# ATMOSPHERIC CORROSION OF METALLIC ROOFING SHEET IN BUILDING CONSTRUCTION IN THE NIGER DELTA REGION OF NIGERIA

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## ABSTRACT

*The unique humid equatorial climate of the coastal Niger Delta region of Nigeria has often been suspected to be a major player in the degradation of metallic building and engineering materials in the region. This study examined the role of dominant climatic factors as well as pollutants' concentrations in the corrosion of galvanized iron roofing sheets in the region. Twelve experimental racks composed of cut pieces of galvanized iron were planted across three sites in the region for one year. Monthly readings of four climatic factors (temperature, relative humidity, rainfall, and wind velocity) and concentrations of aerosol and sulphur dioxide ($SO^2$) were taken at each rack station during the period. The mass loss of each of the specimens was determined at the end of the experiment. The obtained data, both of mass loss and atmospheric factors were subjected to multiple regression analysis and correlation analysis to determine their relative influences in the corrosion plague. It was revealed that there is synergism amongst the factors in their contribution to corrosion impact. Of special note is the fact that the sulphur dioxide was observed not to suit our purpose. To ameliorate the situation, alternative roofing materials that are cheap and durable but less susceptible to corrosion attack as galvanized iron should be explored.*

**Keywords:** *Climate factors, corrosion, galvanization, Niger Delta, synergism.*

## INTRODUCTION

The dynamism and variability of the atmosphere often make predictions of phenomena difficult. The atmospheric corrosion of metallic materials is one of such phenomena. The physical world of technology is built and sustained on metals. The strength, stability and aesthetics of our built environment depend on the size, shape and durability of the core components, often made of metals. Different metals resist corrosion menace differently depending on their internal resistance. The higher resistant metals have limited applications due to cost. Therefore, the choice of construction industry is often iron and steel, considered to be cheap and to have the strength and stability to span space and to resist gravity, though highly vulnerable to corrosion attack.

The unique qualities of strength, durability and malleability of iron make it a ready choice as roofing material. The tendency of this material to degrade in the wet atmosphere necessitates its being subjected to further treatments with higher resistant but moderately expensive materials like zinc. However, galvanization (coating with zinc) of iron used in roof coverings is not totally corrosion-proof as the protective zinc layer gradually gives way under persistent and adverse climatic influences (Gittman, 1986, Dean & Lee, 1987, Graedel & McGill 1986 & Graedel, 1989). The defining climatic factors of rainfall, temperature, relative humidity, sunshine and wind are notoriously known to have influenced the behaviour and growth of exposed materials and plants (Johnson & Linder, 1993, Cole et al, 1999, Chotimongkol et al, 1999 & Tidblad et al, 2000). While these factors have shaped and defined the ecological and geographical regions of the world over the years, their noticeable influence on the man-made materials had been of recent (Gelspan, 1997, Christianson, 2000 & Goodrej, 2001). Most atmospheric corrosion studies have been done by scientists who are based in Europe and North America where the climate is temperate (Graedel & McGill, 1986, Cole et al, 1999 & Tidblad et al, 2000). The humid tropical zones such as the southeastern extremity of Nigeria have seen less of the studies even as it plays host to high industrial activities.

This study is essential because of the near universal application of galvanized iron in the region as roofing material. The acceptability of this material is brought to question now as most roofs in the region hardly survive for a long time especially when compared to other parts of the country (Obia, 2008). A major controversy exists in the region whereby indigenes attribute their plight to industrial activities of oil prospecting companies (Obia, 2008). The latter had always denied responsibility for the plagues, citing low sulphur content of their product as a defense (Inyang, 2001). Notwithstanding any other factors, the unique climate of the region has often been cited as a prime cause of this plaque (Inyang, 2001).

This study therefore examines the influences of four dominant climatic factors of temperatures, relative humidity, rainfall and wind speed (velocity) as well as pollutant factors of sulphur dioxide ($SO^2$)and an aerosol that might influence this impact. The two atmospheric pollutants (gaseous sulphur dioxide and aerosol) are suspected to be products of industrial exhaust if hydrocarbon industry as well as sea salts (Enguna, 1987 & Obia, 2008). These climatic factors, in their extremes, characterize a humid tropical climate and are noted to be among the highest in the world (World Bank, 1995). Experimental exposure of this metal in the atmosphere had been confirmed in past studies to accelerate corrosion (Tidbald et al, 2000). Though the local climate indicates the heavy presence of these factors across the region, it was discovered that there were differences in the rate of wear of galvanized iron in different microenvironments within the region (Obia, 2008). This experiment involved the exposure of metal in three different microenvironments within the region of study.

## MATERIALS AND METHODS

The materials for the experiment included cut pieces of corrugated galvanized iron, wooden rack and plastic strings to suspend the specimens. Others were sensors for relative humidity, temperature, rain gauge and wind vein attached to an International Environmental Monitoring Station Manufactured by ELE International of United Kingdom and a WA210 model analytical electronic weighing balance manufactured by Adam Equipment Company Limited, United Kingdom.

