



---

## Investigation of Aluminium Behaviour (Corrosion) in Acidic and Alkalinity Media

Awe OI<sup>1</sup>, Owoeye FT<sup>1</sup>, Odunlami SA<sup>2</sup>

<sup>1\*</sup>Metallurgical Engineering Department, School of Engineering, Yaba College of Technology, P M B 2011, Yaba, Lagos. Nigeria.

<sup>2</sup>Mechanical Engineering Department, Federal Polytechnic Ilaro Ogun State. Nigeria

---

**Abstract** Aluminum and its alloys are of economic important because of their low cost lightness and good corrosion resistance at moderate temperature. Aluminum metal is a soft, lightweight, malleable metal with an appearance varying from silvery to dull gray, depending on the surface roughness. The main objective of this work is to investigate effect Aluminium samples on corroding media. The samples for weight loss tests were prepared in accordance to the procedure recommended by ASTM G.1. The aluminum samples of three different thicknesses 0.9, 1.2 and 1.5mm were cut into square sizes of 5 cm by 5cm. These samples were cut from the parent materials with the help of shears, while a steel rule and scribe were used for the dimensioning. Twenty-four (24) samples were prepared from each of the Aluminium thickness for both media (1, 2 and 3 molar for acidic and alkalinity media) making a total of one hundred and forty four (144) samples. The samples were measured before and after immersion for specific exposure time. The corrosion rates in acidic medium increased generally with an increase exposure time while the corrosion rate in alkalinity decreased with an increase in exposure time that is as corrosion rate in acidic medium ascended, the alkalinity declined. It was noticed that the corrosion rates in both molarities reacted in an opposing way as corrosion rate in acidic medium increased it decreased in alkalinity medium. It was also observed that the both molarity and thickness of Aluminium samples had significant impact on the corrosion rates; increase in thickness reduced corrosion rate. It can then be concluded that corroding medium of acidic had the more impact (corrosion rate) on Aluminium samples most especially 3 molar on the least thickness of Aluminium than its alkalinity counterpart.

**Keywords** Aluminium, corroding media, corrosion rate, exposure time, immersion)

---

### Introduction

Aluminum and its alloys are of economic important because of their low cost lightness and good corrosion resistance at moderate temperature [1]. Aluminum metal is a soft, lightweight, malleable metal with an appearance varying from silvery to dull gray, depending on the surface roughness. Its light in weight and its flexibility has made it a good material for domestic use in making cooking utensils and others items such as containers, appliances, and building materials [2]. As a result of the good thermal and mechanical properties, aluminum is often used in making cooking pots. Aluminum pots have a rounded-bottom shape that provides good thermal efficiency. It has much better heat-transfer characteristics and provides an improved and uniform thermal dispersion into the substance being cooked. This has actually helped and attributed important economic considerations, where fuel is both scarce and expensive [3]. Paradoxically, Uppa and Bhatia [4] observed that aluminum theoretically tends to react with air and water by some of the most energetic chemical reaction known but provided that these media are neither excessively acidic nor alkaline and are free from aggressive contaminants, the initial reaction products form a vanishingly thin impervious barrier separating the metal from its environment. The protection afforded by this condition is so effective that aluminum and some of its alloys are standard materials for cooking utensils, food and beverage container, architectural use and other applications in which a normally bare metal surface is continuously exposed to air and water, similar effect are responsible for the utility of some other metals exploited for their corrosion resistance including cobalt, and nickel.



### Corrosion of Aluminum and Aluminum Alloys

Corrosion on aluminum surfaces is usually quite obvious, since the products of corrosion are white and generally more voluminous than the original base metal. Even in its early stages, aluminum corrosion is evident as general etching, pitting, or roughness of the aluminum surfaces. Aluminum alloys commonly form a smooth surface oxidation that is from 0.001 to 0.0025 inch thick. This is not considered detrimental; the coating provides a hard shell barrier to the introduction of corrosive elements. General surface attack of aluminum penetrates relatively slowly, but is speeded up in the presence of dissolved salts. Considerable attack can usually take place before serious loss of structural strength develops. At least three forms of attack on aluminum alloys are particularly serious: (1) the penetrating pit-type corrosion through the walls of aluminum tubing, (2) Stress corrosion cracking of materials under sustained stress, and (3) Intergranular corrosion which is characteristic of certain improperly heat-treated aluminum alloys. In general, corrosion of aluminum can be more effectively treated in place compared to corrosion occurring on other structural materials used in aircraft. Treatment includes the mechanical removal of as much of the corrosion products as practicable, and the inhibition of residual materials by chemical means, followed by the restoration of permanent surface coatings.

