Evaluations of Inhibitive Property of *Chromolaena odorata* Extract on Aluminum in 1M HCl and 0.5M NaOH Environment.

C.M. Ibegbulam, B.Eng.[1*]; C.N. Anyakwo, Ph.D.[2]; O.K. Ukoba, M.Eng[1]. (in view); R.I. Ekwujuru, B.Eng.[2]; E. Ekos, B.Eng.[2]; and C.S. Nwaosu, B.Eng.[2]

[1]Engineering Materials Development Institute, Akure, Nigeria.
[2]Federal University of Technology, Owerri, Nigeria.

E-mail: chinedu.ibegbulam@live.co.uk*

ABSTRACT

This research is aimed at investigating the corrosion inhibition of aluminum in HCl and NaOH using *Chromolaena odorata* leaf extract. This study was conducted with 15 liters of 1M HCl and 0.5M NaOH to which 10ml, 15ml, 20ml, 25ml, of the extract were used. Appreciable corrosion inhibition of the aluminum was achieved by *Chromolaena odorata* in the acid and base solutions. Results showed that lowest corrosion rate was attained with inhibitor concentration of 25ml/liter in both the acid and base solutions. Furthermore, corrosion was higher in the base solution than in the acid solution based on weight losses which were 1.241g and 0.965g per day, respectively. Highest inhibitor efficiency of 34.45% and 33.8% in 1M HCl and 0.5M NaOH were attained with inhibitor concentration of 25ml/liter, respectively. The inhibiting efficiency increased with increasing inhibitor concentration. It is probable that higher inhibition efficiencies would be attained as the utilized inhibitor concentration that is markedly low increases.

(Keyword: aluminum, *Chromolaena odorata*, hydrochloric acid, HCl, sodium hydroxide, NaOH, corrosion, inhibition)

INTRODUCTION

Aluminum is known to exhibit passive behavior in aqueous solution and corrosion of the metal is known to depend on processes associated with the passivating surface oxide film. Due to the wide spread utility of aluminum in a variety of corrosive environments, different classes of compounds have being studied in effort to develop more efficient inhibitors of metal corrosion. The protective efficiency of some compounds is based on the adsorption ability of their molecules with the polar group acting as active centers for adsorption to the metal surface. The resulting adsorption film then acts as a barrier, separating the metal from the corrosive. Inhibition efficiency depends on such factors as metal composition as well as molecular structure of the inhibitor, which determine the chemical, mechanical and structural characteristics of the adsorption layers formed (Oguzie, et al., 2004).

The study of organic corrosion inhibition is an alternative field of research due to its usefulness in various industries. Most of well known acid inhibitors are organic compounds that contain nitrogen, sulphur, and multiple bonds in the molecules through that which are adsorbed on the metal surface (Ebenso et al., 2004).

Chromolaena odorata is a species of the flowering shrub in the sunflower family, Asteraceae. It is native to North America, from Florida and Texas to Mexico and the Caribbean and has been introduced to tropical Asia, West Africa, and parts of Australia. Common names include Siam Weed, Christmas Bush, and Common Floss Flower. It is sometimes grown as a medicinal and ornamental plant. It is used as a traditional medicine in Indonesia. The young leaves are crushed, and the resulting liquid can be used to treat skin wounds.

It was earlier taxonomically classified under the genus Eupatorium, but is now considered more closely related to other genera in the tribe Eupatorieae (Schmidt and Schilling, 2000). *Chromolaena odorata* is considered invasive weed of field crops in its introduced range, and has been reported to be the most problematic invasive species within protected rainforest in Africa (Struhsaker et al., 2005).

Figure 1: *Chromolaena odorata* Leaf.

MATERIALS AND METHODS

Methodology

Sheets were cut to specific sizes, prepared and then tested in various environments. Tests were carried out periodically.

Materials

The materials for this experiment include aluminum sheet of 60mm by 30mm, hydrochloric acid, sodium hydroxide and *Chromolaena odorata* leaves.

