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Corrosion Rates of Aluminum As Roofing Sheet In Acidic Media

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ABSTRACT
The study characterizes Aluminum-Silicon alloy sheets as roofing sheet material. This was actualized by fabrication of rectangular flat sheet samples of about 0.55 mm thickness by First Aluminum Nigeria Limited, Port Harcourt. Six coupon specimens (3 x 5cm size) of each composition labeled A, B, C, D, E and F were polished, cleaned, washed in running warm-water and dried. Laboratory accelerated test was adopted and Standard corrosion examination by weight loss technique was applied to the coupons under five different media to ascertain the corrosion rates of the samples. Also, the tensile strengths of the Aluminum alloys were experimentally measured before and after exposure to the various environments. The data obtained indicated a progressive increase and later decrease of corrosion rates as exposure time increases. In the same vein, Sample D(0.59171 wt%) has an increase in corrosion rate relative to the exposure time, but have a different trend compared with the other coupons. The tensile strengths were observed to have decreased in the reverse order. In summary, all the sample results shows normal rate profile (for passivity of metals) of an initial steep rise, then a progressive decline in all the media except sample D. As the segment of the reinforcing phase increases, there was heavy uniform attack observed on sample D. This attack could be associated to increased grain boundary concentration arising from maximum solid solubility processes. The initial results concludes that controlled silicon additions as alloying element could be applied to obtain relatively low corrosion attack on aluminum roofing sheets on hostile urban and industrial environments characterized as basic or acidic.

KEYWORDS:* *Concentration Samples Environment Exposure Solubility Materials

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I. INTRODUCTION

Roofing sheets are materials rolled or fabricated for covering of the upper part of a building, with the aim of protecting the building and its contents from the effects of, rain, sun or other weathering conditions. Dwelling homes, cathedral or stadium and other types of Structures require different roofing. In most cases, as mentioned earlier, a roof protects primarily against rain fall and sun shine. Depending on the nature of the building, the roof may also protect the building against heat, sunlight, cold, wind and organism like ants, reptiles (snakes, lizards), rodents (rats, mice) and others.

The characteristics design of roofing materials are dependent upon the purpose of the building to which it covers and the availability of design materials (Usman *et al*., 2024). Several factors must be considered in designing alloy of metals as roofing sheets, such as the properties of the alloying elements, accurate design method, and durability (performance) of the roof in service specific environmental condition, cost, ease of installation and durability, among other factors (Chukwudi *et al*., 2018).

Roofing sheets should be light - weight, portable, and durable. Design flexibilities, such as large sprung curves, energy efficiency, rolled bull nose shapes are equally obtained. Studies have proved that in design of roofing sheet for acidic environment, a pre - assessment of its oxidation and corrosion behavior is important (Daniel *et al*., 2021; Joseph *et al*., 2021). They indicated that it is one of the surest means for justification of such material as been reliable and stable for marine use.

In contrast, for the corrosion resistance aluminum alloys as roofing sheet, contacts with other metals should be avoided in the presence of an electrolyte; because galvanic corrosion of the aluminum could take place within the vicinity of the contact area (Ujam *et al*., 2014; Enedoh, 2023).

In addition, Chukwudi *et al*. (2018) concluded that in designing aluminum system, note should be taken when it comes into contact with dissimilar metals. Sacrificial attack of aluminum and its alloys might occur when in contact with most other metals under corrosive environment.

The growing understanding that the entire life cycle of a building and its fittings must be considered and balanced against the realities of design, function and economy has seen aluminum and its alloy fast becoming the material of choice. Its properties mean that intricate, stable and lightweight structures can be designed without concern, as even thin structures do not wrap. Therefore, it is important to understand the various characteristics of aluminum alloys used as material for architects design or roofing sheet, particularly when exposed to the harsh environment, because of corrosion.

Materials to one degree or another, experience some type of interaction with a large number of diverse environments. Often, such interactions impair a material's usefulness as a result of the deterioration of its mechanical properties due to corrosion (Chukwudi *et al*., 2018).

The problem of metallic corrosion has remained a major concern. It can lead to economic loss and hazards, even loss of lives. It was estimated that approximately 5% of industrialized nation's income is spent on corrosion prevention and the maintenance or replacement of products lost or contaminated (Chukwudi *et al*., 2018; Usman *et al*., 2024). The consequences of corrosion are common to roofing sheets. The aim of this study is to characterize aluminum-silicon alloy as roofing sheet material by revealing the impact of Si addition to the alloy material in wirhstanding the effect of acid media on metals corrosion.