**Reasons of Corrosion** The two most common causes of reinforcement corrosion are Localized breakdown of the passive film on the steel by chloride ions and General breakdown of passivity by neutralization of the concrete, predominantly by reaction with atmospheric carbon dioxide [5]. Loss of Alkalinity due to Chlorides: The passivity provided by the alkaline conditions can also be destroyed by the presence of chloride ions, even though a high level of alkalinity remains in the concrete. The chloride ion can locally de-passivate the metal and promote active metal dissolution. Chlorides react with the calcium aluminate and calcium aluminoferrite in the concrete to form insoluble calcium chloroaluminates and calcium chloroferrites in which the chloride is bound in non-active form; however, the reaction is never complete and some active soluble chloride always remain in equilibrium in the aqueous phase in the concrete. It is this chloride in solution that is free to promote corrosion of the steel. At low levels of chloride in the aqueous phase, the rate of corrosion is very small, but higher concentration increases the risks of corrosion [6]. Calcium hydroxide is also known as hydrated lime, slaked lime, lime water, and calcium hydrate [7]. Certain properties of calcium hydroxide which are crystals or soft, odorless granules or powder that it readily absorbs carbon II oxide from air, forming calcium oxide and it attacks many metals in the presence of water forming flammable explosive hydrogen gas. Sulfuric acid is a strong acid, that is, in aqueous solution it is largely changed to hydrogen ions ( $H^+$ ) and sulfate ions ( $SO_4^{2-}$ ). Each molecule gives two  $H^+$  ions, thus sulfuric acid is dibasic. Dilute solutions of sulfuric acid show all the behavior characteristics of acids. They taste sour, conduct electricity, neutralize alkalies, and corrode active metals with formation of hydrogen gas. From sulfuric acid one can prepare both normal salts containing the sulfate group,  $SO_4$ , and acid salts containing the hydrogen sulfate group,  $HSO_4$ . The main objective of this work is to investigate effect Aluminum samples on corroding media.

### Methodology

#### Samples and Media Preparation

The samples for weight loss tests were prepared in accordance to the procedure recommended by ASTM G.1. The aluminum samples of three different thicknesses 0.9, 1.2 and 1.5mm were cut into square sizes of 5 cm by 5cm. These samples were cut from the parent materials with the help of shears, while a steel rule and scriber were used for the dimensioning. Twenty-four (24) samples were prepared from each of the Aluminium thickness for both media making a total of one hundred and forty four (144) samples. Thirty-six containers were used for this experimental research in which four samples of the same thickness were inserted in a container. For the media, three different concentrations (1, 2 and 3 molarities) acidic medium that is sulphuric acid [ $H_2SO_4$ ] and three different concentrations (1, 2 and 3 molarities) of lime solutions (calcium hydroxide, [ $CaOH_2$ ]) were prepared from Chemical laboratory, FUNAAB, Abeokuta, Ogun state, Nigeria. The chemical compositions of each of the four different thicknesses of aluminum samples were analyzed by a Quatometer/Metal Analyzer from the Quality Control Department of Aluminium Rolling Mills Sango-Otta. These compositions are shown in Table 1 with aluminum thickness of 0.9 mm, 1.2mm and 1.5mm.

### Experimental Procedures

All the prepared samples were first rinsed in distilled water to remove all the foreign materials and were dry-cleaned with acetone solution in order to remove any traces of water on their surfaces. Each of the samples was weighed by electric weighing balance of Adventurer TM (power requirement 50/60Hz, 6VA, model number of AR3130 and readability of 0.001g) as the initial weight  $M_1$  (g). The pH values of each of the four solutions and the initial temperature were determined by using pH meter and thermometer as shown in Table 2.