Equipment

1. Syringes
2. Masking
3. Tape
4. Thread
5. Mortar and pestle
6. Sieving net
7. Mechanical vice
8. Electronic weighing balance
9. Guillotine
10. Acetone
11. Cotton wool
12. Razor blade
13. Plastic square buckets and bowls
14. Hand file
15. Abrasive paper
16. Pipette
17. Burette
18. Plastic jerry cans
19. Nylon hand gloves

Experimental Procedure

Experimentation involves immersion of the coupons in the media and retrieving at specified durations and checking the weight loss in grams. On preparation of the HCl and NaOH solutions, a quantity of about fifteen liters (15 liters) were measured out using the graduated plastic bowl and purred inside the a rectangular plastic buckets and labeled with the aid of the polymeric twine (thread) each coupon is tied and suspended from a horizontally placed stick on top of each bucket. With the aid of a clinical syringe the desired quantity of the inhibitor were collected and injected inside each solution according to the required inhibitor content and the whole solution stirred.

Each coupon was suspended such that it is totally immersed in the solution without touching either the side or bottom of the container. For each bath were suspended (immersed) five coupons labeled and left uncovered to react freely on the atmosphere. And finally the suspended coupons are immersed simultaneously and the time of immersion noted. After 24hrs a coupon is retrieved from each of the baths, washed gently and properly in water dried with a cotton wool and dipped in acetone to remove every moisture and oxygen. Thereafter, each of the dried coupons was carefully weighed on the electronic weighing balance and the weight loss recorded.

$$\text{Corrosion Rate } (gcm^{-2}hr^{-1}) = \frac{weight}{Area \times Time}$$

Inhibitor Efficiency

Inhibitor efficiency was calculated from the relation:

$$\text{Inhibitor efficiency } (\%) = \frac{(CR_{uninhibited} - CR_{inhibited}) \times 100}{CR_{uninhibited}}$$

$$IE\ (\%) = \frac{(R_0 - R) \times 100}{R_0}$$

Where:
R_0 = corrosion rate uninhibited
R = corrosion rate inhibited.

RESULT AND DISCUSSION

Table of Values

Table1: 1M HCl Solution Uninhibited (Control).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
57	6.893	5.923	0.970	0.00105	24
58	6.833	4.955	1.878	0.00102	48
59	6.952	3.990	2.962	0.00107	72
60	6.564	3.022	3.542	0.00106	96
61	6.870	2.054	4.816	0.00104	120

Table 2: 1M HCl Solution Inhibited (10ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
17	6.726	5.967	0.759	0.000820	24
18	6.694	5.210	1.484	0.000802	48
19	6.942	4.451	2.491	0.000897	72
20	6.564	3.693	2.871	0.000897	96
21	6.584	2.939	3.645	0.000788	120

Table 3: 1M HCl Solution Inhibited (15ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
22	6.640	5.920	0.720	0.000778	24
23	6.825	5.202	1.623	0.000877	48
24	6.982	4.484	2.498	0.000899	72
25	6.735	3.766	2.969	0.000802	96
26	6.408	3.048	3.360	0.000726	120

Table 4: 1M HCl Solution Inhibited (20ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
27	6.814	6.102	0.712	0.000769	24
28	6.713	5.293	1.420	0.000767	48
29	6.627	4.409	2.218	0.000798	72
30	6.808	3.897	2.911	0.000769	96
31	6.579	3.248	3.331	0.000719	120

Table 5: 1M HCl Solution Inhibited (25ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
52	6.630	5.955	0.675	0.00729	24
53	6.599	5.281	1.318	0.00712	48
54	6.530	4.576	2.014	0.00730	72
55	6.621	3.949	2.672	0.00722	96
56	6.434	2.277	3.157	0.00682	120

