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Correlation of Visibility with Aerosol Optical Depth at Ikeja Nigeria (2000-2014).

[1]Ezere, U. A.,[2] Nwofor, O.K and [3]Okpechi, U. P. K

[1&3]*Department of Physics, Michael Okpara University of Agriculture Umudike.*

[2]*Department of physics, Imo State University, Owerri.*
*ezere.uchechi@mouau.edu.ng**

Abstract

Visibility impairment has not only been a challenge to aviation industry, but also to road users. This visibility impairment is due to scattering of light by suspended particles such as fine and coarse aerosol. Aerosol optical depth (AOD) for this region (urban) under study was analyzed and correlated with visibility during the two seasons (dry and wet season) of the region to understand the trend and possible influence of aerosol loadings. Data for visibility and AOD were obtained from Nigeria Meteorological Agency and MODIS respectively. Pearson's correlation was used to check the relationship between these data at different seasons and their trends noted. Visibility (in km), fine and coarse AODs for Ikeja maintain a seasonal circle, further at any instance AOD affect the visibility at minimal rate with a positive but weak correlation of R^2=0.246, having R^2=0.1972 during dry season and R^2=0.00 at rainy season. This implies that visibility within the area is not solely inhibited or dependent on aerosols and therefore, a recovery plan to tackle this challenge should be drawn.

Keywords: *Visibility, Impairment, Inhibition, Aerosol optical depth*

1.0 Introduction

Visibility degradation has become an important urban atmospheric environmental problem due to fast development in urbanization and industrialization (Bret *et al*., 2001). Visibility is reduced by the scattering and absorption of solar radiation of particles and gaseous pollutants (Latha and Badarinath, 2003). Aerosol plays an important role in atmospheric radiation transmission, though their mass is less than one billion of the total atmospheric mass. Atmospheric visibility impairment is as a result of scattering and absorption of visible light by gaseous pollutants and by suspended fine particles in the ambient atmosphere (Hodkinson, 1966).

Aerosols influence the behavior of the atmosphere by acting as cloud condensation nuclei, thus exerting a strong effect on the radiation properties of the atmosphere. In urban environments, aerosol particles can affect human health through inhalation.

During the past, many studies were done on the influence of meteorological factors and particle size distribution on atmospheric extinction coefficient and optical depth, while little attention was paid to the effect of aerosol chemical components on visibility (Chen *et al*., 2006).

Visibility is a critically important parameter, because low visibility can disrupt traffic, impair businesses, affect public safety and degrade tourism.

The atmospheric light extinction is the reciprocal of visibility; hence an atmosphere of high light extinction records a low meteorological visibility and vice-versa.

Light traveling through the atmosphere can be absorbed or scattered by aerosol particles and gas molecules. Scattering changes the direction of the photon's propagation while absorption removes the photon from the beam by conversion to thermal or electronic energy in the particle or molecule. These two processes are collectively known as light extinction, act to remove light from a beam and thus lead to a decreased visible range. Maximum visible range is defined as the furthest distance at which a dark object can be distinguished from the horizon. In a pristine environment at sea level, this range is about 300 km for λ=520 nm (Seinfeld and Pandis, 2006).

In Nigeria, the increased frequency of fatal air mishaps, especially between 2004 and 2005, raised serious awareness of the importance of meteorological facilities, especially for visibility measurements at airports and the need to step up fundamental research on environmental situations that affect air safety (Nwofor, 2006).

Due to high industrial emissions, increased dependence on private motor vehicles associated with high population, and natural topographical and meteorological conditions, Lagos has the tendency of experiencing severe particulate pollution and frequent haze episodes. This area also consists of large water bodies leading to increased tiny fine aerosol in the atmosphere.

In this research, MODIS Aerosol Optical Depth data, AIRS (Atmospheric Infrared sound) fine aerosol and NIMET visibility data of Lagos over 20 years (1992-2012) were examined to infer any possible changes in dust aerosol on how it affects visibility in Lagos, Nigeria (West Africa), for this period.

This study investigates the mechanism of visual impairment in Lagos from the view of fine and coarse aerosols under meteorological conditions- visibility, so as to elucidate the combined effects of aerosols on visibility degradation by examining contribution of aerosols to visibility reduction and Correlating visibility with MODIS AOD and AIRS fine/ coarse aerosols.