### Immersion of Samples

The prepared samples were dried clean and fully immersed at room temperature after the initial weight has been recorded. Each sample from different container was removed every three days for a period of twelve days to measure weight losses by electric weighing balance which gave final weight of  $M_2$  (g). The corrosion rates of all samples after the weight loss measurement were then calculated by using the mathematical formula by Fontana (1987) [8]:

$$C R = \frac{87.6W}{\rho AT} \text{ (mm/yr)}$$

Where, C R = corrosion rate in millimeter per year, W = weight loss in mg, this was done by subtracting the final weight measured from initial weight which gave the weight loss (weight difference)  $\rho$  = density of each sample in  $\text{mg/m}^3$ , A = Area, the area of each samples was determined by calculating the total surface area in  $\text{m}^2$  and T = Time, this was an exposure time in hours of each of the samples spent inside the different concentrations of the acidic media.

### Results and Discussions

Table 1 shows the chemical composition of the three thicknesses of Aluminum samples. The analysis showed that 1.55 mm thickness of aluminum has the highest percentage of aluminum purity while the least is 1.2 mm thickness.

**Table 1:** Chemical Composition of Aluminium

Al samples	Fe	Si	Mn	Cu	Ti	Al
0.9mm	0.493	0.194	0.005	0.004	0.150	99.27
1.2mm	0.454	0.183	0.032	0.035	0.011	99.17
1.55mm	0.397	0.221	0.011	0.011	0.016	99.32

Table 2 shows the corrosion rate of Aluminium samples in three molarities of acidic medium, the corrosion rates of samples increased with an increase in molarity of acidic medium. The corrosion rates in the first three (3) days 0.9 mm of Aluminium samples in 1, 2 and 3 molars gave 15.256, 16.308 and 20.816 mm/yr respectively. The corrosion rates of 0.9 mm in 1 molar also increased as the exposure time increased from 3 to 12 days for 15.256, 17.780, 22.472 and 26.707 mm/yr in that order. The corrosion rates of 1.2 mm of Aluminium also increased with an increase in exposure time as well as increase in molarity of corroding medium. Aluminium sample thickness of 1.5 mm had the least corrosion rate, in the last day of exposure time the corrosion rates in 2 molars for 0.9, 1.2 and 1.5 mm were 40.403, 29.012 and 26.028 mm/yr respectively. It was observed that the rate of corrosion of the three different thicknesses of Aluminium samples decreased with an increase in sample thickness.

**Table 2:** Corrosion rate of Aluminium samples in three molarities of acidic medium

Al samples	H <sub>2</sub> SO <sub>4</sub>	C.R in 3days	C.R in 6 days	C.R in9 days	C.R in12 days
0.9 mm	1M	15.256	17.780	22.472	26.707
	2M	16.308	20.684	37.183	40.403
	3M	20.816	25.840	30.095	35.714
1.2mm	1M	12.183	14.614	19.111	25.003
	2M	15.020	18.433	23.777	29.012
	3M	18.716	20.080	24.221	31.000
1.5 mm	1M	10.091	15.419	20.441	21.304
	2M	12.099	17.142	23.911	26.028
	3M	16.901	21.074	27.488	30.191

In Table 3; corrosion rate of Aluminium samples in three molarities of alkalinity medium, the corrosion rate of all aluminium samples in all three molarities significantly reduced generally from the first (3 days) to second time of exposure (6 days) and maintained the trend. The corrosion rates in corroding medium of alkali increased with an increase in its molarity; in the first exposure time (3 days) of 1.2 mm of Aluminium samples in 1, 2 and 3 molars gave 4.528, 7.609 and 9.715 mm/yr respectively. In this corroding medium the aluminium samples decreased as exposure time increased from 3 days to 12 days, in 1 molar, the corrosion rates were 4.528, 3.371, 1.729 and 1.732 mm/yr in that order while in 1.5 mm of Aluminium soaked in 2 molar of calcium hydroxide gave 6.446, 4.332, 2.905 and 2.450 mm/yr respectively. In the same 1.5 mm of Aluminium inserted in 3 molars gave corrosion rate of 7.222, 3.321, 2.091 and 1.847 mm/yr for 3, 6, 9 and 12 days respectively.