Table 6: 0.5M NaOH Solution Uninhibited (Control).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
63	6.728	5.483	1.245	0.00135	24
64	6.901	4.236	2.665	0.00144	48
65	7.040	2.998	4.042	0.00146	72
66	6.964	1.758	5.206	0.00147	96
67	7.015	0.520	6.495	0.00147	120

Table 7: 0.5 M NaOH Solutions Inhibited (10ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
32	6.819	5.578	1.241	0.00134	24
33	6.587	4.340	2.247	0.00123	48
34	6.470	3.101	3.339	0.00122	72
35	6.805	1.865	4.940	0.00120	96
36	6.600	0.627	5.973	0.00120	120

Table 8: 0.5 M NaOH Solutions Inhibited (15ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
37	6.955	5.839	1.116	0.00121	24
38	6.578	4.722	1.856	0.00104	48
39	6.361	3.608	2.757	0.00103	72
40	6.514	2.493	4.021	0.00103	96
41	6.857	1.376	5.481	0.00102	120

Table 9: 0.5 M NaOH Solutions Inhibited (20ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
42	6.716	5.721	0.995	0.00108	24
43	6.664	4.727	1.937	0.00105	48
44	7.111	3.882	3.229	0.00116	72
45	6.798	2.907	3.891.	0.00105	96
46	6.695	1.912	4.783	0.00103	120

Table 10: 0.5 M NaOH Solutions Inhibited (25ml).

Coupon No.	Initial Mass (g)	Final Mass (g)	Weight Loss (g)	Corrosion Rate ($gcm^{-2}hr^{-1}$)	Time (hrs)
47	6.704	5.729	0.975	0.00105	24
48	6.909	4.754	1.855	0.00100	48
49	6.548	3.770	2.778	0.00102	72
50	6.699	2.795	3.904.	0.00100	96
51	6.600	2.100	4.500	0.000975	120

Table 11: Table of Weight Loss% wrt Time in HCl (Control).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
57	6.893	0.970	14.1	24
58	6.833	1.878	27.5	48
59	6.952	2.962	42.6	72
60	6.564	3.542	54.0	96
61	6.870	4.816	70.1	120

Table 12: Table of Weight Loss% wrt Time in HCl (10ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
17	6.726	0.759	11.3	24
18	6.694	1.484	22.2	48
19	6.942	2.491	35.9	72
20	6.564	2.871	43.7	96
21	6.584	3.645	55.4	120

Table 13: Table of Weight Loss% wrt Time in HCl (15ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
22	6.640	0.720	10.8	24
23	6.825	1.623	23.8	48
24	6.982	2.498	35.8	72
25	6.735	2.969	44.1	96
26	6.408	3.360	52.4	120

Table 14: Table of Weight Loss% wrt Time in HCl (20ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
27	6.814	0.712	10.4	24
28	6.713	1.420	21.5	48
29	6.627	2.218	33.5	72
30	6.808	2.911	42.8	96
31	6.579	3.331	50.6	120

Table 15: Table of Weight Loss% wrt Time In HCl (25ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
52	6.630	0.675	10.9	24
53	6.599	1.318	20.0	48
54	6.530	2.014	30.8	72
55	6.621	2.672	40.4	96
56	6.434	3.157	49.1	120

Table 16: Table of Weight Loss% wrt Time In NaOH (Control).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
63	6.728	1.245	18.5	24
64	6.901	2.665	38.6	48
65	7.040	4.042	57.4	72
66	6.964	5.206	74.8	96
67	7.015	6.495	92.6	120

Table 17: Table of Weight Loss% wrt Time In NaOH (10ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
32	6.819	1.241	18.2	24
33	6.587	2.247	34.1	48
34	6.470	3.339	51.6	72
35	6.805	4.940	72.6	96
36	6.600	5.973	90.5	120

Table 18: Table of Weight Loss% wrt Time In NaOH (15ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
37	6.955	1.116	16.0	24
38	6.578	1.856	28.2	48
39	6.361	2.757	43.3	72
40	6.514	4.021	61.7	96
41	6.857	5.481	80.0	120

Table 19: Table of Weight Loss% wrt Time in NaOH (20ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
42	6.716	0.995	14.8	24
43	6.664	1.937	29.1	48
44	7.111	3.229	45.1	72
45	6.798	3.891.	57.2	96
46	6.695	4.783	71.4	120

Table 20: Table of Weight Loss% wrt Time in NaOH (25ml).

