

PAPER • OPEN ACCESS

Analysis of aerosol optical depth and aerosol loading Over Voinjama: A projected estimation of atmospheric corrosion

To cite this article: M.E. Emeteri *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **331** 012009

View the [article online](#) for updates and enhancements.

Analysis of aerosol optical depth and aerosol loading Over Voinjama: A projected estimation of atmospheric corrosion

Emetere M.E.^{1,3}, Sanni S.E.² and Okoro S.E.⁴

¹Department of Physics, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria.

²Department of Chemical Engineering, Covenant University Canaan land, Ota, Nigeria.

³Department of Mechanical Engineering and Science, University of Johannesburg, APK, South Africa

⁴ Department of Petroleum Engineering, Covenant University Canaan land, Ota, Nigeria.

E-mail: emetere@yahoo.com

Abstract. The World Health Organization (WHO) warning on air pollution is a verified in this research by corroborating it with fifteen years primary (aerosol optical depth) dataset that was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR) over Voinjama-Liberia. The detailed statistical and computational analysis was carried out using computational softwares. The spatial and surface plot the pollution over the geographical location may constantly be dispersed from same sources of pollution. The implication of the aerosol optical depth (AOD) on the atmospheric corrosion was corroborated using mathematical estimations. The highest corrosion rate is given as 2.6 and the average corrosion rate over Voinjama is 0.5.

Keywords: aerosol loading, aerosol, Voinjama, Liberia, model

1. Introduction

The World Health Organization (WHO) released a report that “92% of people worldwide breathe unhealthy air, resulting in about 6.5 million deaths annually” (1). The west African region in this light had shown through satellite imagery that the pollution source is enormous at the moment (2). The properties of the atmospheric aerosols are found to be made-up of basically sand dust, sulfur dioxide, carbon ash, nitrogen dioxide and VOC. The health implication on the human and animal life-form is sickness and death. As a matter of fact, WHO claimed that one-third of deaths from the leading non communicable diseases (stroke, lung cancer, heart attacks and chronic obstructive pulmonary disease) are due to air pollution (1).

In this research, the area of interest is the analysis of the aerosol optical depth and aerosol loading over Voinjama to determine the atmospheric corrosion rate. The corrosivity of atmosphere refers to the extent of corrosion suffered by a metal caused by exposing it in the atmosphere (see Figure 1). Atmospheric corrosion in west Africa is of great concern because the sand and sahara dust that are predominant contains salt content which is one of the basic agent for metallic corrosion. Moreso, the sulfur dioxide is another corrosion stimulant present in the west Africa atmosphere. The corrosivity of atmospheres are of several stages depending on the type of metal. Table 1 shows the ISO classification of corrosivity of the atmospheres over zinc metal.





Figure 1: metallic corrosion caused by atmospheric aerosols

Table 1: ISO classification of corrosivity of the atmosphere (3).

C1	$R \leq 0.1 \mu\text{m}/\text{y}$	$R \leq 0.0023 \sigma\text{z}/\text{ft}/\text{y}$	$R \leq 0.71 \text{g}/\text{m}^2/\text{y}$
C2	$0.1 < R \leq 0.7$	$0.0023 < R \leq 0.016$	$0.71 < R \leq 4.9$
C3	$0.7 < R \leq 2.1$	$0.016 < R \leq 0.049$	$4.9 < R \leq 15$
C4	$2.1 < R \leq 4.2$	$0.049 < R \leq 0.097$	$15 < R \leq 30$
C5	$4.2 < R \leq 8.4$	$0.097 < R \leq 0.19$	$30 < R \leq 59$

The corrosivity of the atmosphere depends on the content of the atmospheric aerosols. The significance of the research is the huge cost of maintenance of zinc roof in buildings such as schools, residential houses, churches and mosques. In developed countries, the cost due to corrosion is known. For example, Gerhardus et al. (4) revealed that corrosion of metals cost about \$276 billion annually in the United State.

In this research, the analysis of the aerosol optical depth as well as the aerosol loading was carried out to estimate the atmospheric corrosion rate over the research area.

2. Experimental Design, Materials and Methods

Voinjama is located in Liberia on latitude and longitude of 8.4202°N and 9.7539°W respectively. The satellite map of the research location is presented in Figure 2. The research site is located in the hilly region, north of Liberia and near the Guinean border. The average human population of the area is about 60,000. The community is an agrarian community with the presence of some industries. At the moment, there are no ground measurement of air pollution in the research area. Hence, fifteen years aerosol optical depth (AOD) satellite dataset was obtained from the Multi-angle Imaging Spectro-Radiometer (MISR)(5).