II. MATERIALS AND METHODS

The aluminum alloy used was obtained from First Aluminum (Nigeria) Plc with characteristics as shown in Table 1. The materials used are Tetraoxosulphate (vi) acid (H_2SO_4), Hydrochloric acid (HCl), Acid rain water, Acetone, Beakers of 250ml, pH meter, sand paper, hanging rope, distilled water, metal shearing machine and a timing clock. Other materials include; coupons of Al – Si alloys, electronic digital weighing balance of model CS200 and spectrometer.

Table 1: Results of Spectrometer Analysis (Wt %) of Test Samples

AL-SI Samples	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
Al (%)	98.7993	98.8943	98.2854	98.3082	98.2854	98.2977
Si (%)	0.20511	0.30121	0.49141	0.59171	0.74931	0.82011
Fe (%)	0.79889	0.58527	0.81538	0.79347	0.79347	0.7913
Cu (%)	0.03101	0.44176	0.2796	0.0706	0.0706	0.02451
Mn (%)	0.05871	0.9476	0.06782	0.0706	0.0681	0.03316
Mg (%)	0.0117	0.02484	0.02615	0.02795	0.02795	0.00733
Zn (%)	0.447	0.5706	0.00719	0.00581	0.00581	0.0051
Ti (%)	0.01902	0.01421	0.01653	0.01576	0.01576	0.02185
Cr (%)	0.0861	0.00601	0.00177	0.0014	0.0014	0.0085
Ni (%)	0.00536	0.00391	0.00171	0.00146	0.00146	0.00231
V (%)	0.00802	0.00754	0.00662	0.00633	0.00633	0.00803
Pb (%)	0.00153	0.02021	0.00583	0.00686	0.00686	0.01224

The designed rectangular flat sheets of 0.55mm thick and 5cm x 3cm size of each composition (samples A, B, C, D, E and F) were polished to mirror finish, cleaned, degreased with acetone and then dried as previously mentioned.

The stimulated environments for the work were acidic of varying concentration. Five different concentrations of Nitric acid (HNO_3), Ammonium Hydroxide (NH_4OH) and Seawater were prepared. The measured concentrations were in 0.5M and 1M of the two types of solution.

In each beaker containing the various concentrations were immersed six samples each of the different alloys. The set up was allowed to stand for 144 hours. A set of coupons were withdrawn 24 hourly, washed with distilled water, cleaned and dried in an open air.

The initial and final weights of each of the experimental samples before and after exposure to the measurement environments (media) were determined using a sensitive electronic digital analytic weighing balance (model number CS200) capable of accuracy of 0.01g.

The corrosion rates of the test samples were then calculated by using weight loss data obtained from laboratory accelerated tests and with the expression;

$$CPR = \frac{534W}{\rho AT} \qquad (1)$$

Where W is the weight loss in milligrams, T is the exposure time in hours, ρ is the sample density in grams per cubic centimeters (g/cm^3), A is area of exposure in square inches (In^2) and 534 is a universal constant.

III. RESULTS AND DISCUSSION

3.1 RESULTS

Table 2: Weight Loss values (g) of sample A (0.20511 Si content) in HNO_3, NH_4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.1	0.4	0.2	0.7	0.3
48	0.1	0.3	0.2	0.8	0.5
72	0.2	0.2	0.4	0.8	0.4
96	0.2	0.3	0.5	0.9	0.2
120	0.3	0.3	0.5	0.9	0.4
144	0.2	0.4	0.9	1.0	0.3

Table 3: Weight Loss values (g) of sample B (0.3012 Si content) in HNO_3, NH4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.2	0.7	0.6	0.9	0.1
48	0.2	0.8	0.7	0.8	0.1
72	0.3	0.8	0.6	0.8	0.2
96	0.2	0.9	0.7	0.9	0.2
120	0.2	0.9	0.8	0.9	0.3
144	0.1	1.2	0.9	1.0	0.3

Table 4: Weight Loss values (g) of sample C (0.4914 Si content) in HNO_3, NH4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.1	0.8	0.6	0.9	0.1
48	0.4	0.7	0.9	0.7	0.3
72	0.4	0.8	0.8	0.8	0.3
96	0.3	0.9	0.9	0.6	0.3
120	0.3	0.9	0.9	0.9	0.3
144	0.3	1.0	0.9	0.9	0.3