Coupon No.	Initial Mass (g)	Weight Loss (g)	Weight Loss (%)	Time (hrs)
47	6.704	0.870	13.0	24
48	6.909	1.953	28.3	48
49	6.548	2.460	37.6	72
50	6.699	3.481.	52.0	96
51	6.600	4.261	64.6	120

Table 21: Table of Inhibition Efficiency wrt Time in HCl.

Inhibition Efficiency (%)				Time (hr)
10ML	15ML	20ML	25ML	
21.9	25.9	26.8	30.6	24
21.4	14.0	24.8	30.2	48
16.2	15.9	25.4	31.8	72
15.4	24.3	27.5	31.9	96
24.2	30.2	30.9	34.4	120
Ave =19.82	*=22.06*	*=27.08*	*=31.78*	

Table 22: Table of Inhibition Efficiency wrt Time in NaOH.

Inhibition Efficiency (%)				Time (hr)
10ML	15ML	20ML	25ML	
0.7	10.4	20.0	22.2	24
14.6	27.8	27.1	30.6	48
16.4	29.5	20.5	31.9	72
18.4	29.9	28.6	30.6	96
18.4	30.6	29.9	33.8	120
Ave = 13.07	*=21.36*	*= 26.02*	*= 29.74*	

Table 23: Table of log (IE) wrt log (Inhibitor Concentration) in HCl.

Inhibitor Concentration (ml)	Log [Inhibitor concentration]	Average IE (%)	Log [IE]
10	1.000	19.82	1.297
15	1.176	22.06	1.344
20	1.301	27.08	1.433
25	1.398	31.78	1.502

Where IE = Inhibition Efficiency

Table 24: Table of log (IE) wrt log (inhibitor concentration) in NaOH.

Inhibitor Concentration (ml)	Log [Inhibitor Concentration]	Average IE (%)	Log [IE]
10	1.000	13.7	1.137
15	1.176	21.36	1.330
20	1.301	26.02	1.415
25	1.398	29.70	1.473

Where IE = Inhibition Efficiency

GRAPHICAL REPRESENTATION

Graphical Results

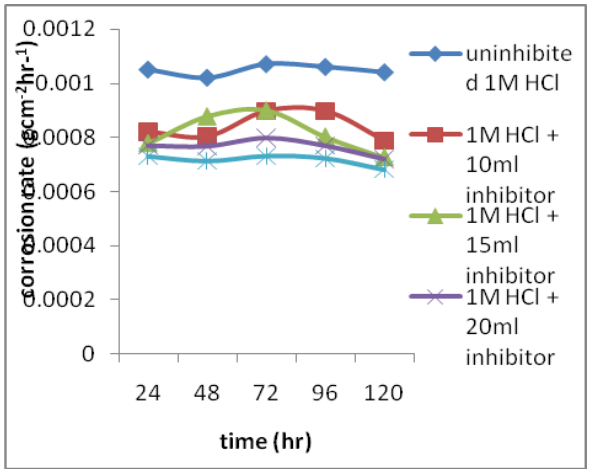

Figure 1: Corrosion Rate of Aluminum with Time in Environment of 1M HCl Containing Different Concentrations of *Chromolaena odorata* Extract.