The raw dataset was treated using excel programme. The statistical and computational analysis of the treated dataset was carried-out using the CERN Root C++ code. The aerosol loading was calculated using the West African regional scale dispersion model (WASDM). The WASDM is represented as (6-8):

$$\psi(\lambda) = a_1^2 \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_1 \pi \tau(\lambda)}{2} y\right) + \dots \dots a_n^2 \cos\left(\frac{n_n \pi \tau(\lambda)}{2} x\right) \cos\left(\frac{n_n \pi \tau(\lambda)}{2} y\right) \quad (1)$$

a is atmospheric constant gotten from the fifteen years aerosol optical depth (AOD) dataset from MISR, n is the tuning constant, $\tau(\lambda)$ is the AOD of the area and $\psi(\lambda)$ is the aerosol loading.

The atmospheric corrosion rate of metals (9) over the Yekepa was calculated using the Faraday equation. It is given as :

$$CR \left(\frac{\mu\text{m}^3}{\text{yr}} \right) = k \frac{i_{\text{corr}}}{d} EW \quad (2)$$

Where k is a conversion factor ($3.27 \times 10^6 \mu\text{m} \cdot \text{g} \cdot \text{A} \cdot \text{cm}^2 \cdot \text{yr}^{-1}$), i_{corr} is the corrosion current density in $\mu\text{A}/\text{cm}^2$ (calculated from the measurements of R_p), EW is the equivalent weight, and d is the density of Alloy 22 ($8.69 \text{ g}/\text{cm}^3$).

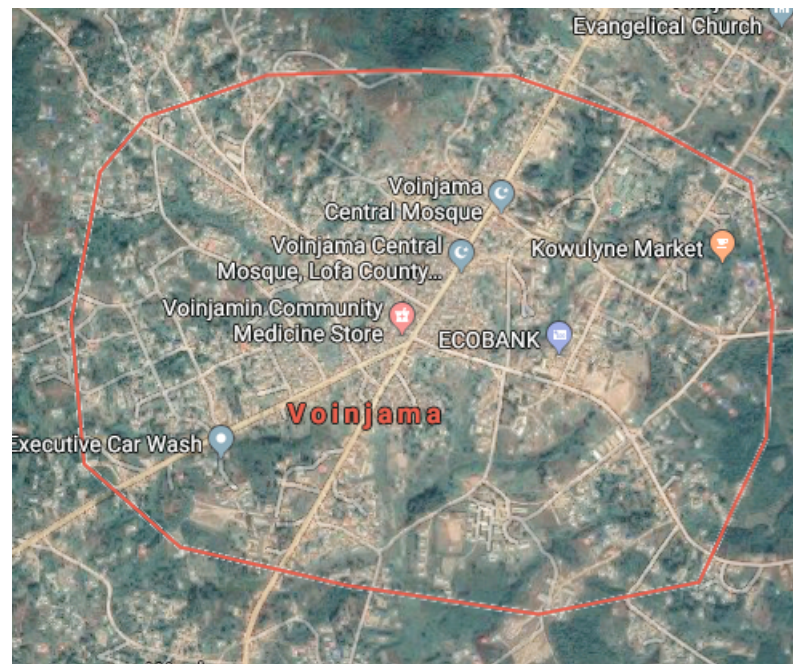


Figure 2: Satellite map of Voinjama

Based on equation (4), the modification in the work is the inclusion of aerosol loading.

$$CR \left(\frac{\mu\text{m}^3}{\text{yr}} \right) = k \frac{i_{\text{corr}}}{d} EW / \exp \left(\frac{AOD \cdot 10^{12}}{2.32} \right) \quad (3)$$

In this study, the corrosion current density of iron was considered and it is given as $3.2 \times 10^{-3} \mu\text{A}/\text{cm}^2$. The EW of iron is given as 27.9225.

3. Results and Discussion

The daily AOD dataset is presented in Figure 3. The peaks of the diagrams denoted the maximum AOD in the year. The maximum AOD occurs towards August. The diagram shows the four spectra bands of the MISR. The four spectra bands are used to estimate AOD over land and ocean. In this case, since marine aerosols pollution travels over long distances, the use of all spectra bands is justified for an indepth analysis of the atmospheric corrosion effect over the study area.

