

Assessment of Roof Covering Materials in an Aggressive Environment: Niger Delta Region of Nigeria

^{1*}, Ega, I.J., ²Anowai, I.S., and ³Job, O.F.

^{1*} Department of Building Technology, Federal College of Education (Technical), Asaba, Delta State, Nigeria, egasaves@gmail.com

² Department of Building, Faculty of Environmental Sciences, University of Jos, Jos, Plateau State, Nigeria.

³ Department of Building, Faculty of Environmental Sciences, University of Jos, Jos, Plateau State, Nigeria.

Corresponding author Email: egasaves@gmail.com

Abstract

Roof coverings in the Niger Delta region are observed to deteriorate more rapidly than in other parts of Nigeria. This study assessed the impact of an aggressive environment on roof coverings in the Niger Delta region. The study adopted a survey research design; field and data surveys to ascertain the region, the impact of weather and patterns of roof deterioration. A total of 72 samples of metallic roof covering were collected for analysis, and non-invasive techniques were used to assess the extent of deterioration on site; descriptive statistics were used for the analysis. The results show the Niger Delta region to be corrosive due to oil exploration activities with variable weather; average temperature (24.40 - 34.2)⁰C; however, it could be up to 40⁰C near flaring sites; pH is as low as 4.0 in certain locations. Among the materials studied in the region, asbestos, which is currently not in use, is the most resistant to acid rain and therefore the most durable material. The deterioration of zinc and aluminium shows that, at the eave-end, the loss in thickness is 60% and 40% respectively. At about 1800mm from the eave-end, no significant loss in thickness was recorded. The severe deterioration of these materials requires frequent replacement. Lower roof pitches, which delay runoff, were also found to increase deterioration. Consequently, materials of plastic or rubber origin that are acid-resistant and can withstand excessive heat, and sustainable roof designs allowing quick runoff are recommended.

Keywords: Aggressive environment; Deterioration; Niger Delta; Roof covering.

Introduction

Roof coverings are most vulnerable to environmental deterioration among building materials due to their exposure to aggressive elements. These hazardous elements degrade the finished product by lowering resistance and increasing susceptibility to deterioration (Gana, Erasmus, & Shehu, 2020). This is apparently the case in the Niger Delta Region of Nigeria, where oil exploration activities produced high concentrations of acid gases in the environment (Olukaejire, Ifiora, Osaro, Osuji, & Hart, 2024). Geographically, the Niger Delta Region of Nigeria is bound by latitude (4.15N – 7.17N) and longitude (5.05E – 8.68E) (Oweikeye, 2017). This region is made up of nine oil-producing states, namely, Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers, and has over 900 oil wells (Aniefiok, Udo, Margaret, & Sunday, 2013). It is an area experiencing continuous gas flaring, air pollution and the release of heat and harmful chemicals into the environment (Awara, 2019). Generally, the dominant temperature range is very wide (18 – 34°C) in the region; depending on the season, location and industrial activities, it can be higher (above 40°C) in some locations near flaring sites (Ubuoh, Nwakanma, & Ogbuji, 2017), while rain has an average pH of 4.34 (Akhionbare, 2007). The primary acid gases identified as causing this deterioration are sulfur dioxide (SO₂) and nitrogen oxides (NO_x) (Omokaro, Efeni, Adeyanju, Obomejero, & Akpotu, 2025).

However, different roof covering materials are indiscriminately used in the region without giving adequate consideration to the environment. Again, some roof designs appear to have worse deterioration than others. Consequently, this study assessed the impact of an aggressive environment on roof covering materials in the Niger Delta environment. To achieve this, the following objectives were drawn:

Examine the environmental parameters causing rapid deterioration.

Determine the deterioration pattern of roof materials in the region.

Find the relationships between roof design and deterioration in the region.