2.0 Data Sources and Treatment

The site studied in this work is Ikeja, Lagos state, located on longitude $3^0$21’E to $5^0$35’E latitude $6^0$36’N to 6^0 617’ N. Like most location in West Africa, there are two seasons, the wet and dry seasons, which differ by level of precipitation, temperature and humidity. The wet season records higher precipitation, higher humidity and lower temperature when compared to the dry season. The wet season spans from April to September while the dry season last from October to March of the succeeding year.

The aerosol optical depth data used in this research was obtained from MODIS (Moderate Resolution Imaging Spectro-radiometer). Visibility data was obtained from NIMET (Nigeria Meteorological Agency). Time series plots of visibility and AOD were taken, also at different seasons. Visibility and AOD at various seasons were correlated using Pearson’s correlation method to check its relation.

3.0 Analysis and results

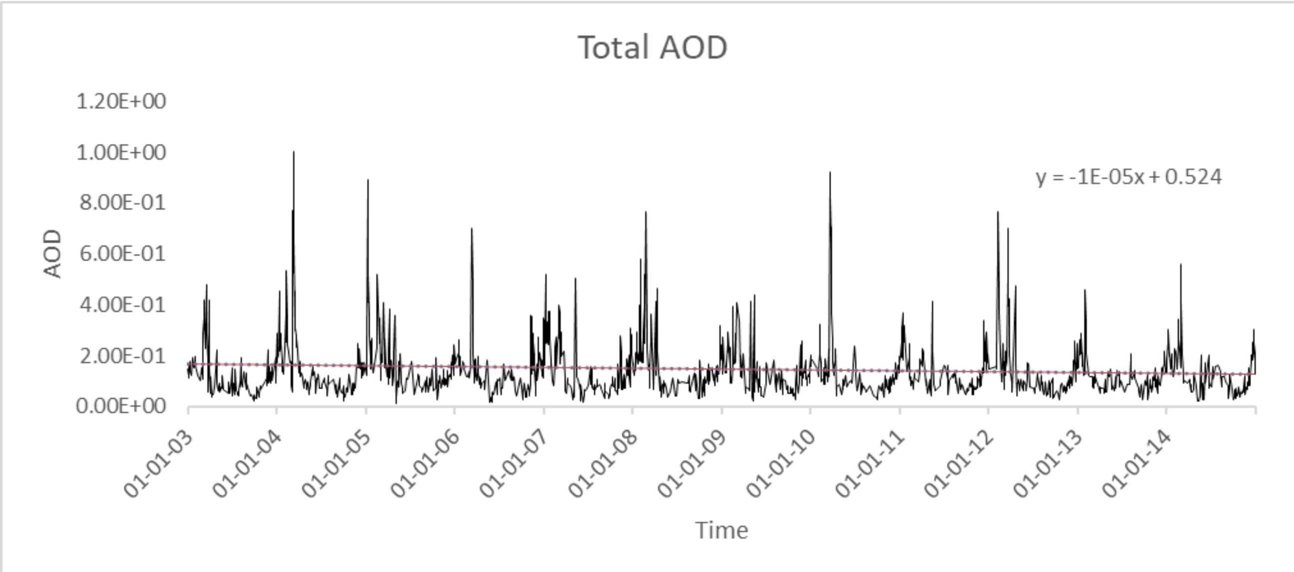

Figure 1: AOD (Aerosol Optical Depth) time series for Ikeja from 2003- 2014.

The time series plot for Ikeja for the period depicted in figure 1 indicates that aerosol loading maintains a seasonal cycle with the peak occurring during the dry season; between November and March each year. Meanwhile during the rainy season, the aerosol loading is at a near zero level; between April and October each year. Furthermore, the results show that aerosol loading decreased every odd year; this could be due to little or no changes of aerosol loading in the area. Generally, the trend line shows that over the years there is a general decrease in AOD over the study area. Subsequently, figure 2 revealed that coarse aerosol loading also maintains a seasonal cycle and is also on the decrease over the years. In figure 2, it could also be observed that the least coarse loading occurred in 2011, 2013 and 2014. Similarly, figure 3 also shows that fine aerosols which also maintain a seasonal cycle with the peak occurring during the dry season.