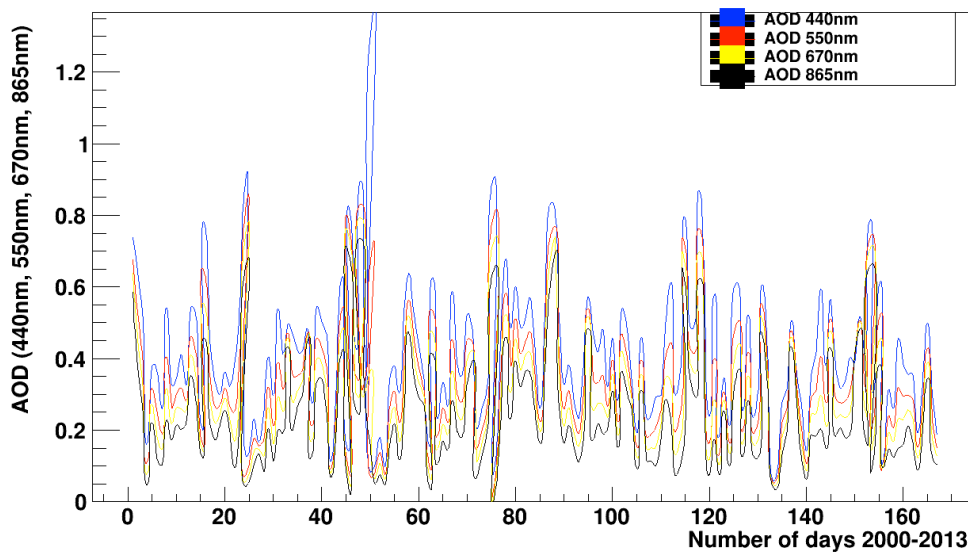


Figure 3: AOD daily dataset between 2000 and 2013

The spatial distribution of the AOD is presented using the contour map. It shows that aside the usual anthropogenic pollution, there are influx of certain pollution suspected to be Sahara dust (Emetere, 2016b). The significance of the sahara dust influx is obvious in the surface plot shown in Figure 5,

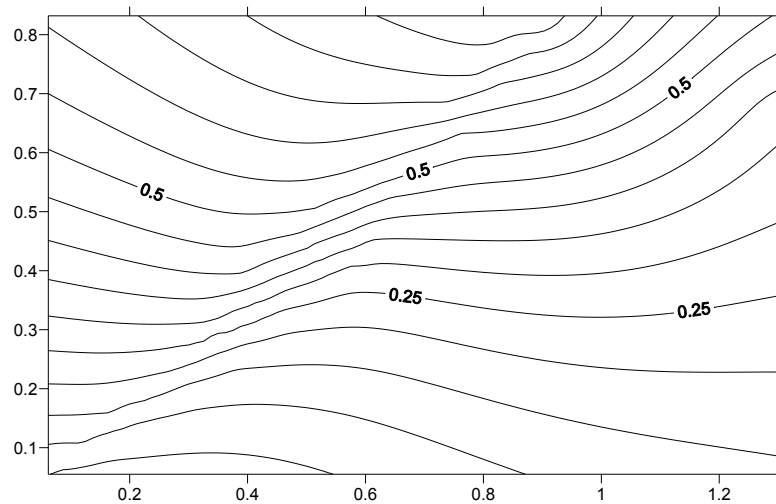


Figure 4: Contour plot of AOD distribution over Voinjama

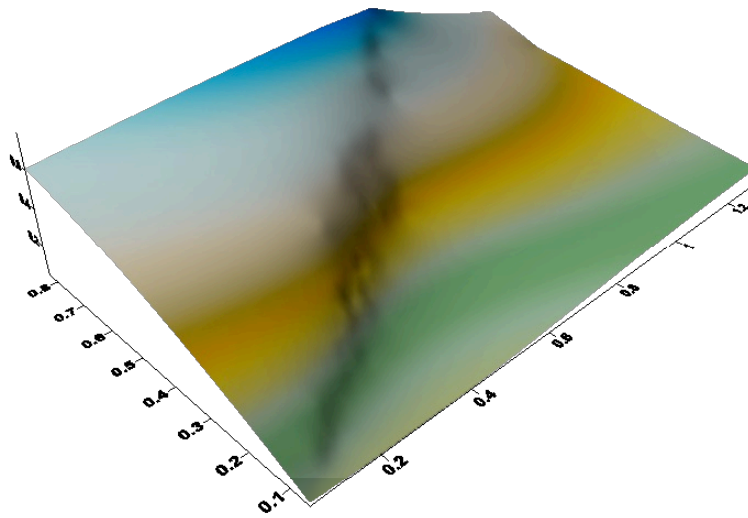


Figure 5: Surface plot of AOD distribution over Voinjama

The 3D plot of the interdependency of the spectra band is presented in Figure 6. This diagram is very important as it graphical shows that the satellite AOD dataset is quite reliable for derivative calculation such as aerosol loading. The reliability of the dataset was further tested using statistical treatment.