Research Design and Methods

The study adopted a survey research design comprising field and data surveys. This was limited to critical areas in the region (Delta and Rivers States), which host most of the oil wells with the highest gas-flaring activities (Bodo & Gimah, 2020). Secondary data, including historical Weather parameters from specialised Agencies: National Aeronautics and Space Administration (NASA) and the Nigerian Meteorological Agency (NiMet) for 15 years; as well as published literature in the area for Delta and Rivers States. These consist of temperature, humidity/rainfall, and pH or acid rain concentration. Non-invasive techniques were used to assess the levels and patterns of deterioration of the existing roof coverings. The materials investigated include zinc, aluminium, concrete, steel-coated, plastics and asbestos roof coverings. The roof design, construction and positioning were examined in relation to deterioration. The non-invasive techniques adopted include: visual inspection, touch and feel, and photography. This method allows consideration in context (Ega & Job, 2012). Visual inspection is suitable for assessing the condition. At the same time, photography is useful for documenting the state of deterioration that may never be succinctly described in words, as exists in the field. The instruments for data collection include field survey reports and a checklist, a camera, a video recorder, a measuring tape, and a sketchbook and descriptive statistics were used for data analysis

The survey was carried out mainly on public buildings in critical condition, and a total of 72 samples, 3 each of aluminium and zinc, were purposefully selected 12 public schools and their environs, namely: Ozoro, Onne and Warri in Delta State and Eneka, Abuloma and Rumurolu in Rivers State. The samples were carefully brushed using brass bristles to remove the corroded portions before measuring the thicknesses at intervals of 300 mm with a digital Vernier Calliper to ascertain the degree of deterioration as loss in thickness using Equation 1.

$$\text{Deterioration (Loss in Thickness)} = \frac{\text{Original thickness} - \text{measured thickness}}{\text{Original thickness}} \times 100 \quad (1)$$

Results and Discussion

The results of the study are presented in two subsections, namely, the deterioration pattern of roof materials and the relationship between roof design and deterioration in an aggressive environment.

Environmental parameters

Table 1 shows a summary of average meteorological data for the Niger Delta Region. The secondary data (weather history revealed that the temperature varies depending on the time of measurement and location, but can be as high as 40°C or higher near flaring sites. Rainfall has wet and dry seasons with a maximum of 450mm and complete dry seasons (appendices 1 and 2). However, these conditions are similar to some parts of the country except for high concentrations of acid rain.

Table 1: Summary of Average Meteorological Data (Secondary data) for Niger Delta Region (2000-2023)

Source	Value	Wind Speed (M/s)	Temp. (°C)	Rel. hum. (%)	Rainfall (mm)	Cloud cover (Oktas)	Prominent wind direction
NASA	Max.	4.46	33.54	97.12	521.69	-	SW
	Min.	0.01	24.40	60.12	0.01	-	
NiMet	Max.	4.46	34.2	96.06	549.17	6.5	SW
	Min.	0.01	24.40	60.12	0.01	7	

The use of acid rain in the Niger Delta region is shown in Table 2. The meteorological condition reveals that the rain is generally acidic, therefore aggressive towards the roof covering. The pH of acid rain is as low as 4.0 (4.30 ± 0.40) and as high as 7.9 (6.2 ± 1.70), depending on the location and time of measurement. The rain becomes more acidic when there is an increase in acidic gases in the air than when the existing gases have already been washed by previous rain. The implication is that the concentration of acid rain should likely increase at the beginning of the rainy season. These data demonstrated the presence of a corrosive environment, and it is considered the main factor responsible for the rapid deterioration of the roof covering in the region.