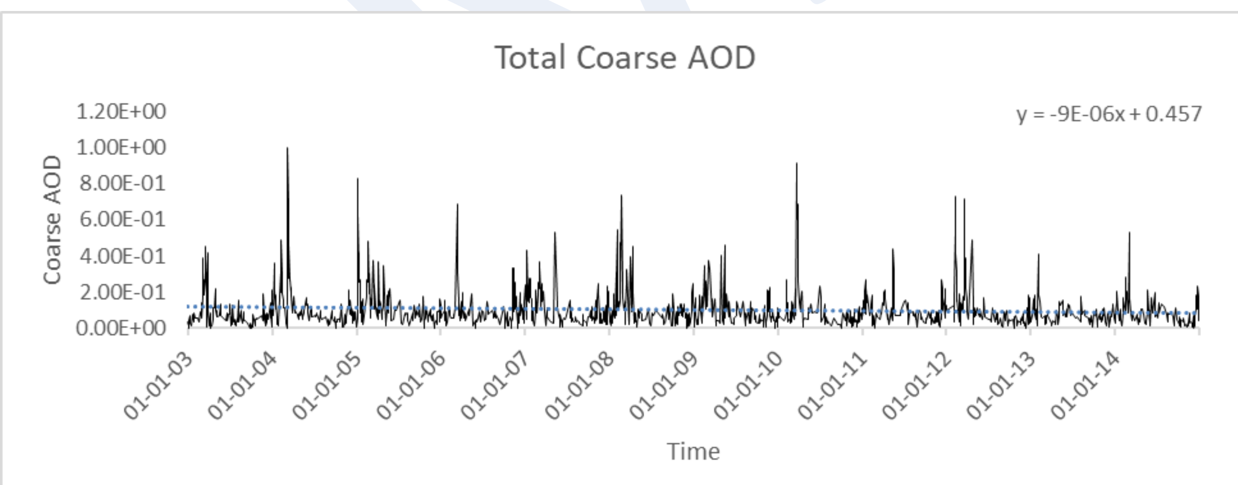

Figure 2: Time series plot of Coarse AOD between 2003 and 2014

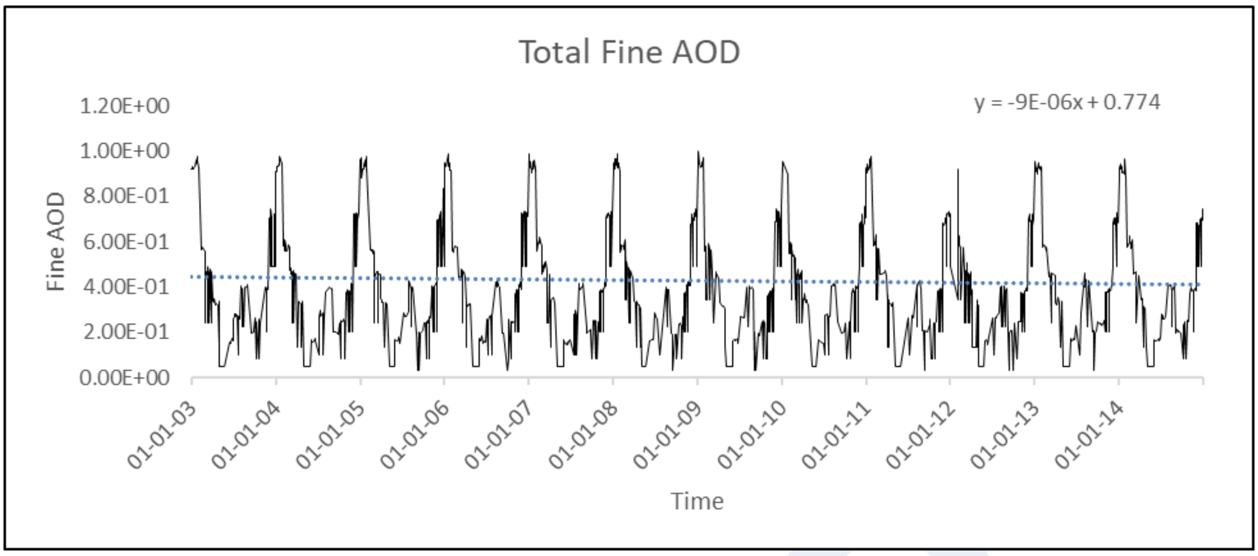

Figure 3: Time series plot of Fine AOD between 2003 and 2014

Subsequently, comparing figure 2 and 3, the results showed that fine aerosols maintains an almost constant value at the peak and trough. The peak values could be seen to be of the same value each cycle, while coarse aerosols have varying peak and trough values. The rainy season phenomena could be because the sources of fine aerosol in Ikeja may be constant, which are likely from the industries while the dry season boost could be as a result of other fine aerosol sources which have a seasonal connotation, such as intrusion from the neighboring locations as a result of bush burning, etc.