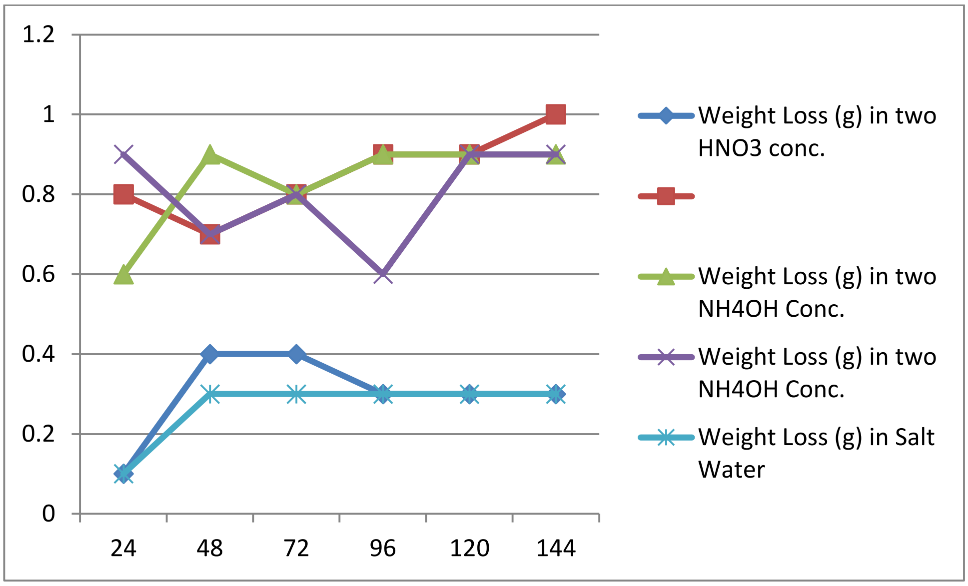

Figure 1: The trends of weight loss in sample C exposed to acidic media

Table 5: Weight Loss values (g) of sample D (0.5917 Si content) in HNO_3, NH4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.1	0.8	0.3	0.4	0.1
48	0.3	0.7	0.5	0.6	0.2
72	0.6	0.8	0.5	0.8	0.3
96	0.5	0.9	0.7	0.8	0.2
120	0.8	0.9	0.7	0.9	0.2
144	0.7	0.9	1.0	1.2	0.1

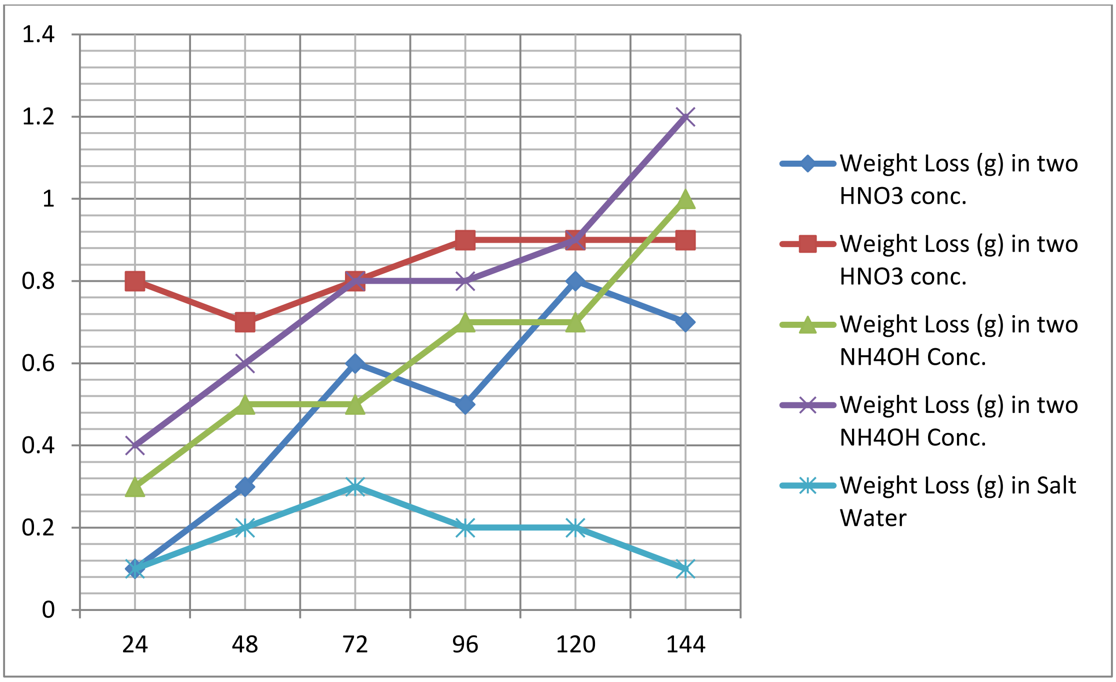

Figure 2: The trends of weight loss in sample D exposed to acidic media

Table 6: Weight Loss values (g) of sample E (0.74930 Si content) in HNO_3, NH4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.5	0.7	0.5	0.9	0.1
48	0.5	0.7	0.6	0.9	0.1
72	0.7	0.9	0.7	0.8	0.1
96	0.7	0.9	0.8	0.9	0.3
120	0.8	1.2	0.9	0.9	0.3
144	0.8	1.3	0.9	1.7	0.3

