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CORROSION RESISTANCE OF COMMERCIAL ROOFING SHEETS TO ACID RAIN WATER IN ELEME, RIVERS, NIGERIA

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ABSTRACT: Acid rain deposition affects most materials to some degree. Carbon-steel, nickel, zinc, copper, paint, some plastics are vulnerable while stainless steel and aluminium are more resistant metals. Sulfur dioxide is the main pollutant in respect to corrosion of roofing sheets from acid rain, but others take their toll, including nitrogen oxide, carbon dioxides, ozone etc.This study, investigated the acidity of rainfall at Eleme, Rivers state of Nigeria. The effect of acid rain on aluminium alloy and galvanized steel roofing sheets was studied as well as their relative corrosion resistance. The simple immersion test method was used to determine corrosion rates by weight loss. Results obtained indicated that Eleme does experience acid rain of average pH 4.34; which corrodes roofing sheets used by the community, with greatest damage on galvanized steel. Corrosion rates of aluminium alloy and galvanized steel are 0.0049 g/dm^2.day and 0.0156 mg/dm^2.day respectively. Statistical analysis using the method of least square principle and coefficient of correlation indicated positive correlation between weight loss of Aluminium alloy and time with (r = 0.9872) and (r = 0.9480) at pH of 3.0 and 4.34 respectively and between weight loss of galvanized steel and time with (r = 0.9982) and (r = 0.9974) at pH of 3.0 and 4.34.This shows that aluminium alloy is a better choice of material for roofing in Eleme, Rivers state.

Keywords
Acid Rain; Corrosion; Galvanized Steel; Aluminium Alloy; Electrochemical.

INTRODUCTION

Corrosion can be defined as the chemical or electrochemical reaction between a material, usually a metal, and its'environment that produces a deterioration of the material and its properties[1]. Electrochemically, corrosion is understood as a destructive process developed by electrolyte action over a metal. The electrolyte is a solution which must of necessity conduct electricity example, sea water. The complete corrosion reaction is divided into an anodic portion and a cathodic portion, occurring simultaneously at discrete points on metallic surfaces. Flow of electricity from the anodic to the cathodic area may be generated. The different types of corrosion are uniform/General, galvanic/bimetallic, Pitting, Crevice, Erosion, Fretting, intergranular and filiform [2]. For corrosion to occur four essential factors are required. The factors are; the anode, cathode, electrolyte and an electrical connection as illustrated in figure 1 below.

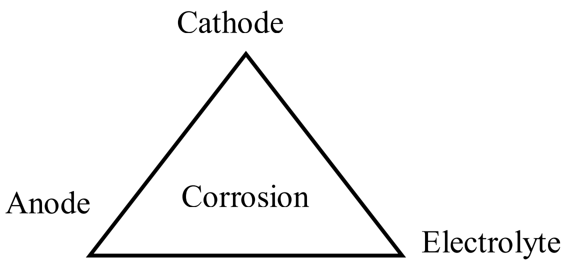

Figure 1. The Corrosion Triangle

The corrosion resistance of metals and alloys is a basic property related to the easiness with which these materials react with a given environment[3]. Corrosion generally seeks to reduce the binding energy in the metals, the end result involves a metal atom being oxidized; whereby it losses one or more electrons (at the anode) and leaves the bulk metal. The lost electrons are conducted through the bulk metal to another site

(Cathode) where they are reduced. The corrosion resistance of a metal/alloy is also usually attributed to its' passivity. This is a phenomenon in which a metal or an alloy exhibits a much higher corrosion resistance than that expected from its' position in the electrochemical series[4]. It is the result of the formation of a highly protective but very thin and quite invisible film on the surface of a metal or an alloy, which makes it more noble. This film is considered to be insoluble, non-porous and self healing in nature, such that when broken, it will repair itself on re-expose to an oxidizing condition.