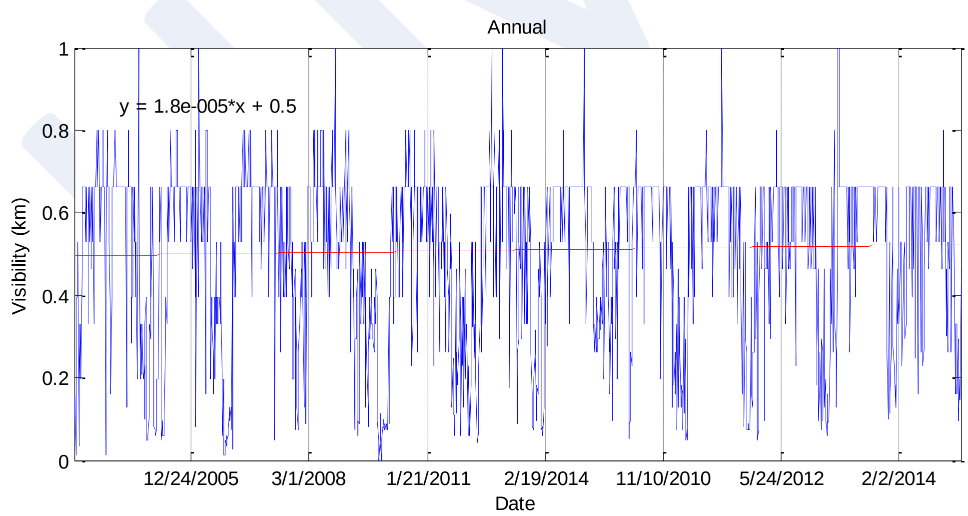

Figure 4:

Time series plot for visibility from 2000 to 2014

The result depicted in figure 4 showed that visibility maintains a near steady average over the entire study period. The trend line indicates that visibility slightly increased towards the end of years of study period. Figure 5 showed that visibility increases during the dry season, while visibility is on the decrease during the rainy season as shown by the slope values in figure 5 and 6 respectively. This could be as a result of water vapour in the atmosphere which is absorbed by aerosols as it gives rise to phenomenon such as haze, dews, etc.