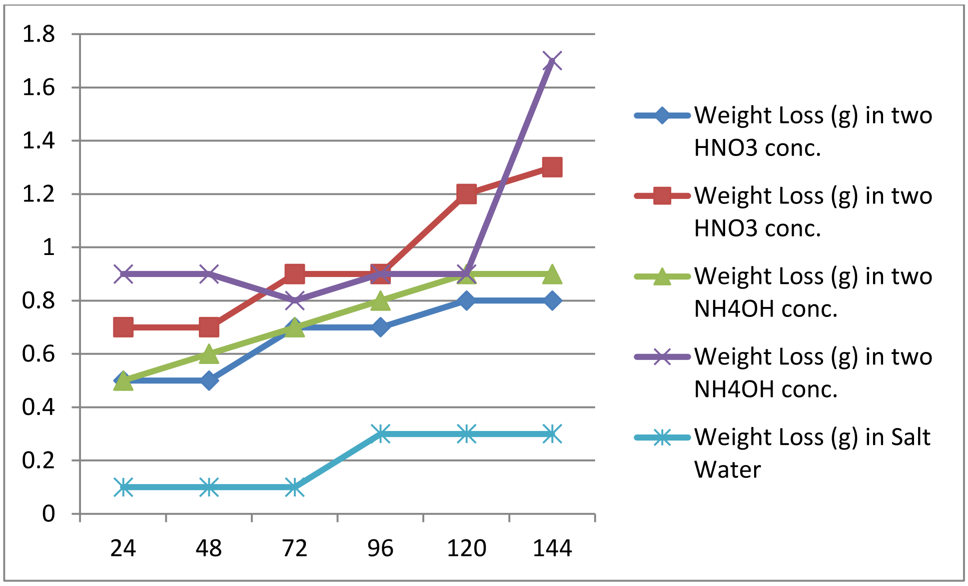

Figure 3: The trends of weight loss in sample E exposed to acidic media

Table 7: Weight Loss values (g) of sample F (0.82011 Si content) in HNO_3, NH4OH and Salt Water media

Exposure Time (Hrs)	Weight Loss (g) in two HNO_3 conc.		Weight Loss (g) in two NH_4OH conc.		Weight Loss (g) in Salt Water
	0.5 M	1 M	0.5 M	1 M	
24	0.2	0.4	0.3	0.7	0.1
48	0.4	0.4	0.8	0.9	0.1
72	0.7	0.9	0.8	1.0	0.2
96	0.7	1.3	0.9	1.5	0.2
120	0.7	1.3	0.9	1.4	0.3
144	0.9	1.3	1.2	1.4	0.3

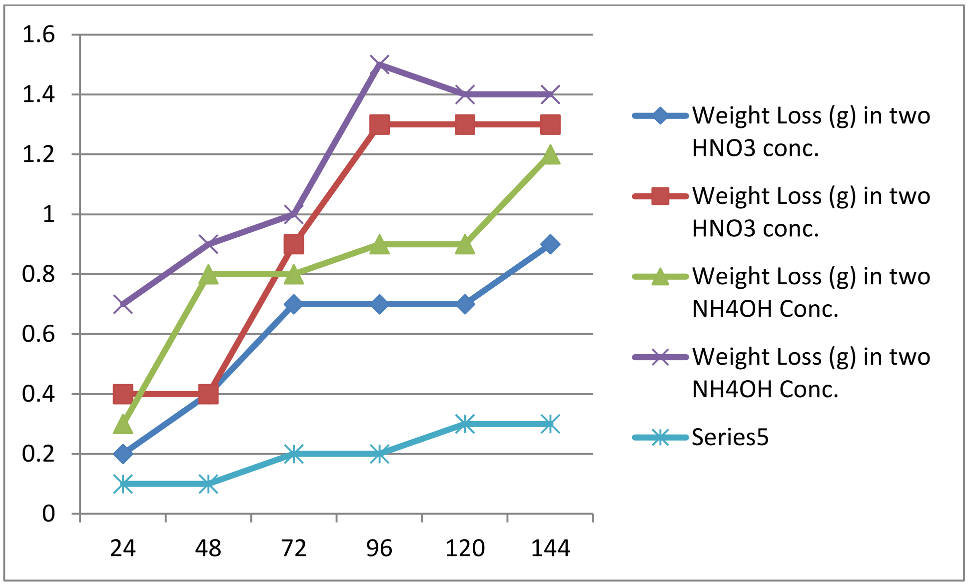

Figure 4: The trends of weight loss in sample F exposed to acidic media

Table 8: Corrosion Rates variation data for Sample A

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	0.1357	0.1694	0.4165	1.5296	0.3827
48	0.2353	1.0798	0.1415	1.5296	0.2914
72	3.2642	0.4532	0.4028	0.7198	0.1942
96	0.2545	1.4532	1.2882	0.5399	0.3399
120	0.3192	0.3399	1.0305	0.2719	0.2719
144	0.1632	0.2266	0.4331	0.0971	0.2266