Table 2: Variable pH-Values of Acid Rain in the Niger Delta Region

Source	Period of measurement	Rain pH	
		Delta State	Rivers State
Orajaka, et al. (2026)	-	4.30 ± 0.40	4.50 ± 0.30
Gbadebo, et al. (2026)	-	4.33 ± 0.12	7.44 ± 0.41
Itodo et al. (2021)	-	5.60 ± 1.50	-
Uzoma et al. (2015)	-	-	6.2 ± 0.70
Olowoyo (2011)	-	6.61 ± 0.19	-
Ejelonu et al. (2011)	-	5.10 ± 0.70	-
Gobo et al. (2009)	-	-	6.2 ± 1.70
Abdulkarim et al (2009)	-	4.34 ± 0.80	-
Efe, S. I. (2008)	Onset of Rain (April-June, 2005)	4.81 ± 0.026	6.04 ± 0.013
	pH of Mid Rain (July-August, 2005)	6.15 ± 0.008	5.75 ± 0.009
	End of Rain (September-October, 2005)	4.70 ± 0.017	5.88 ± 0.009
Efe, S. I. (2008)	Onset of Rain (April-June, 2006)	4.79 ± 0.006	6.00 ± 0.006
	pH of Mid Rain (July-August, 2006)	4.72 ± 0.040	5.96 ± 0.006
	End of Rain (September-October, 2006)	4.80 ± 0.056	5.10 ± 0.048
Akhionbare (2007)	-	4.34 ± 0.45	-

Deterioration pattern of roof materials

The impact of the aggressive environment on roof covering materials in the Niger Delta is shown in Figure 1. Aluminium, zinc, concrete, stone-coated steel, plastic and asbestos roof coverings were all observed to be affected. The analysis is summarised in Table 3. Zinc was the most affected among metallic materials. The implication is that zinc may need replacement more frequently than other materials. Asbestos roof coverings show some resistance to corrosive elements. However, the colour turns pale over time, and the material becomes more brittle to the touch, depending on the exposure period.

Clay and concrete roof tiles were not found in the studied areas. However, concrete roof decks exist; they appear unperturbed despite exposure to corrosive elements. Nevertheless, there were some dark spots/growths on the surfaces, indicating high water absorption that sustains plant growth.



Figure 1: Severe corrosion and erosion along the runoff of aluminium roof covering at the sides against the wind direction in the Niger Delta.

Table 3: Roof covering materials and their nature of deterioration over time.

S/N	Material	Observed Defect	Exposed Period
1	Zinc	Highly degraded with open holes	Constructed over 10 years ago
2	Aluminium	Brownish surface, which stains fingers on touching, especially uncoated ones	Constructed over 10 years ago
3	Stone-coated steel	Darkish in colour with falling granules on touching the surface of the material	Constructed over 10 years ago
4	Concrete	Dry-dark growths, dusty, showing plant growth and weathering of the surface.	Constructed over 10 years ago
5	Asbestos	Greyish, fragile - easily broken with fingers into smaller pieces	Constructed over 20 years ago
6	Standard plastic	Brittle and punctured due to persistent heat and aggressive elements	Construction is less than 10 years old

Relationship between roof design and deterioration in an aggressive environment

The deterioration pattern is shown in Figure 3; the deterioration, measured as a loss in thickness of both zinc and aluminium, increases towards the eave. At the eave end, the loss in thickness of zinc and aluminium is 60% and 40% respectively, while at about 1800mm from the eave end, no significant loss in thickness was recorded.

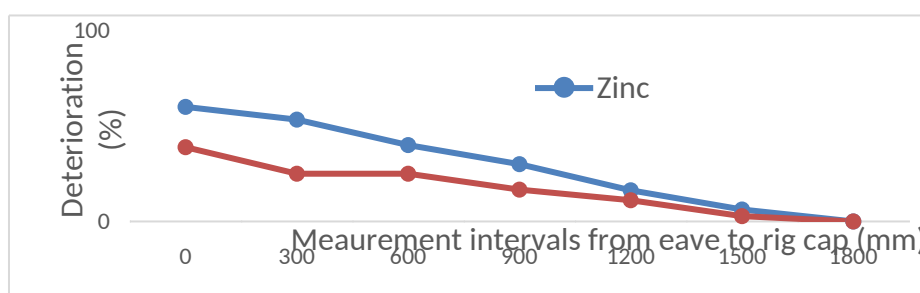


Figure 2: Corrosion Patterns of Metallic Roof Materials in the Aggressive Environment

Figure 3, developed from the survey, shows a model illustrating how vulnerable a roof covering can be in an aggressive environment due to design and construction. It was observed that a low roof design exacerbates or determines the rate of its deterioration in an aggressive environment. Using the model to assess a roof covering of the same material (Aluminium) shows that corrosion (deterioration) tends to increase as:

The pH value decreases; the deterioration of the roof covering increases when compared with the same roof covering materials at different locations.