Two of the sites (Ikang in Akpabuyo LGA of Cross River State and Ibeno in Akwa Ibom State) were marine environments with heavy rainfall almost all year round. The third site, Ekuri village, was a remote location in the tropical Cross River rainforest. However, with less rainfall than the other sites. Ibeno site was unique in the sense that it posted heavy presence of gas flare chambers as it played host to Mobil Producing Unlimited flow stations. The wind velocity is generally low across the region with a mean value of 2.5m/s, the relative humidity is always high in the area, between 80%-85% while the temperature oscillates around 30$^{o}$C.

The cut pieces of the corrugated galvanized iron specimens (100mmx 150mm) were first washed in ethanol solution degreased and scrubbed and cleaned with 120 number abrasive papers in accordance with ASTM GI standards

(Chotimongkol et al, 1999 & Cole et al, 1999). Each specimen was then weighed on the electronic balance and its initial mass recorded. Four replicates of the specimens were suspended on a wooden rack using the plastic strings. The entire assembly was inclined at 220 to the horizontal an elevated 1.2m from the ground. The 220 inclination represents the advantage roof slope in the region (Obia, 2008) while the 1.2m elevation was to avoid water splashes due to rain drops. Each assembly was stationed in an open field away from trees and buildings. The experiment lasted a period of twelve months at the end of which the specimens were removed, and cleaned as described earlier (Cole et al, 1999) and re-weighed to know the new mass. The difference between the initial mass and the final mass is the specimen's mass loss. The mean of the mass losses of the four replicates became the representative mass loss at the station. A total of 12 stations were set among the three sites; four per site and stationed within 500m radius.

The descriptive statistics (the means, standard deviations and coefficients of variation) of the data were first determined to measure their variability before subjecting them to further statistical treatment. The multifarious and almost indeterminate factors that shape atmospheric processes call for the adoption of multivariate approaches in the statistical analysis of this study (Eze, 2002). Two statistical tools were adopted to analyze the obtained data; correlation analysis and multiple regression analysis were used to show the relative contributions of climatic pollutants to the corrosion scourge.

## RESULTS AND DISCUSSION

The mass losses at each station and the corresponding reading of the climatic factors are as shown on table 1. The means, standard deviations and coefficients of variation of the variables are as shown on table 2. The mass loss had the highest coefficient of variation while temperature had the least value. The multiple regression result shows a significant change value of 0.005, an F ratio of 10.243 and coefficient of determination $R^2$ of 0.854. The partial and part coefficients of all the regressor variables are as shown on table 3. Result from the table indicates that only rainfall with partial and part coefficient of 0.841 and respectively contributed positively to the impact. Other factors, temperature, relative humidity and wind velocity contributed negatively.

The descriptive statistics showed unique behaviour of the data. Examination of the coefficient of variation (Table 2) shows that mass loss (CV85.35%), rainfall (CV=61.08%) and sulphur dioxide ($SO^2$), (59.77%)

indicated wide spread data distribution. On the contrary, temperature (CV=4.59%) and relative humidity (CV=7.25%) show little or no data spread. Aerosol concentration and wind speed show low variation in spread. Similarly, the two parameters show high standard deviation compared to others.

The wide variation in mass loss could be an indication of possible difference in corrosion impact across the stations. This could be accounted for by variation in intensities of the climatic events and pollutant concentrations, for instance, while the stations recorded very high rainfall at site 'B', QIT (150.65mm - 498.30mm), the situation at 'A' and 'C' were different. At these stations the ranges were 60.78mm - 300.00mm for site, 'A' and 25.65mm - 357.25mm for site 'C'. In the same vein, pollutant concentrations (aerosol; 15.37 - 20.65mg/m3 and $SO^2$; 0.31 - 0.68mg/1) were high at QIT. The coefficient of determination, $R^2$ of 0.874 indicates that climatic factors and atmospheric pollutants indeed contributed highly (87.4%) to the corrosion impact.

A closer examination of the data shows these factors contributed differently to the impact. A 0.05 level of significance, temperature with partial coefficient of 0.644, relative humidity, -0.826 and sulphur dioxide, -0.148 are negative contributors to the impact. Rainfall with partial and part correlation coefficient of 0.798 and 0.471 makes the highest positive contribution to the impact. Temperature and relative humidity are shown here to be negative contributors to the impact contrary to the result of past studies conducted in the industrialized world (Guttman, 1968; Hanrikkson & Rode, 1986, Chotinmongkol et al, 1999 and Tidblad et al, 2000). Aerosol is a positive contributor with partial coefficient of 0.328 while wind speed is a statistically insignificant contributor with coefficient of 0.072.

The presence of aerosol, which concentration is most at site 'B', QIT (Ibeno), could be due to the presence of gas flare chambers and the proximity of the site to the sea (Cole et al, 2003). Notwithstanding the negative individual contributions of some of the various parameters, their joint influence ($R^2$=0.854) is surprisingly high, suggesting that synergism exists in the reaction. Another interesting discovery is that sulphur dioxide not only has small correlation coefficient but contributes negatively to the impact. This is contrary to commonly held view in scientific community (Graedel & McGill, 1986; Henrikkson & Rhode, 1986).