Acid rain occurs when sulfur dioxide and nitrogen oxides in the atmosphere react with oxygen in the air to form sulfuric acid (H_2SO_4) and nitric acid (HNO), which falls to the surface as rain, snow or dust. To be considered acid, precipitation has to have a pH of 5.0 or lower[5]. Sulfur dioxide (SO_2) from human sources comes primarily from smelters and coal burning power plants. Hot sulfur dioxide also originates from natural sources. Nitrogen oxides come primarily from automobile exhaust and other combustion processes, and some is created by lightening and soil microbes, flaring of gases and other industrial processes; house hold with wood-burning stoves, also emit SO_2 and NO_x into the atmosphere[6]. Acid ran also contains in additional to sulfur dioxide and nitrogen dioxide, heavy metals, carbonmonoxide and photochemical oxidants. Reactions between these substances strengthen their damaging effect, which is referred to as synergistic effect. Because an electrolyte is a necessity for corrosion, roofing sheets tend to corrode, where acid rain water and/or condensation cannot run off or becomes trapped. Sulfur dioxide is the main pollutant in respect to corrosion, but others take their toll, including Nitrogen oxide, carbon dioxides, ozone etc.

The reaction between roofing sheets and pollutants are very complex and many variables are involved. Deposition of pollutants onto surface depends on atmospheric concentrations of the pollutants and the climate around the surface. Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. The objectives of this research are to carry out a comparative study on the effect of acid rain on Eleme commercial roofing sheets and to determine the relative corrosion resistance of these roofing sheets to acid rain. The research should also provide recommendations on the most suitable roofing sheets for acid rain regions based on experimental results. For the purpose of this research work, Simple immersion test was used where basically, small sections of the candidate materials were exposed to the test medium and the loss of weight of the materials were measured for a period of time. Though there is no simple way to extrapolate the results obtained from this simple test to the prediction of system lifetime, it is the quickest and most economical means for providing a preliminary selection of best suited materials[7].

MATERIALS AND METHODS

Rainwater collected from Sangere, Girei local government area, Yola which is not an industrial area was taken as the control experiment. The coupons not immersed in the acid rain water were immersed in this rain water of pH 6.25, which can not be considered as acid rain. The test solution (rain water) was collected from Eleme, Port Harcourt, Rivers State of Nigeria; an industrial area housing the Refinery and Eleme Petrochemicals Nigeria Limited. The collection was done in open air, using plastic basins, which were kept at a reasonable distance above the ground (acidity changes once the rain water touches the roof, ground, metal or china ware) [7]. The pH of the test solution was determined using a pH meter (EDT Instruments Ltd, Dover Kent CT 16 2AA). The pH of Eleme rainfall over the sampling period varied between 4.0 and 4.34. Since Acid rain regions have been known to register rainfall with pH of as low as 3.0 .The intensified solution was made to pH 3.0.

The test pieces, Aluminium Alloy (BORNO Aluminium) and Galvanized Steel (SWAN BRAND, Lagos) were cut to size (4 cm x 4 cm) and cleaned, using silicon carbide paper (sand paper), they were then degreased by washing in warm water containing detergent and further washed in methylated spirit. The coupons were air dried and stored in a desiccator (JENCONS HEVEL HEMPSTEAD, ENGLAND). These coupons were weighed and separately immersed in 500 ml beakers containing the acidified water. They were withdrawn every week and re-weighed. The simple immersion test continued for a total time period of 8 weeks. Since the Corrosion resistance cannot be directly measured, the corrosion rate was measured using the slopes of the graphs; weight loss versus time for each metal. The relative steepness of these graphs indicates the corrosion resistance of the sheets. The corrosion rate (CR) was determined using equation (1).

$$CR\ (mg/dm^2.day) = \frac{\text{wt loss} \times 372}{\text{Area} \times \text{Time}} \quad (1)$$

Where wt loss = weight loss

RESULTS AND DISCUSSION

The initial weights of the metal coupons, Comparisons of weight loss of Aluminium and galvanised Steel roofing sheets in intensified water of pH 3.0 and weight loss of Aluminium and galvanized Steel roofing sheets in rain water of pH 4.34 are presented in Table 1, figure 1 and 2 respectively.