The exposure period increases when compared with the same type of roof material constructed at different times in the same location. The pitch decreases- low pitches show greater corrosion than higher ones due to longer retention of corrosive elements, and this was observed when comparing similar roof materials with different pitches in the same location. One moves downward on the same pitch roof - the corrosion increases from the ridge cap in the direction of the runoff to the eave gutter, corresponding to the exposure period at which corrosive elements remain on the material surface. The heat intensity increases - the roof covering materials facing the sun's rays show an increase in deterioration compared to the other sides. Side against the wind direction - corrosion increases as the driving rain strikes the material, increasing the wear and runoff on the surface of the roof. This is evident in the level of corrosion on the material face against the wind direction compared to the non-wind direction.

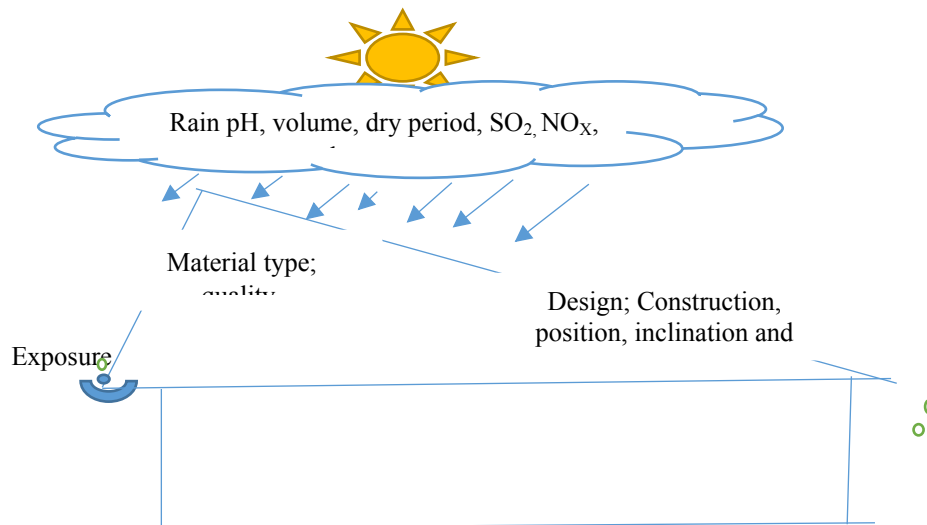


Figure 3: Design-Related Vulnerability Model for Roof Covering in an Aggressive Environment

Discussion

Deterioration of roof covering materials is related to environmental conditions, material quality, design/construction and the exposure period. These deterioration dynamics and their relationships are demonstrated in Figure 4. The interactions of these dynamics are cyclic, with roof deterioration at the centre, surrounded by the four factors and four relationships. These factors are paired: the vertical pair (material characteristics and design/construction/use) and the horizontal pair (exposure period and environmental conditions). However, there is little anyone can do to alter the exposure period or environmental conditions. It is therefore important to focus on developing roof covering materials with weather-resilient characteristics and embrace designs/constructions of roofs that are weather-friendly.