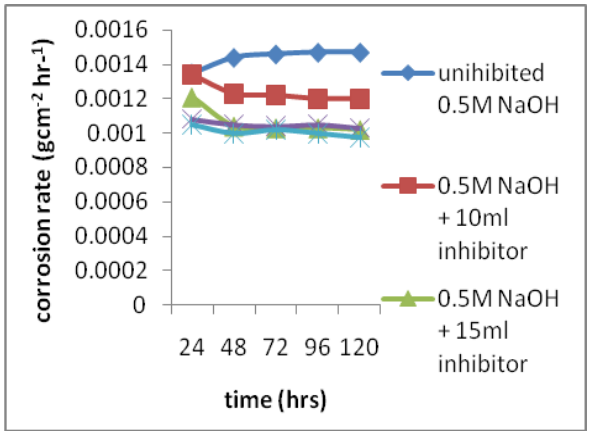

Figure 2: Corrosion Rate of Aluminum with Time in 0.5M NaOH Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

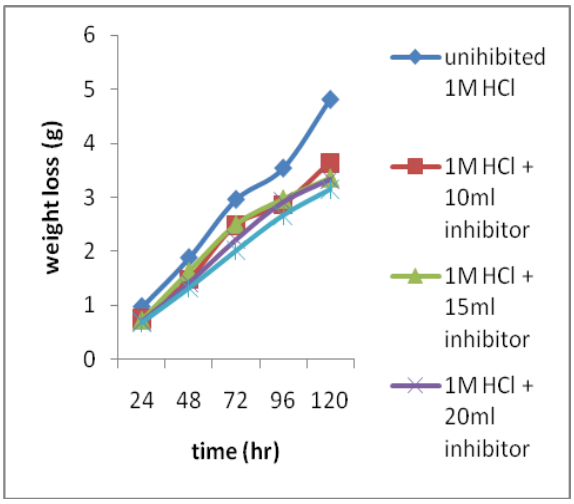

Figure 3: Weight Loss of Aluminum with time in 1M HCl Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

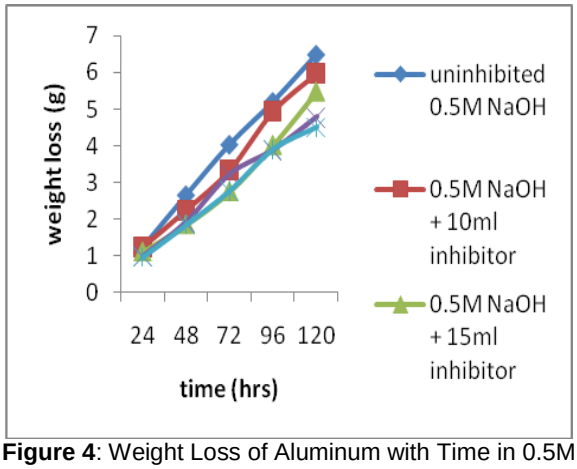

Figure 4: Weight Loss of Aluminum with Time in 0.5M NaOH Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

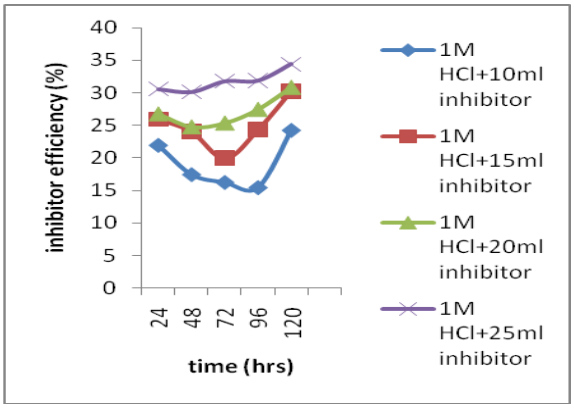

Figure 5: Inhibiting Efficiency of Aluminum with Time in 1M HCl Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