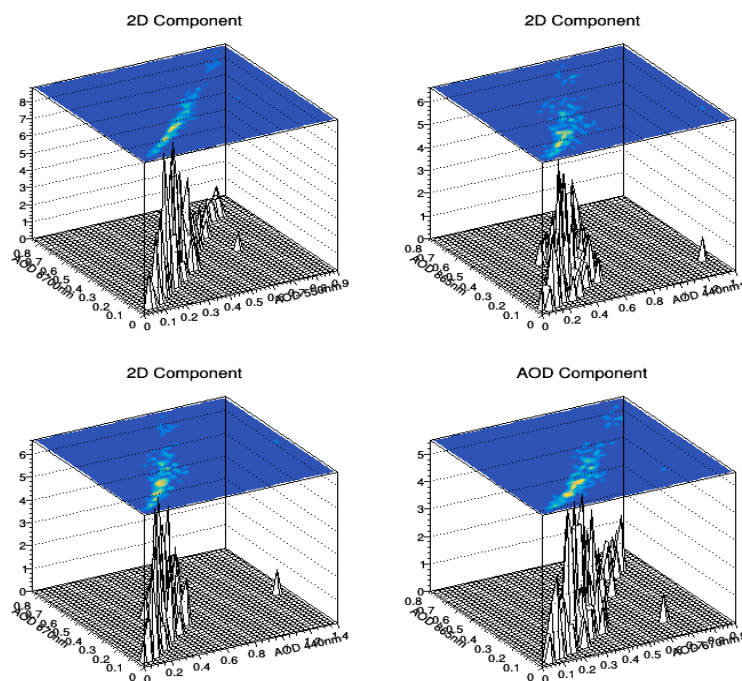


Figure 6: 3D dataset reliability test

The summation of the univariate statistics, inter-variable correlation, inter-variable covariance, planar regression, inter-parameter correlations and ANOVA show that the AOD of Yekepa has almost exceeded the limits described by World Health Organization (10).

Table 2: Univariate Statistics over Voinjama

	X	Y	Z
Minimum:	0.062	0.055	0.05
25%-tile:	0.297	0.223	0.173
Median:	0.382	0.315	0.262
75%-tile:	0.521	0.429	0.367
Maximum:	1.304	0.832	0.793
Midrange:	0.683	0.4435	0.4215
Range:	1.242	0.777	0.743
Interquartile Range:	0.224	0.206	0.194
Median Abs. Deviation:	0.117	0.1	0.093
Mean:	0.41468862275449	0.33985628742515	0.29180239520958
Trim Mean (10%):	0.40487417218543	0.33090728476821	0.28128476821192
Standard Deviation:	0.18694005905354	0.16098031550915	0.15353999418595
Variance:	0.034946585678942	0.025914661981426	0.023574529814622
Coef. of Variation:			0.52617797765394
Coef. of Skewness:			1.0165717081232

Table 3: Inter-Variable Correlation over Voinjama

	X	Y	Z
X:	1.000	0.961	0.897
Y:		1.000	0.984
Z:			1.000

Table 4: Inter-Variable Covariance over Voinjama

	X	Y	Z
X:	0.034946585678942	0.028909805550575	0.025745243859586
Y:		0.025914661981426	0.024323055434042
Z:			0.023574529814622

Table 5: Planar Regression: $Z = AX+BY+C$ over Voinjama

Fitted Parameters

	A	B	C
Parameter Value:	-0.51531037174422	1.5134512696895	-0.0088601861562642
Standard Error:	0.0081776226650521	0.009496349035516	0.0010335305726505

Table 6: Inter-Parameter Correlations over Voinjama

	A	B	C
A:	1.000	0.961	-0.281
B:		1.000	-0.029
C:			1.000

Table 7: ANOVA Table over Voinjama

Source	df	Sum of Squares	Mean Square	F
Regression:	2	3.93200964689	1.966004823445	65310
Residual:	164	0.0049368321519374	3.0102635072789E-005	
Total:	166	3.9369464790419		

Coefficient of Multiple Determination (R^2): 0.99874602507852

Using equation (1) and (3), the corrosion rate was estimated from the aerosol loading over Voinjama as presented in Figure 7.