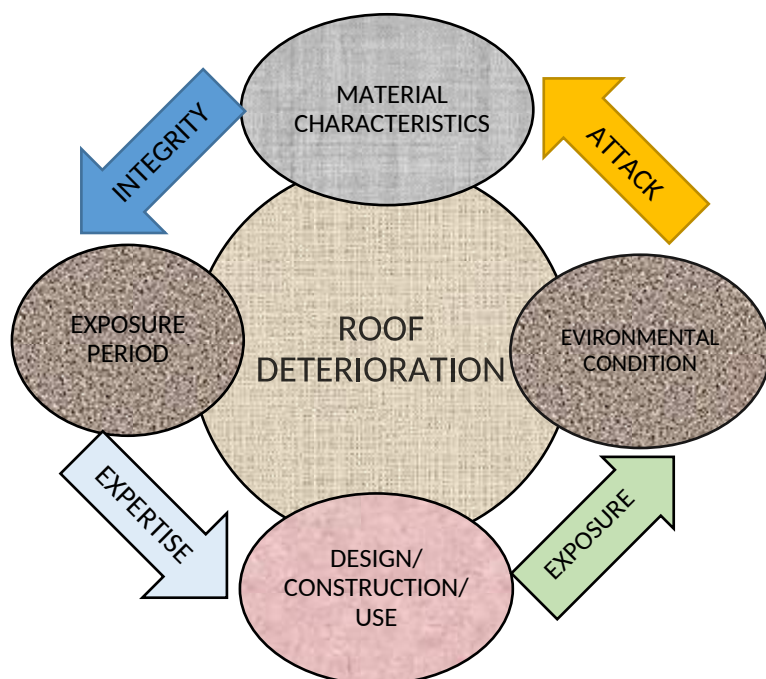


Figure 4: Model of Roof Deterioration Dynamics

Further, the deterioration dynamics are in a chain; while the aggressive elements (environmental conditions) attack the material, the rate of deterioration depends on the material characteristics. The number of years the material can serve in an aggressive environment determines its integrity or durability. However, between the exposure period and design/ construction, expertise comes into play; if the environmental knowledge is considered in the roof design and choice of materials, the rate of deterioration is likely to be reduced. On the other hand, if the roof is designed or constructed without adequate environmental consideration, the material becomes more vulnerable to deterioration. Therefore, inadequate roof design in an aggressive environment increases deterioration.

Thus, the impact of the Niger Delta environment on roof coverings is devastating, especially for metallic materials due to the corrosive atmosphere; inadequate choice of materials and lack of environmentally friendly designs will lead to deterioration. The combination of acid rain, heat and ultraviolet radiation on exposed roofs accelerates the degradation of metallic and plastic materials under persistent adverse climatic influences (Obia & Obot, 2010). Moreover, designs or constructions that retain rain or delay runoff increase degradation by prolonging the acid reaction with the material. This was also observed by Abdulkarim, Abdullahi and Salam (2009), who noted that corrosion of roof coverings tends to take place where acid rain and/or condensation cannot run off or become trapped. Concrete and asbestos are more resilient in aggressive environments; however, due to health hazards of asbestos, it is no longer used in modern buildings. Concrete, because of its high water absorption and weight, is considered uneconomical to use. It is therefore imperative to source weather-resistant materials and properly assess the environment for adequate design and construction of roof coverings to minimise weather effects.

Conclusion

The impact of the aggressive environment on roof covering in the Niger Delta region of Nigeria was observed to be severe. Thus, indiscriminate use of roof materials in the Niger Delta is discouraged. Materials of plastic or rubber origin that are acid-resistant and can withstand excessive heat are recommended for the environment. Additionally, sustainable roof designs aiming at reducing weather effects and allowing quick runoff are proposed for the environment by adopting a high pitch to ensure rapid runoff, setting roof orientation to reduce the area facing the wind and sun, and avoiding traditional roof trimmers that delay

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runoff. Notably, roof coverings intended to serve for more than 20 years in the region should have design and material systems with enhanced durability to maximise their service life.

Limitations

It was not difficult to remove a large number of habitable building roofs for samples; thus, few samples were collected.

Direct environmental measurement will take several years to obtain a reasonable Weather history; however, to overcome that, existing data from specialised agencies were adopted.