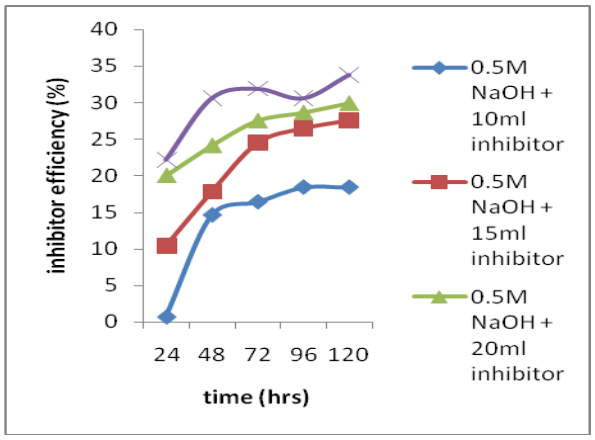

Figure 6: Inhibiting Efficiency of Aluminum with Time in 0.5M NaOH Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

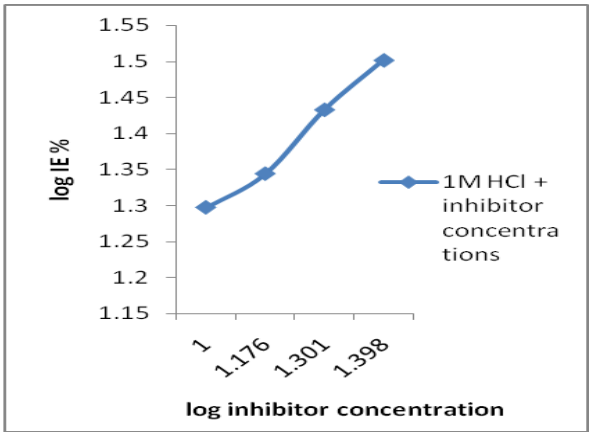

Figure 9: Plots of log of Inhibition Efficiency against log of Inhibitor Concentration in 1M of HCl.

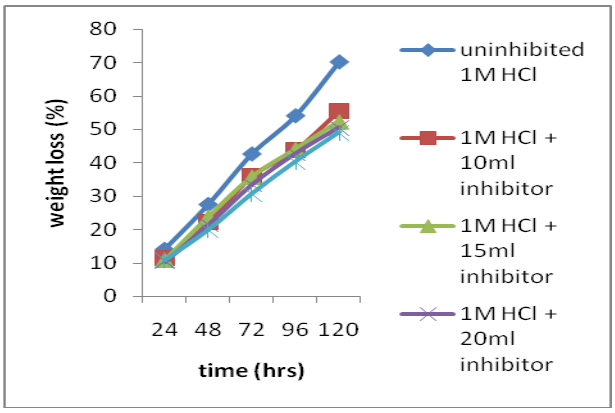

Figure 7: Weight Loss Percentage of Aluminum with Time in 1M HCl Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

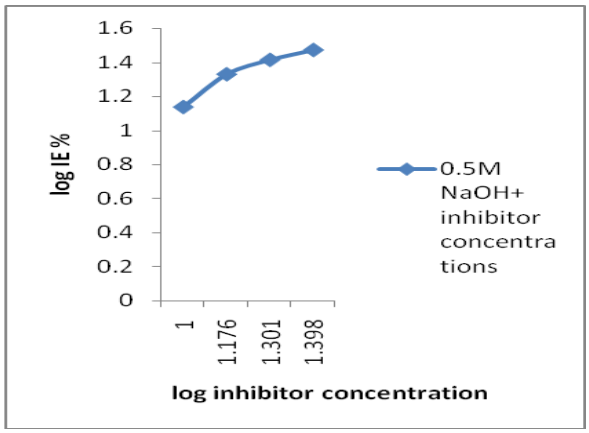

Figure 10: Plots of log of Inhibition Efficiency against log of Inhibitor Concentration in 0.5M of NaOH.