Table 9: Corrosion Rates variation data for Sample B

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	1.1657	0.5838	7.5304	2.7192	0.5827
48	0.5827	0.333	2.142	1.7997	0.2914
72	0.5099	0.3399	1.718	1.0198	0.4532
96	0.266	0.5736	1.7209	0.3399	0.5399
120	0.2879	0.4589	1.3965	0.4319	0.4319
144	0.0816	0.1699	1.6034	0.3599	0.3599

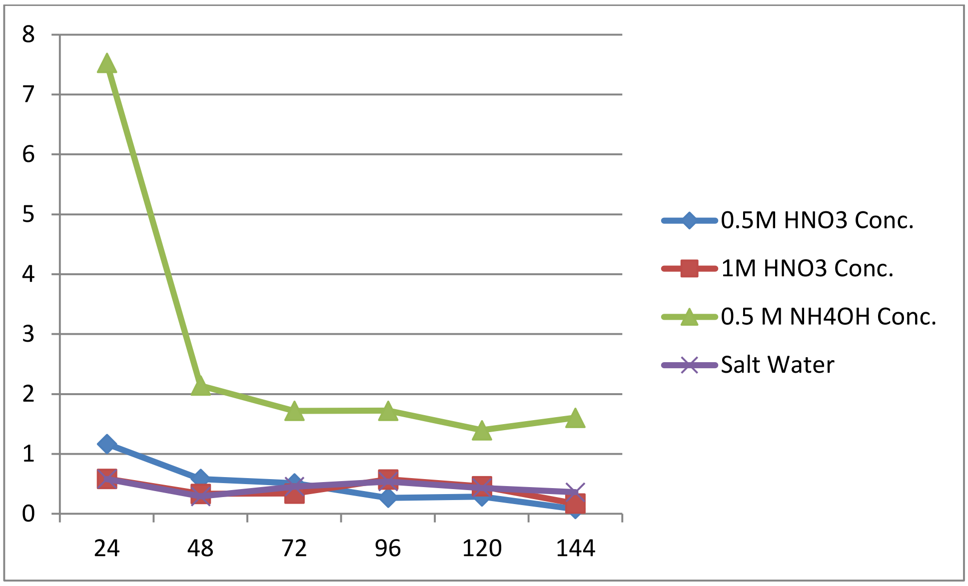

Figure 5: Variation in corrosion rate of sample B exposed to acidic media

Table 10: Corrosion Rates variation data for Sample C

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	0.4707	0.6441	6.883	6.5891	0.5827
48	0.7649	0.675	0.489	4.0791	1.2472
72	0.777	1.0140	2.5104	1.0198	1.0878
96	0.255	0.5634	1.5302	0.5736	0.5736
120	0.204	0.4319	1.0494	0.4590	0.2719
144	0.1854	0.3599	2.5099	0.1700	0.2266

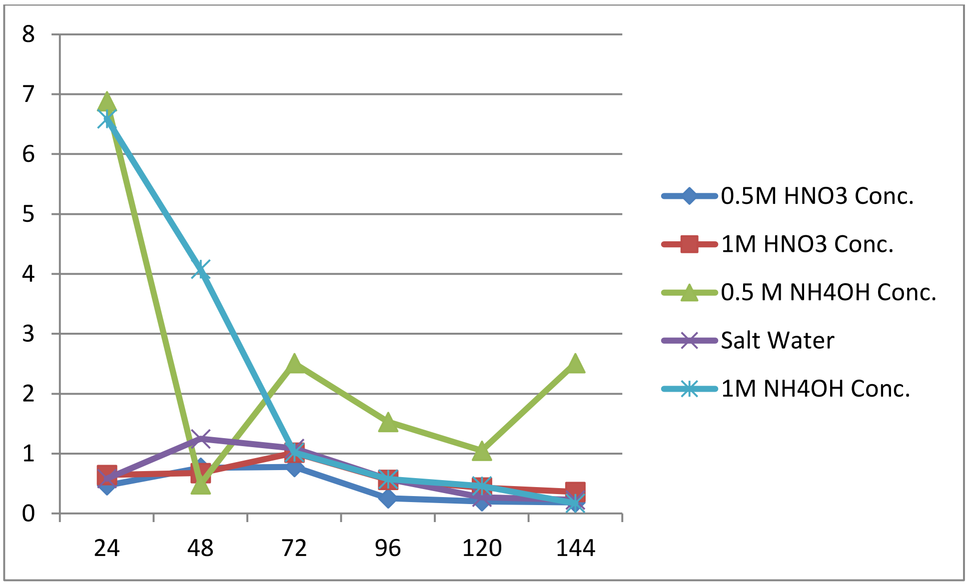

Figure 6: Variation in corrosion rate of sample C exposed to acidic media

Table 11: Corrosion Rates variation data for Sample D

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	0.6441	0.5827	2.16	1.3596	0.4827