**Table 3:** Corrosion rate of Aluminium samples in three molarities of alkalinity medium

Al samples	Ca(OH) <sub>2</sub>	C.R in 3days	C.R in 6 days	C.R in9 days	C.R in12 days
0.9 mm	1M	7.190	2.322	2.192	1.609
	2M	7.989	3.174	2.426	1.802
	3M	9.212	2.682	1.802	1.419



1.2mm	1M	4.528	3.371	1.729	1.732
	2M	7.609	3.691	2.481	1.909
	3M	9.715	1.888	1.875	1.529
1.5 mm	1M	5.052	3.233	2.903	2.411
	2M	6.446	4.332	2.905	2.450
	3M	7.222	3.321	2.091	1.847

Figure 1 shows the corrosion rate of 0.9 mm Aluminium in three molars of corroding media (acidic and alkalinity media), the corrosion rates in acidic medium increased generally with an increase exposure time while the corrosion rate in alkalinity decreased with an increase in exposure time that is as corrosion rate in acidic medium ascended, the alkalinity declined. The highest corrosion rate at first exposure time (3 days) in acidic medium was on 3 molar but the highest corrosion rate was noticed on acidic medium of 2 molars.

Figure 2 shows the corrosion rate of 1.2 mm thickness of Aluminium in three molars corroding media (acidic and alkalinity media); the corrosion rates in acidic medium also increased as exposure time increased while the corrosion rate in all the three different molars of alkalinity medium decreased with an increase in exposure time. In acidic medium, the highest corrosion rate was noticed on 3 molars and the least was on 1 molar. In alkalinity medium, 3 molars had the highest had the highest corrosion rate in the first exposure time (3 days) but it was the most declined value at exposure time of six days.

The corrosion rate of 1.5 mm of aluminium in the three molars of corroding media is shown in Figure 3. Generally, the corrosion rate of aluminium (1.5mm) in both media exhibited different reactions, the corrosion rate in acidic medium increased as the exposure time increased while the corrosion rate in alkalinity decreased as the exposure time increased.