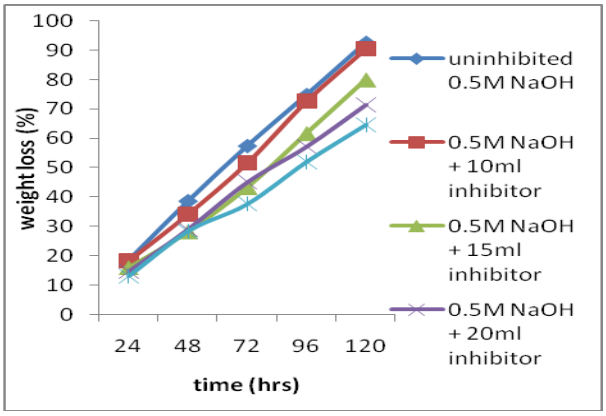

Figure 8: Weight Loss Percentage of Aluminum with Time in 0.5M NaOH Environment Containing Different Concentrations of *Chromolaena odorata* Extract.

DISCUSSION

The results are presented in Tables 1 – 24 and Figures 1 – 10. From the results show in Figures 1 and 2, it is observed that the corrosion rate of aluminum in HCl and NaOH, with *Chromolaena odorata* as inhibitor decreases with increases in inhibitor concentration. Hence, in Figures 3 - 4, the weight loss of aluminum in HCl and NaOH in the said inhibitor increases with time but there is a general decrease in weight loss with the introduction of the plant extract. Also in Figures 5 – 6, the inhibitor efficiency in HCl remained almost constant but increases in NaOH with increase in time. Eventually, increases with increase in inhibitor concentration in both media. In Figures 7 - 8 the weight loss (%) of aluminum in HCl and NaOH in *Chromolaena odorata* increases with time but decreases with the

introduction of the plant extract. Furthermore, in Figures 9 – 10, log of inhibitor efficiency increases with increase in log of inhibitor concentration in both HCl and NaOH media.

Effect of Inhibitor Concentration

The effectiveness of *Chromolaena odorata* as an inhibitor for the corrosion of aluminum alloy vessels in the industry has been clearly demonstrated in Tables 1 – 24. The corrosion rate curves of the aluminum alloy in 1M HCl and 0.5M NaOH solutions at different time decreased with increasing concentration of inhibitor. This corroborates the works of several other researchers who recently developed interests in the use of plant juice extracts as inhibitors. It is believed that there are some acting inhibiting chemicals and / or chemical compounds in plants that inhibit corrosion in aqueous or acidic/basic environments. Tannin has for instance being identified as the active compounds in plants that effectively act as inhibitor for metals corroding in the above media.

CONCLUSION

In conclusion, the experiment quite agrees with the theory of the aluminum protective oxide layer being only effective within the pH of 4.5-8.5, and hence leaves the materials very vulnerable in strong acid and alkaline solutions. Also the Chromolaena leaf extract was effective as an inhibitor in both corrosive media. The rate of corrosion of 3103 Al alloy in an uninhibited 1M HCl acid and 0.1M NaOH base environment is very rapid and it is enhanced by the solutions. Generally, the corrosion rate of 3103 Al in the media above declines when *Chromolaena odorata* leaf extract is introduced. The extent of the decline depends on their concentrations. It may therefore be concluded that the inhibitive efficiency of *Chromolaena odorata* increases with increase in the concentration of the inhibitor.

RECOMMENDATION

In respect to the results of this study and in addition to the fact *Chromolaena odorata* is a medicinal plant and has no associated health hazards like most of the other inhibitors. Therefore, it can be recommended for use to inhibit the corrosion of aluminum alloy containers for both commercial and domestic purposes. Also in coating application, the inhibitor can be mixed with the paint hence, on application acts as a barrier film which in turn passives corrosion within the coated material or metal.

REFERENCES

1. Oguzie, E.E., B.N. Okolue, C.E Ogukwe, and A.I. Onuchukwu. 2004. “Studies on the Inhibition Action of Methylene Blue Dye on Aluminum Corrosion in KOH Solution”. *Journal Vijendra Singh*.