48	1.3604	1.0798	4.5893	2.5298	0.6799
72	1.3331	1.0136	10.489	1.7482	1.2878
96	0.3498	0.3399	1.8827	3.0198	0.4399
120	0.4319	0.2719	1.4475	4.6317	0.4266
144	0.2266	0.0971	1.8045	5.2551	0.2971

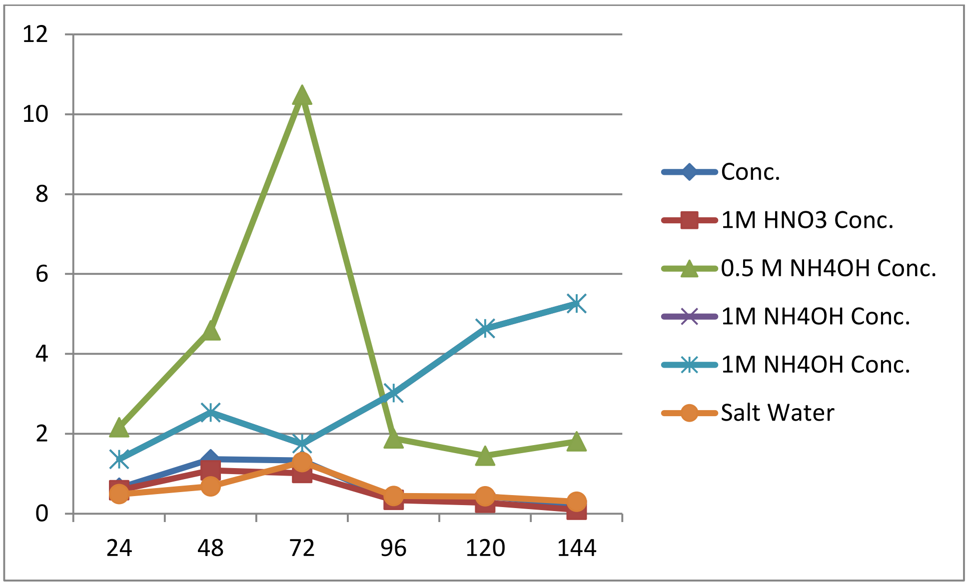

Figure 7: Variation in corrosion rate of sample D exposed to acidic media

Table 12: Corrosion Rates variation data for Sample E

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	0.0378	1.3596	2.0125	10.1596	0.5827
48	1.6997	3.6799	3.0594	4.0396	0.6914
72	2.0396	4.7198	2.7195	3.1965	0.7942
96	1.5297	3.3112	2.5031	5.2946	0.8457
120	0.6799	2.0426	0.2448	4.3813	0.7719
144	0.4294	1.8741	8.6680	3.2551	0.8266