**Table 1:** Mean readings of mass losses and climatic factors across the stations

| Site | Station | Mass loss(mg) | Temp. $0^o$ | RH% | Rainfall mm | Wind velocity | Aerosol mg/m$^3$ | $S0^2$ mg/1 |
|---|---|---|---|---|---|---|---|---|
| "A" | $S_1$ | 31.30 | 28.00 | 79.30 | 208.40 | 2.30 | 16.70 | 0.15 |
| Ikang | $S_2$ | 43.00 | 28.30 | 80.75 | 300.00 | 2.00 | 12.30 | 0.09 |
| | $S_3$ | 23.10 | 31.70 | 72.67 | 60.78 | 2.30 | 18.77 | 0.55 |
| | $S_4$ | 0.40 | 29.89 | 82.36 | 180.90 | 3.20 | 7.22 | 0.10 |
| "B" | $S_5$ | 41.30 | 28.68 | 77.90 | 286.90 | 2.50 | 17.80 | 0.68 |
| QIT | $S_6$ | 51.80 | 28.90 | 79.20 | 279.10 | 2.80 | 16.08 | 0.51 |
| Ibeno | $S_7$ | 41.20 | 31.20 | 70.30 | 150.65 | 2.10 | 20.65 | 0.61 |
| | $S_8$ | 42.50 | 29.40 | 82.60 | 498.30 | 2.80 | 15.37 | 0.31 |
| "C" | $S_9$ | 5.50 | 31.10 | 74.37 | 70.10 | 3.10 | 8.75 | 0.16 |
| Ekuri | $S_{10}$ | 1.80 | 29.10 | 87.60 | 358.25 | 2.50 | 9.87 | 0.31 |
| Village | $S_{11}$ | 0.60 | 28.60 | 85.60 | 260.74 | 2.40 | 15.45 | 0.48 |
| | $S_{12}$ | 2.60 | 31.80 | 70.30 | 25.65 | 3.00 | 8.32 | 0.25 |

Source: recorded field data between January, 2007 and December, 2007.

**Table 2:** Descriptive Statistics

| Variable | No of reading | Mean | Standard deviation | Coefficient of variation (CV) % |
|---|---|---|---|---|
| Y | 12 | 23.758 | 20.276 | 85.34 |
| $X_1$ | 12 | 29.723 | 1.365 | 4.59 |
| $X_2$ | 12 | 78.579 | 5.694 | 7.25 |
| $X_3$ | 12 | 223.264 | 136.374 | 61.08 |
| $X_4$ | 12 | 2.583 | 0.393 | 15.20 |
| $X_5$ | 12 | 13.940 | 4.4996 | 32.28 |
| $X_6$ | 12 | 0.3492 | 0.2087 | 59.77 |

Where:

Y = mass loss
$X_1$ = temperature
$X_2$ = relative humidity
$X_3$ = rainfall
$X_4$ = wind velocity
$X_5$ = aerosol
$X_6$ = Sulphur dioxide ($SO^2$)

**Table 3:** Regression summary

| Model | $R^2$ | F change | $Df_1$ | $Df_2$ | Sig. F change |
|---|---|---|---|---|---|
| 1 | 0.874 | 5.764 | 6 | 5 | 0.037 |

Predictors:

| | | |
|---|---|---|
| Y | = | mass loss |
| X1 | = | temperature |
| X2 | = | relative humidity |
| X3 | = | rainfall |
| X4 | = | wind velocity |
| X5 | = | aerosol |
| X6 | = | sulphur dioxide |

Source: Author's computation from SPSS computer software

**Table 4:** Correlation Coefficients

| Model | Constant | Correlation Partial Part |
|---|---|---|
| $X_1$ | -0.644 | -0.299 |
| $X_2$ | -0.826 | -0.522 |
| $X_3$ | -0.798 | 0.471 |
| $X_4$ | 0.072 | 0.026 |
| $X_5$ | 0.328 | 0.123 |
| $X_6$ | -0.148 | -0.051 |

Where:

| | | |
|---|---|---|
| Y | = | mass loss |
| X1 | = | temperature |
| X2 | = | relative humidity |
| X3 | = | rainfall |
| X4 | = | wind velocity |
| X5 | = | aerosol |
| X6 | = | sulphur dioxide ($SO^2$) |

Source: Author's computation using SPSS computer software.

## CONCLUDING REMARK

From the study, it is obvious that galvanized iron roof corrosion in this region is due to a combination of atmospheric climatic and pollutant factors; rainfall and aerosol are the two positive contributors. The disturbing situation is that not much could be done about the climate. In order to arrest this situation, effort has to be made in sourcing for alternative roofing materials that have the positive qualities of galvanized iron but without being susceptible to corrosion attacks. It is also being suggested that there should be a deliberate attempt to stop gas flaring so as to limit the influence of aerosol to only its sea salt component, which could be insignificant.

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