in 200cm^3 of the vegetable extracts in molar concentrations of HCl.

Coupon Sample	Time (hours)	Weight loss (g)	Corrosion rate (mm/yr)
0.5M HCl + 100cm^3 UGU LLEAF+100cm^3 BITTER LEAF EXTRACT			
AI-1.0%Zn	168	2.10	14.5004
AI-1.0%Zn	336	3.40	11.5970
AI-1.0%Zn	504	5.20	11.8244
AI-1.0%Zn	672	5.00	8.5272
0.5M HCl + 100cm^3 UGU LEAF+100cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	2.30	15.6901
AI-1.0%Zn	336	3.40	11.5970
AI-1.0%Zn	504	7.20	16.3723
AI-1.0%Zn	672	3.10	5.2869
0.5M HCl + 100cm^3 BITTER LEAF+100cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	3.20	21.8296
AI-1.0%Zn	336	2.70	9.2094
AI-1.0%Zn	504	6.20	14.0983
AI-1.0%Zn	672	4.80	8.1861
1.0M HCl + 100cm^3 UGU LEAF+100cm^3 BITTER LEAF EXTRACT			
AI-1.0%Zn	168	6.60	45.0237
AI-1.0%Zn	336	5.40	18.4188
AI-1.0%Zn	504	3.20	7.2766

AI-1.0%Zn	672	13.20	22.5119
1.0M HCl + 100cm^3 UGU LEAF+100cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	4.80	32.7445
AI-1.0%Zn	336	4.40	15.0079
AI-1.0%Zn	504	10.40	23.6488
AI-1.0%Zn	672	20.80	35.4732
1.0M HCl + 100cm^3 BITTER LEAF+100cm^3 UZIZA LEAF EXTRACT			
AI-1.0%Zn	168	8.60	58.6672
AI-1.0%Zn	336	7.50	25.5816
AI-1.0%Zn	504	5.50	12.5066
AI-1.0%Zn	672	6.80	11.5970

IV. CONCLUSION AND RECOMMENDATION

A conclusion is drawn that the combination of vernonia amygdalina, piper nigrum and telfaria occidentalis extracts does not successfully inhibit the corrosion of Al-1.0wt%Zn in HCl environment and follows no definite trend which is unexpected since the individual application of these extracts has been found to effectively inhibit corrosion of aluminium alloys in acidified environment [5].The reason for the fluctuations in the plots of weight loss against time for AI-1.0wt%Zn immersed in 0.5M and 1.0M HCI containing 100cm^3 and 200cm^3 respectively of the different vegetable extracts in their combined forms is suspected to be as a result of non-compatibility in their molecular structure. As there may be some expletive polyphasic dispersion (two immiscible phases or discontinuous interfaces) which is a very common occurrence in dispersed systems.
It is therefore not advisable to use a combination of these extracts as corrosion inhibitor for AI-1.0wt% Zn alloy in HCl environment.

REFERENCES

[1] Pierre R. Roberge, Handbook of Corrosion Engineering, McGraw-Hill Companies, Inc., 2000; p 833
[2] Rekha N. Nair, Shashi Sharma, I. K. Sharma, P.S. Verma, Alka Sharma Rasayan, Inhibitory efficacy of Piper Nigrum Linn Extract on corrosion, J. Chem., 2010; Vol. 3, No.4, pp. 783-795
[3] Gregory O. Avwiri and F. O. Igho, Inhibitive action of Vernonia Amygdalina on the Corrosion of Aluminum Alloys in acidic media, Materials Letters, July 2003; Vol. 57, Issues 22-23, pp. 3705-3711.
[4] D. Eaton & C. Klaasen, The Basic Science of Poisons, 5th Edition 1996, McGraw-Hill, New York.
[5] N. E. Idenyi, C. E. Ekuma, and S. I. Neife, Comparative Analysis of The Influence of Inhibitor Concentrations on the Corrosion Susceptibility of Al–1.0% Zn Alloy in Acidified Vernonia Amegdalina, Pipernigrum and Telferia Occidentalis. The Minerals, Metals and Materials Society (TMS) Annual Meeting and Exhibition, 2008, p 307.
[6] C.O. Nwajagu, Foundry Theory and Practice, 1st Edition 1994, ABC Publisher Limited, Enugu, Nigeria, pp. 288, 289, 293.
[7] M.O. Abatan and M.J. Makinde, Screening Azadirachtaindica and Poisum Satirum for possible anti Malaria activities, Journals of Ethmophamacology, 1986; Vol. 17, pp. 85-93.
[8] William D. Callister, Jr. and David G. Rethwisch, Materials Science and Engineering - An Introduction, 9th Edition 2014, John Wiley & Sons, Inc., pp 690-691