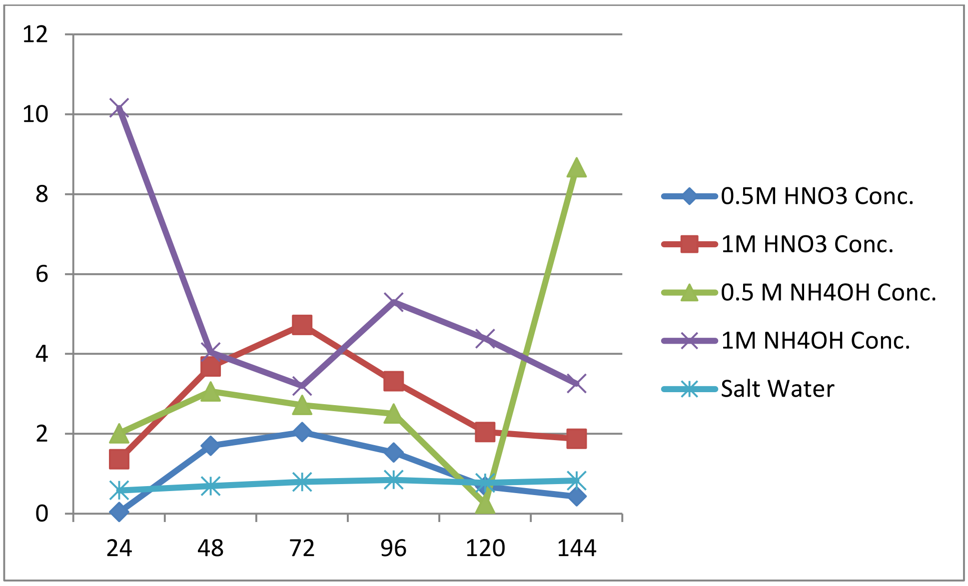

Figure 8: Variation in corrosion rate of sample E exposed to acidic media

Table 13: Corrosion Rates variation data for Sample F

	Corrosion Rate (mm/yr)				
Exposure Time (Hrs)	0.5M HNO_3	1M HNO_3	0.5 M NH_4OH	1M NH_4OH	Salt Water
24	1.3542	2.5823	1.0395	2.3596	0.5827
48	1.4397	3.0798	2.0614	3.5296	0.2914
72	1.7481	4.3597	2.0396	3.0198	0.4532
96	1.3112	2.6473	2.1180	2.3011	0.5399
120	1.3179	1.6317	1.6944	2.6317	0.4319
144	1.5297	2.5099	2.4475	1.6688	0.3599

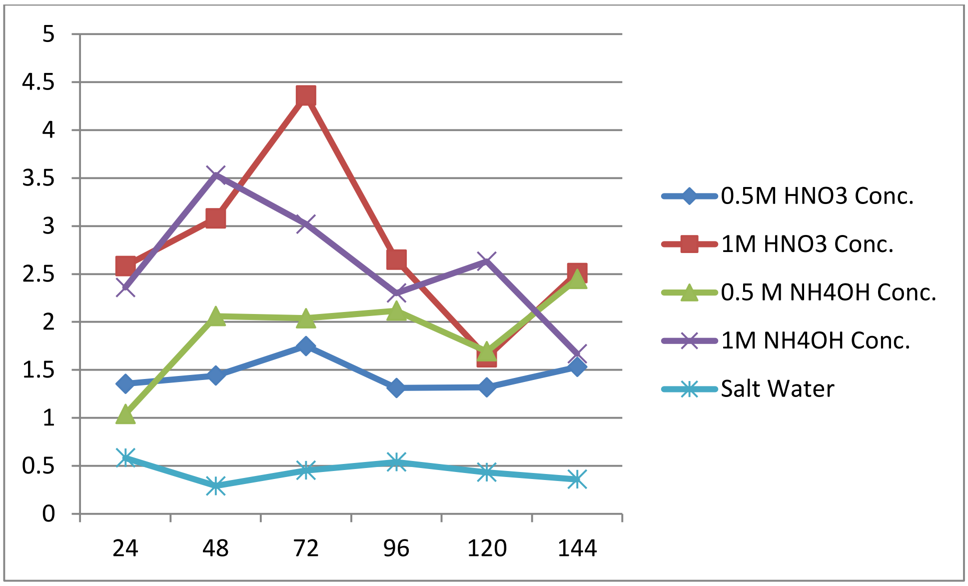

Figure 9: Variation in corrosion rate of sample F exposed to acidic media

3.2 DISCUSSION

Through the application of the weight loss values and corrosion rate expression (equation 1), the corrosion rate profile for the samples in various media were determined. Tables 2 to 7 and Figures 1 – 4 presented the weight loss values (g) corresponding to the exposure time for the experimental alloys in different media concentrations, while Tables 6 - 13 and Figures 5 – 9 show corrosion rates variation profiles for test samples.

The tables and figures revealed that test samples B, C, D and E showed initial progressive increase in corrosion rate with increased period of exposure. In contrast, the weight loss values slowly decreased. This agrees with the previous work of (Usman *et al.*, 2024) on coupon immersion test; that the corrodibility of coupon in test medium may decrease as a function of time because of the formation of protective scale or the removal of a less resistant surface layer of the coupon. Also, Joseph *et al.* (2023) opined that this could be as a result of dissolved corrosion products, there by diluting the concentration of the medium. Again, Ujam *et al.* (2014) explained that increase in concentration of metal ions can influence the process as well as cause a depletion to the corrosion agent in the environment. In the same vein, Daniel *et* al. (2021) concluded that Media saturation is a necessary corrosion monitory index during passivation since the rate of deposition would be hindered by ion mobility, which is generally low for extremely saturated media.

A higher weight lose values was observed on all the samples (A, B, C, D, E, and F) immersed in different concentration media of NH_4OH. Nevertheless, it is highest on the medium with 1.0M NH_4OH concentration that has a higher pH value. This conforms to the previous report of (Ujam *et al.*, 2014) on the influence of pH value of test medium that hydrogen acids such as hydrochloric acid are characterized highly aggressive towards Aluminum and its alloy which rate of attack increases with the strength of the acid.