Table 1. Initial weights of the metal coupons

Metal	Weight (g)
Aluminium Alloy	2.440
Galvanized Steel	1.960

It can be seen from Figures 1 & 2, the relative greater steepness of the two lines that galvanized steel corroded faster than aluminium alloy. In the course of the test, bubbles were observed to form below the coupons after the first seven days; probably bubbles of hydrogen, as expected was particularly obvious in the steel coupon. The bubble formation was followed by a darkening of the steel coupon; it became dark grey in colour.

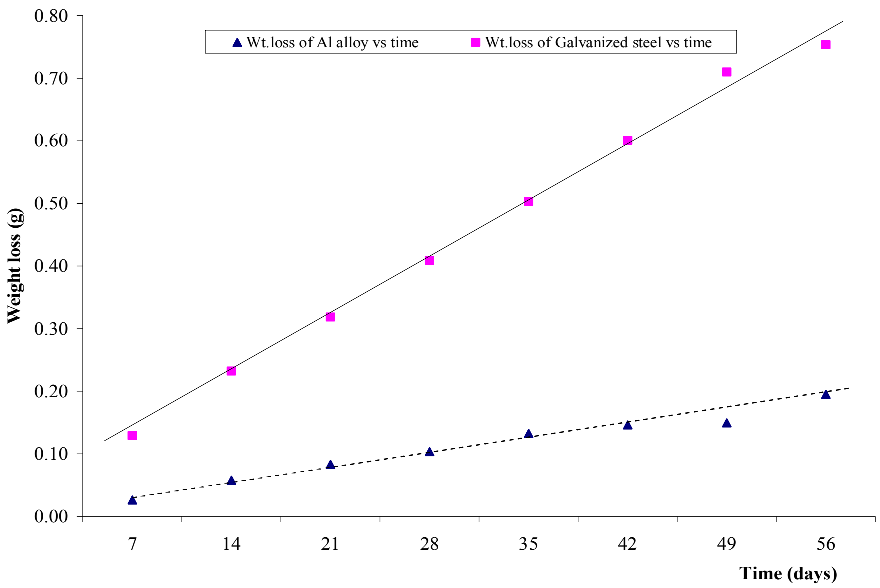

Figure 1: Comparison of weight loss with Time of Al alloy and Galvanised Steel in Intensified Water of pH 3.0

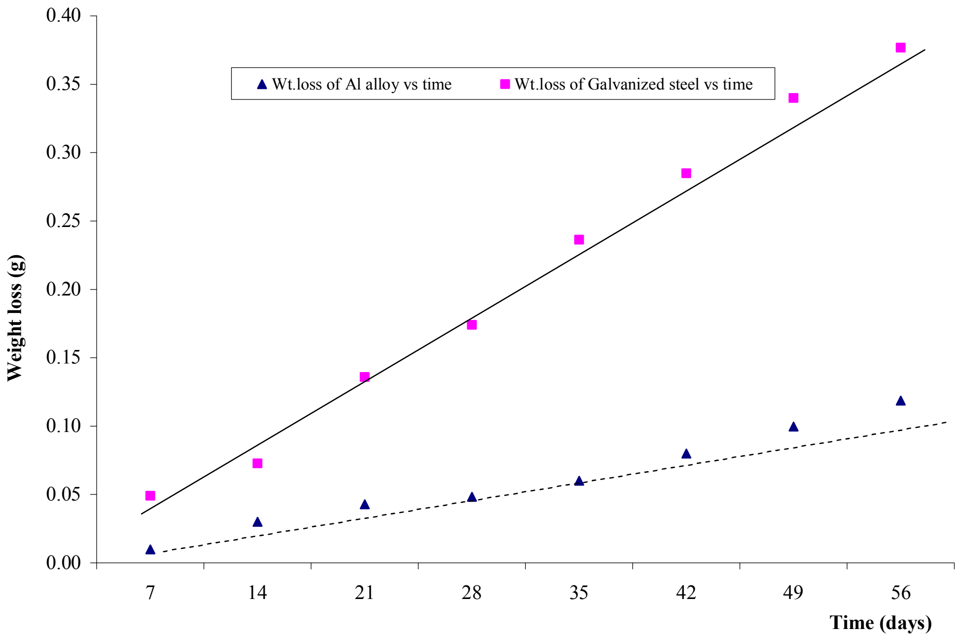

Figure 2: Comparison of weight loss with Time of Al alloy and Galvanised Steel in Eleme Rain Water of pH 4.34