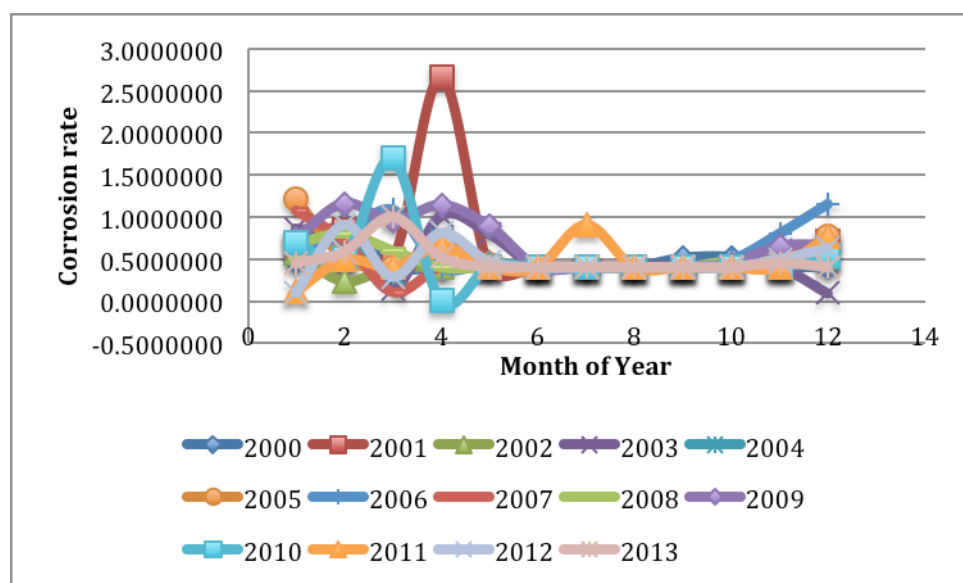


Figure 7: Corrosion rate over Voinjama

It is observed that the corrosion rate is highest between December and April. More so, the highest corrosion rate is given as 2.6. It is observed that it is only in two cases the corrosion rate in Voinjama exceeded unity i.e. 1. The average corrosion rate over Voinjama is 0.5. Hence, it can be inferred that the corrosion rate is directly proportional to the aerosol loading over Voinjama.

4. Conclusion

From the dataset reliability test, it was observed that the AOD satellite dataset has significant correlation and an R-squared calculate the aerosol loading and corrosion rate over Voinjama. The highest corrosion rate is given as 2.6 and the average corrosion rate over Voinjama is 0.5. This means that the atmospheric corrosion over Voinjama is significantly high. This portends higher cost of replacing corroded metallic surfaces in Voinjama.

Acknowledgement

The authors appreciate Covenant University for partial sponsorship. The authors acknowledge NASA for primary dataset.

5. References

- [1]. WHO 2018a WHO's First Global Conference on Air Pollution and Health, http://www.who.int/airpollution/events/conference/WHO_Conference_on_Air_Pollution_and_Health-Concept_Note-final1.pdf (accessed 26 February, 2018).
- [2]. Emetere, Moses Eterigho 2016 Statistical Examination of the Aerosols Loading Over Mubi-Nigeria: The Satellite Observation Analysis, *Geographica Panonica*, 20(1) 42-50
- [3]. Galvinfo 2018 Atmospheric Corrosion, <http://www.galvinfo.com:8080/zclp/Definition.htm> (accessed on 25 February, 2018).
- [4]. Gerhardus H. Koch, Michiel P.H. Brongers, and Neil G. Thompson 2018 Corrosion costs and preventive strategies in the United States. <https://www.nace.org/uploadedFiles/Publications/ccsupp.pdf> (accessed 27 February, 2019)
- [5]. McGill, M., CATS/ISS L2O D-M7.1 05kmPro HDF-5 File - Version 1.05 [Data set]. NASA Langley Research Center Atmospheric Science Data Center DAAC. 2016 https://doi.org/10.5067/iss/cats/l2o_d-m7.1-v1-05_05kmpro
- [6]. Emetere M.E. 2016 Generation Of Atmospheric Constants Over Some Locations In West Africa: A Theoretical Aid for Measuring Instruments Design, *International Journal of Engineering Research in Africa* 27 119 – 146
- [7]. Moses Eterigho Emetere 2017 Investigations on aerosols transport over micro- and macro-scale settings of West Africa, *Environ. Eng. Res.*, 22(1) 75-86
- [8]. Emetere M.E. 2016 Numerical modelling of West Africa regional scale aerosol dispersion. A doctoral thesis submitted to Covenant University, Nigeria. 65-289
- [9]. ASTM. 2003. Standard practice for preparing, cleaning, and evaluating corrosion test specimens. ASTM G-1-03. West Conshohocken, PA: American Society for Testing and Materials.
- [10]. WHO 2018b. Air pollution, <http://www.who.int/airpollution/en/> (accessed 5th July, 2018)