The experimental alloy D, which comprise Al 0.5917 Wt% Si showed the highest values of weight loss and most affected with heavy pitting. This suggests that sample D could represent the maximum solid solubility of Si in Al corresponding to maximum grain boundary concentration (Owate and Chukwuocha, 2006) said. Hence, higher corrosion attack is expected on this alloy sample since grain boundaries are known to be perfect sites for corrosion attacks.

Furthermore, with reference to Tables 8 – 13, which shows the suspension of test specimens in different concentration of NHO_3 media, revealed minimal weight loss values existing between the test samples.

Also, a considerable passivation was observed in coupons in Salt water in all the samples. This is because salt water has a pH value close to 7 which is termed point of neutrality and less acidic thereby having minimal attack on the coupon. This was also view of Ujam *et al*. (2014).

Generally, the specimens obeyed the rule of decrease in corrosion rates with increasing exposure time. This could be attributed to the partial development of passivity of the aluminum alloy at initiation of corrosion. The data showed initial rapid and steep rise in corrosion rate corresponding the active region, until a maximum was attained after which, the corrosion rates progressively decline with the time of exposure.

In comparison, sample D representing 0.5917wt% Si composition indicated highest values of corrosion rate among the media concentrations especially in $1.0MNH_4OH$. The 0.5917wt% is assumed to represent the maximum solid solubility (Solvus line) of silicon in aluminum meaning that maximum grain boundary concentration existed in this alloy thus enhancing corrosion attacks.

IV. CONCLUSIONS

From the study, it can be concluded that passivation phenomenon of the alloys is a function of the content of the alloying element (Si) and molarities concentration of the acidic media. The observed severity of attack on sample D with 0.5917wt% Si composition is attributed to possible maximum solubility of silicon in aluminum system.

Hence**,** since the samples are evaluated based on extreme accelerated harsh acidic and salt media more than the actual service environment, samples A – C may reliably function considerably well as roofing sheet in hostile urban and industrial environments characterized with hydrogen and nitrogen salts since they show more lower corrosion rates less than 0.5mm/yr with higher tensile strengths. It followed that these set of coupons have better corrosion resistance compared to the rest when exposed to aggressive environment similar to the test media.

Further, this study found that the application of samples D, E and F as roofing sheet in hostile industrial environments may not be too favorable. Because higher corrosion rates of the recommended 0.5mm/yr and above were apparently observed more on the coupons. Therefore, they are characterized as having lower corrosion resistance than the rest of the alloys.

However, to correct the short falls observed in samples D, E, and F, in enhancing the quality and service condition of the alloys, appropriate design and surface treatment processes such as degreasing, deoxidation, anodizing, use of appropriate inhibitors and others are necessary prevention mechanisms can optimize the performance of the samples as roofing sheet materials.

REFERENCES

[1]. Owate, I. O., & Chukwuocha, E. (2006). The effect of Zinc addition to the corrosion rates and tensile strengths of aluminum system. Port Harcourt: Material science group, Department of Physics, University of Port Harcourt.

[2]. Chukwudi, B.C., Agbobonye, T., & Ogunedo, M.B. (2018). Corrosion susceptibility of aluminium step tile roofing sheet. *International Journal of Research and Review*, 5(12), 135-142.

[3]. Daniel O. O, Elshalom C. Onomeje O. and Victor U. O, (2021). Simulation studies on corrosion of stone coated roofing sheets sold in Nigeria. *Bulletin of Chemical. Society of Ethiopia*. 35(2), 461-470.

[4]. Enedoh, M.C. (2023). Determination of the leaching tendencies of various roofing sheets modelled as rain water harvesters in Imo State Nigeria, Journal of Chemical Society of Nigeria, 48(4), 729 – 734.

[5]. Joseph O.O., Joseph, O.O., Dirisu, J.O., Odedeji, A.E. (2021). Corrosion resistance of galvanized roofing sheets in acidic and rainwater environments. *Heliyon*, 7(12), e08647.

[6]. Ujam, A.J. Egbuna, S.O., & Idogwu, S. (2014). Performance characteristics of various corrugated roofing sheets in Nigeria. *International Journal of Computational Engineering Research*, 4(11), 27-39.

[7]. Usman, Y.M., Mohammed, A.B., Muzakir, M.M., Madaki, L.A., & Modibbo, U.U. (2024). Validation of corrosion status of some roofing sheets utilized in Gombe Metropolis. *FUDMA Journal of Sciences*, 8(6), 362-369.