2. Ebenso, E.E., U.J. Ekpe, S. Umoren, E. Jackson, O.K. Abiola, N.C. Oforka, and S. Martinez. 2004. “Corrosion Inhibition Studies on Some Plants Extract on Aluminum in Acid Medium” *Journal of Corrosion Science and Technology*.

3. Schmidt, G.J. and E.E. Schilling. 2000. "Phylogeny and Biogeography of Eupatorium (*Asteraceae eupatorieae*) Based on Nuclear ITS Sequence". *American Journal of Botany* (Botanical Society of America). 87(5): 716726. doi:10.2307/2656858.JSTOR 2656858. PMID 108 11796.).

4. Struhsaker, T.T., P.J. Struhsaker, and K.S., Siex. 2005. "Conserving Africa’s Rain Forests: Problems in Protected Areas and Possible Solutions". *Biological Conservation*. 123(1):45–54. doi:10.1016/j.biocon.2004.10.007. ISSN 0006-3207.)

5. Perryman, J. 2007. “Corrosion Resistance of Aluminium”. *WATERFRONT* Romesh Chander: Khanna.

6. Mubeen and Mubeen. 2004. *Material Science. Third Edition*. Romesh Chander: Khanna.

7. Callista, W.D. 2003. *Physical Metallurgy: Second Edition*.

8. Loto, C.A. and A. Mohammed. 2000. “The Effects of Cashew Juice Extract on Corrosion Inhibition of Mild Steel in HCl”.

9. Moresby, J. 1988. *Toxic Inhibitors Corrosion*. Vol 22: 82.

10. Moore, J.J. 1981, 1990. C*hemical Metallurgy: Second edition*. Butterworth: London, UK.
11.
12. Svenningsen, G. 1991. “Corrosion of Aluminum Alloys”. Department of Materials Technology, 7491 Trondheim, Norway.

13. Pourbaix, M. 1974. *Atlas of Electrochemical Equilibria in Aqueous Solution*". NACE: Huston, TX.

ABOUT THE AUTHORS

Dr. C.N. Anyakwo, is a Senior Lecturer in the Department of Materials and Metallurgical Engineering, and is the former Head of the same Department; Federal University of Technology, Owerri.

C.M. Ibegbulam, is a Bachelor Degree holder in Materials and Metallurgical Engineering and is currently a research officer in the Engineering Materials Development Institute, Akure, Ondo State (EMDI). His research interests are in the areas of corrosion science and materials and metallurgical engineering.

O.K. Ukoba, is a Design and Simulation Engineer in the Manufacturing Department, Engineering Materials Development Institute, Akure, Nigeria. He holds a B.Eng. degree in Mechanical Engineering and currently doing his M.Eng. in Mechanical Engineering. His research interests are in the areas of design/simulation, materials (testing and synthesis), corrosion and ergonomics.

R.I. Ekwujuru, is a Bachelor Degree holder in Materials and Metallurgical Engineering. He is a graduate of the Federal University of Technology, Owerri. His research interests are in the areas of corrosion Science and materials and metallurgical engineering.

E. Ekos, is a Bachelor Degree holder in Materials and Metallurgical Engineering. He is a graduate of the Federal University of Technology, Owerri. His research interests are in the areas of corrosion science and materials and metallurgical engineering.

C.S. Nwaosu, is a Bachelor Degree holder in Materials and Metallurgical Engineering. He is a graduate of the Federal University of Technology, Owerri. His research interests are in the areas of corrosion science and materials and metallurgical engineering.

SUGGESTED CITATION

Ibegbulam, C.M., C.N. Anyakwo, O.K. Ukoba, R.I. Ekwujuru, E. Ekos, and C.S. Nwaosu. 2011. "Evaluations of Inhibitive Property of *Chromolaena odorata* Extract on Aluminum in 1M HCl and 0.5M NaOH Environment". *Pacific Journal of Science and Technology*. 12(2):31-38.