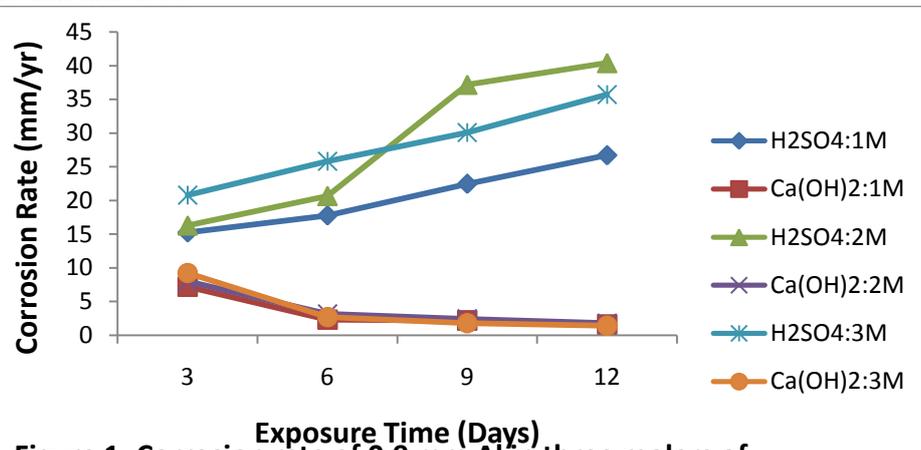


Figure 1: Corrosion rate of 0.9 mm Al in three molars of corroding media

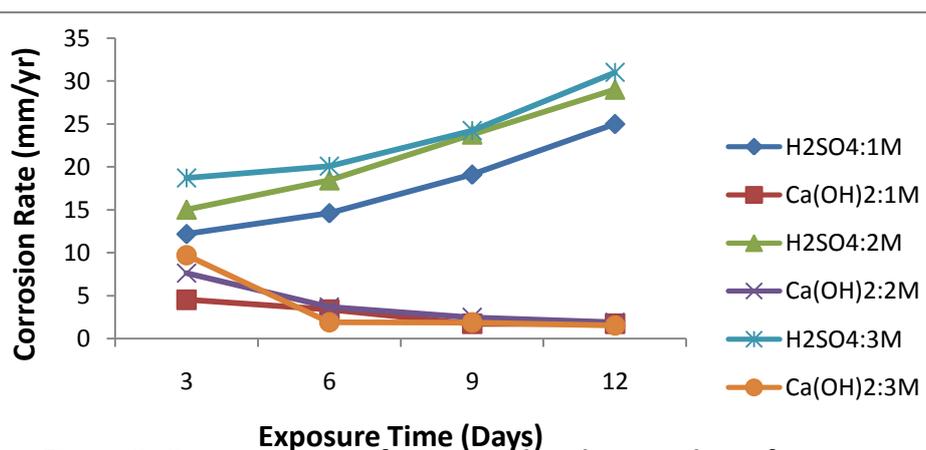


Figure 2: Corrosion rate of 1.2 mm Al in three molars of corroding media



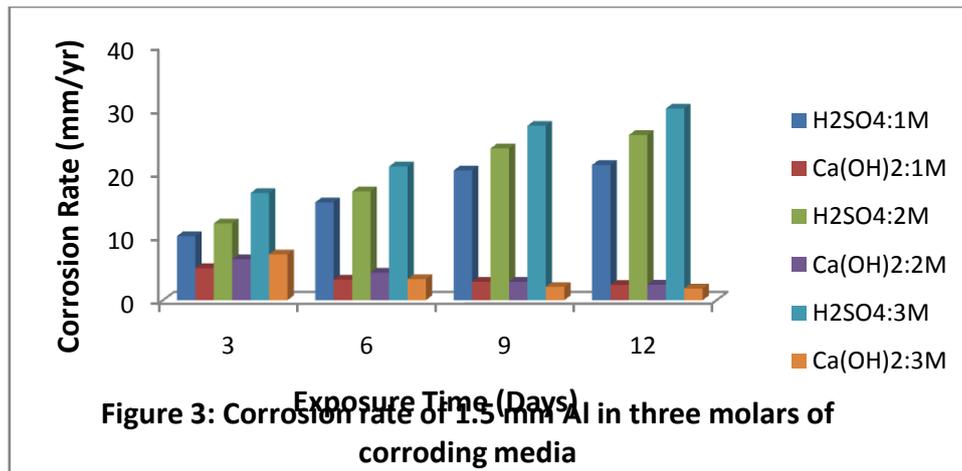


Figure 3: Corrosion rate of 1.5 mm Al in three molars of corroding media

**Optical Micrograph of Aluminum Samples**

Plate 1 shows the optical micrographs for different thicknesses of Aluminium samples before immersion while Plates 2 and 3 show the optical micrographs of Aluminium samples after immersion in acidic and alkalinity media respectively. The texture of these micrographs showed that the corroding media attacked the Aluminium samples which made them to possessed rough surfaces.