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APPENDIX 1

Statistical Summary of Monthly Meteorological Variables Around Onne, Eleme in the Niger Delta Region (2018-2022)

Parameter	Month/ Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp (0C)	Min	26.9 7	26.5 6	26.26	26.7 3	26.69	25.8 5	25.7 3	24.4 0	25.5 0	26.2 2	26.0 9	26.32
	Max.	32.4 5	33.5 4	32.62	31.6 5	31.14	31.1 2	28.0 5	29.9 6	30.4 0	31.2 4	31.5 5	31.56
	Mean	29.8 2	30.4 2	29.56	29.3 0	28.75	27.9 3	27.6 8	27.7 1	27.6 8	28.1 0	28.7 8	29.51
	Stdev.	1.12	1.31	1.07	1.02	0.89	1.06	0.92	0.97	0.90	1.11	1.22	1.20
Rel.hum. (%)	Min.	63.5 6	60.1 2	62.69	66.1 9	66.50	69.1 2	70.1 2	71.7 5	73.5 6	72.3 1	67.4 4	66.50
	Max.	63.5 0	91.5 6	94.06	94.7 5	95.62	96.1 2	97.1 2	95.1 9	95.4 4	95.5 6	96.0 6	94.12
	Mean	82.9 7	83.9 8	88.92	89.3 4	90.93	91.5 3	91.3 4	90.3 6	91.5 8	91.0 4	90.2 0	84.70
	Stdev.	6.84	6.31	3.01	3.24	2.83	3.00	2.84	2.75	2.36	2.19	3.34	6.51
Wind speed (m/s)	Min	.005	0.01	0.04	0.20	0.03	0.80	0.74	0.97	0.24	0.12	0.08	0.09
	Max.	4.17	3.00	3.23	3.15	3.28	3.41	3.81	4.46	4.12	2.95	3.56	2.80
	Mean	1.64	1.74	1.79	1.69	1.61	1.76	2.12	2.46	1.91	1.66	1.70	1.63
	Stdev.	0.78	0.70	0.59	0.58	0.52	0.47	0.65	0.74	0.70	0.45	0.56	0.61
Air pres (kPa)	Min	100. 70	100. 67	100.5 8	100. 62	100.7 9	100. 80	100. 97	100. 87	100. 89	100. 80	100. 66	100.6 8
	Max.	101. 18	101. 18	101.1 6	101. 18	101.3 8	101. 43	101. 47	101. 48	101. 38	101. 30	101. 23	101.2 2
	Mean	100. 96	100. 88	100.8 8	100. 89	101.0 3	101. 16	101. 22	101. 22	101. 13	101. 04	100. 94	100.9 5
	Stdev.	0.10	0.11	0.11	0.12	0.11	0.11	0.10	0.14	0.10	0.09	0.10	0.11
Rainfall (mm)	Min.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Max.	52.4 8	64.4 3	173.5 1	317. 93	363.1 8	419. 74	506. 23	486. 42	521. 69	402. 58	154. 44	33.29
Mean	23.5 7	58.5 3	141.8 2	206. 7	239.8 4	337. 69	428. 73	407. 5	431. 34	281. 37	98.6 2	21.44
Stdev.	12.6 4	29.2 8	47.69	52.1 5	78.21	103. 47	98.6 4	69.4 3	110. 41	83.4 6	97.8 2	27.39
Prominent wind dir.	NE	NE	SE	SW	SW	SW	SW	SW	SW	SW	SW	NE

Source: NASA

APPENDIX B 5

Average Weather Trend for Port Harcourt (1990-2020)

S/No	Month	Average Temp (0C)	Rainfall (mm)	Cloud Cover (oktas)	Pressure (mbar)	R/H (%)	Wind Speed (m/s)	Prominent wind dir.
1	January	33.5	17.2	6.5	1007	74	2.9	NE
2	February	34.2	76.5	6.6	1007	79	2.8	SW
3	March	33.8	95.2	6.8	1006	83	3.6	SW
4	April	31.7	144.1	6.8	1007	83	3.7	SW
5	May	31.9	248.4	7	1007	87	3.8	SW
6	June	30.3	312.2	7	1009	91	3.9	SW
7	July	28.1	368.0	7	1010	92	4.3	SW
8	August	28.6	325.2	7	1010	92	4.3	SW
9	September	28.3	374.5	7	1009	92	4.4	SW
10	October	30.8	241.9	7	1009	89	3.8	SW
11	November	32.4	74.0	6.6	1007	84	2.9	SW
12	December	33.4	20.4	6.5	1007	73	2.6	NE

Source: NIMET, Port Harcourt