The bubbles and graying persisted till a uniform corrosion was observed over the steel. The corrosion products were dark grey and brown, they washed off easily; which is typical of corrosion in steel, where corrosion products have little or no adherence and flake off as they are formed, thus presenting fresh surfaces for further corrosion. Aluminium alloy showed very slight weight loss, and little difference was seen physically; possibly because of the formation of a protective film of aluminium oxide in the presence of oxygen. After the fourth week, Aluminium lost its shine and became dull (loss of aesthetic appeal). At about this same time, perforations appeared on the surface of the steel, and enlarged over time (pitting corrosion). This resulted in a greater weight loss in steel than aluminium alloy.

The corrosion rates gotten from this experiment are not directly those obtainable in the actual environment where the roofing sheets are used. This is the limitation of using a laboratory test, being that; in general, standardized accelerated laboratory corrosion tests are more simplistic and different compared with actual service conditions. Also, by their very nature, accelerated corrosion tests are designed to deviate from actual service exposure to produce results in significantly shortened time frames as that available for this project[8] . The acceleration of corrosion damage was achieved by a continuous immersion and by intensifying the acidity of the rain to a pH of 3.0 (Note that the roofing sheets at Eleme or any tropical region are not continuously in contact with the rain water).To obtain the exact corrosion rates of galvanized steel and aluminum alloy; in their working situation, a field test at a higher level would have to be carried out, which is beyond the scope of this study. In general, actual corrosive environments are more complex and less carefully controlled than accelerated laboratory tests. Therefore, at best, the latter can be used to measure the relative field performance in terms of a particular corrosive medium[3, 9].

From the results and graphs presented, it can be established that; Eleme suffers from acid rain; Galvanized steel will most definitely corrode faster than Aluminium alloy under acidic conditions and the rate of this corrosion will increase with increasing acidity. Aluminum alloy will corrode at a rate of 0.0081 mg/dm^2.day in water of pH 3.0 and 0.0049 mg/dm^2.day in water of pH 4.34; while galvanized steel will corrode at a rate of 0.0313 mg/dm^2.day in water of pH 3.0 and 0.0156 mg/dm^2.day in water of pH 4.34. Aluminium alloy is thus a preferable material to be used as roofing sheet in acid rain regions. This aluminum alloy will however still corrode gradually, if it is subject to continuous abrasion from materials coming in contact with it, like stones and sand particles from storms, ice, contact with objects like tress etc.

Table 2. Corrosion rates for Aluminium alloy and galvanized steel in Rain water of pH 3.0 and pH 4.34.

Coupons	Corrosion rates (mg/dm^2.day)	
	Rain water with pH 3.0 (Intensified)	Rain water with pH 4.34
Aluminium alloy	0.0081	0.0049
Galvanized Steel	0.0313	0.0156

CONCLUSION

From the test results, it is seen that Eleme suffers from acidic deposition with an average pH of 4.34, as compared to the controlled value of 6.25 received from Sangere, Yola. This acidic deposition greatly enhances the corrosion of roofing sheets; the sheets loose aesthetic appeal and fail rapidly; particularly galvanized steel, which corroded faster than aluminium alloy at a rate of 0.0156 mg/dm^2.day. Aluminium alloy corroded much slower at a rate of 0.0049 mg/dm^2.day. These corrosion rates will however increase with increasing acidity of the rainfall. Aluminium alloy proved to be a more corrosion resistant roofing sheet than galvanized steel. Therefore, it is preferable to use the former as roofing sheet in Eleme and other tropical regions of Nigeria suffering from acidic deposition.

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