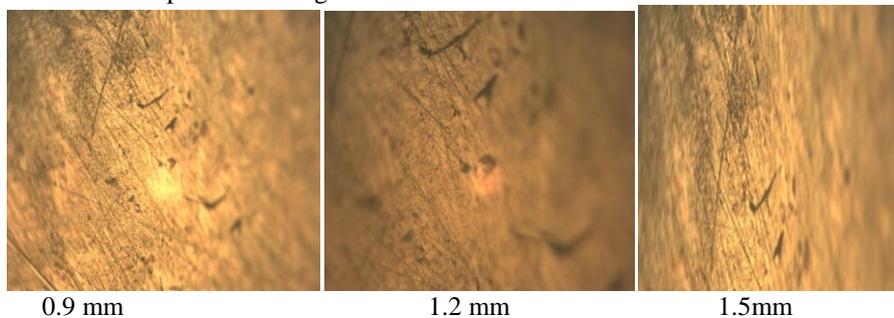


Plate 1: Aluminum samples before immersion

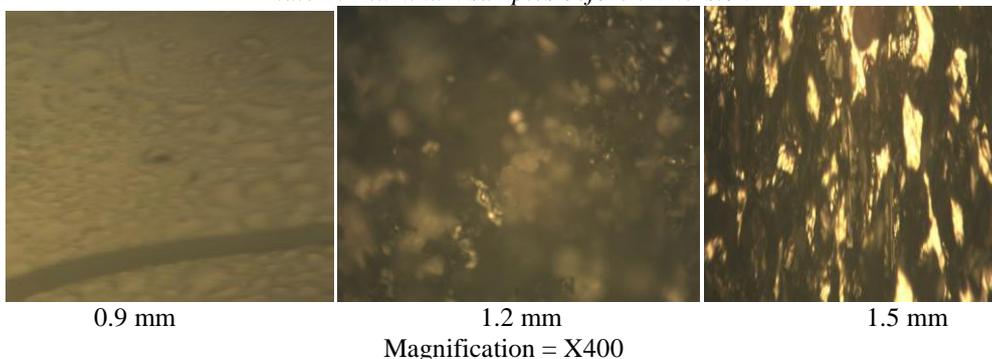


Plate 2: Aluminum samples after immersion in acidic medium

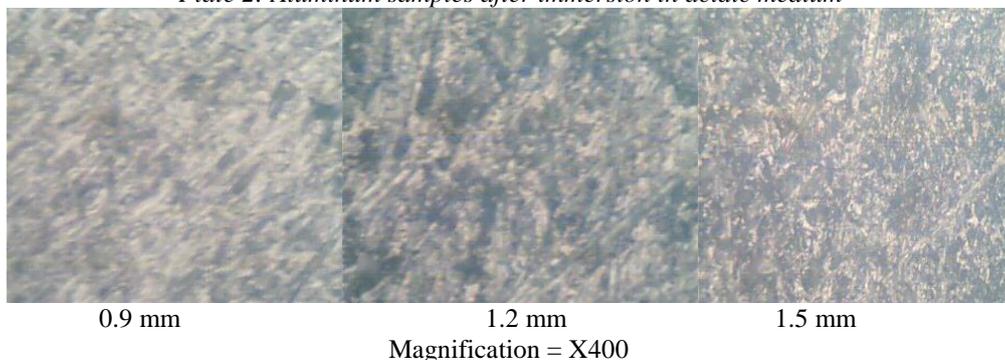


Plate 3: Aluminum samples after immersion in alkalinity medium

**Conclusion**

The corrosion rates in acidic medium increased generally with an increase exposure time while the corrosion rate in alkalinity decreased with an increase in exposure time that is as corrosion rate in acidic medium ascended, the alkalinity declined. It was noticed that the corrosion rates in both molarities reacted in an opposing way as corrosion rate in acidic medium increased it decreased in alkalinity medium. It was also observed that the both molarity and thickness of Aluminium samples had significant impact on the corrosion rates; increase in thickness reduced corrosion rate. Increase in corroding medium of acidic increased rate of attack on samples; while the corrosion rate decreased with an increase in molarity of alkalinity medium. It can then be concluded that corroding medium of acidic had the more impact (corrosion rate) on Aluminium samples most especially 3 molars on the least thickness of Aluminium than its alkalinity counterpart.

**References**

- [1]. Moutarlier, V., Gigandet, M., Normand, B., Pagetti, J. 2005. EIS characterisation of anodic films formed on 2024 aluminium alloy, in sulphuric acid containing molybdate or permanganate species. *Corros.Sci.*, 47, 937.
- [2]. Harnandez, L. 2006. Aluminium. Wiley Interscience (Wiley): New York, NY.
- [3]. Adetunji, O. And F. Owoeye. 2011. "Corrosion Resistance of Aluminum Plates in Lime Solution". *Pacific Journal of Science and Technology*. 12(1):56-61.
- [4]. Uppal, O. and Bhatia, L.N. 2001. Localized corrosion of passive metals. Uhlig's "Corrosion Handbook", Revie, R.W. (editor), John Wiley and Sons, Inc., Canada, 175-186.
- [5]. Shihai, C., Jianmin, H., Yongping, D. and Weijing L. 2007. "Corrosion resistance and wear resistance of plasma electrolytic oxidation coatings on metal matrix composites", *Surface & Coatings Technology* 201 Pp. 5306–5309.
- [6]. Batis, G. and Rakanta, E. 2005. "Corrosion of steel reinforcement due to atmospheric pollution", *Cement & Concrete Composites* 27 Pp.269–275
- [7]. Hardy. 2001. "Lime Water, Lime Burns". *Journal of the National organic Standard Board*.ix:52.
- [8]. Fontana M.G. 1987. *Corrosion Engineering*, 3rd ed. McGraw-Hill, International Ed. p.171.