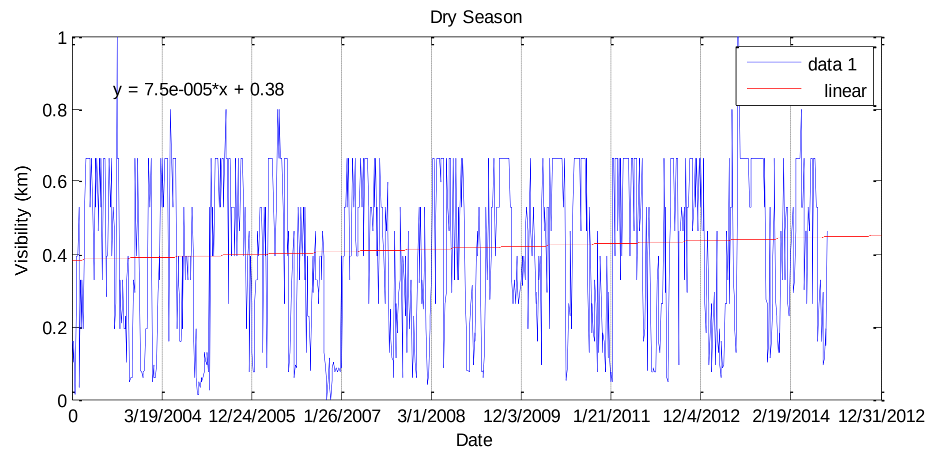

Figure 5: Time series plot for visibility from 2000 to 2014 from the dry season

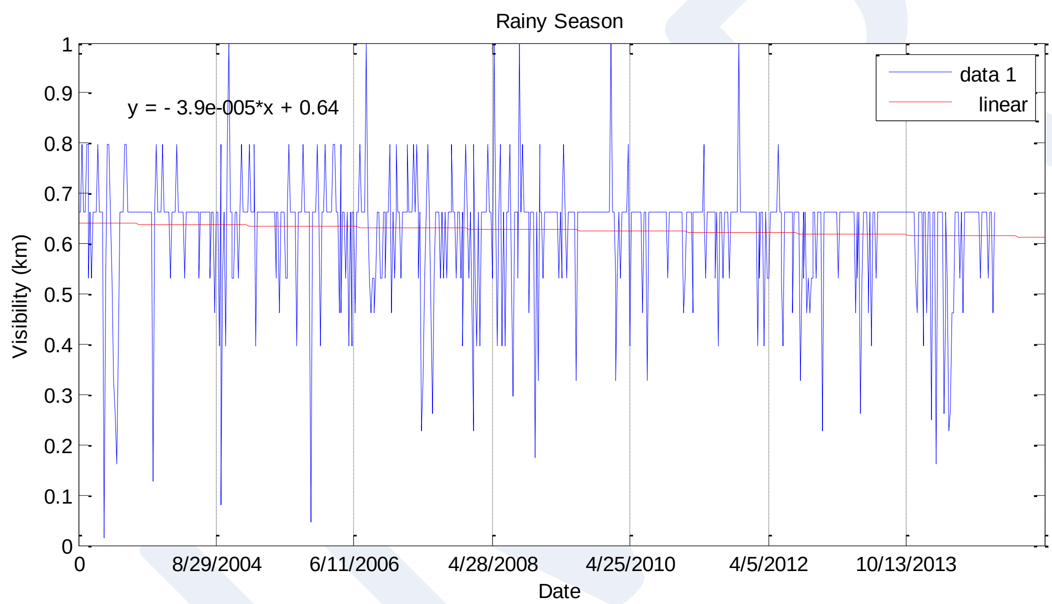

Figure 6: Time series plot for visibility from 2000 to 2014 for the rainy season

Relationship between Visibility and Aerosol Loading

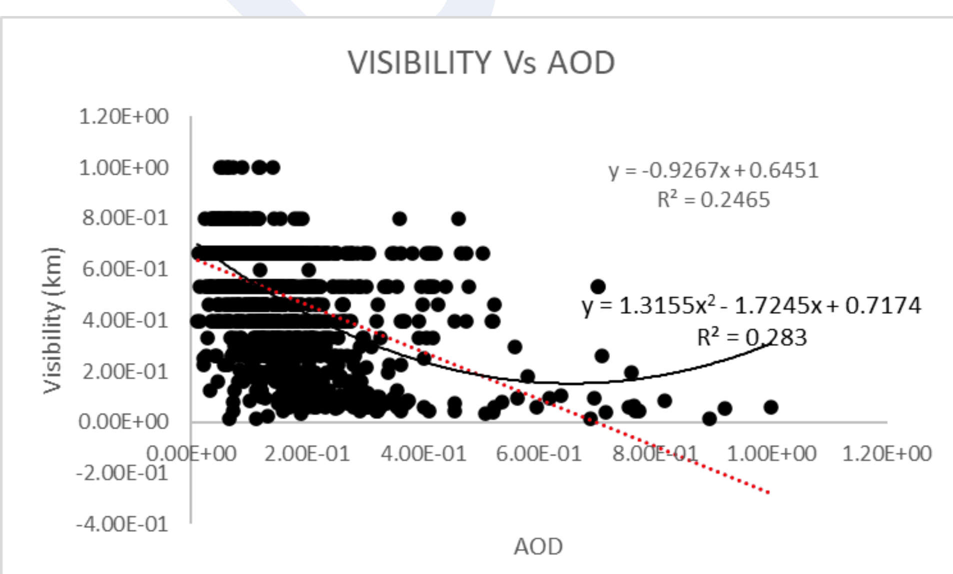

Figure 7: Scatter plot of AOD versus Visibility for the entire study period

In figure 7, R^2=0.246 which indicates positive but weak correlation between visibility and aerosol. Figure 7 - 9 is the general plots for the aerosol-visibility relationship; it encompasses the entire data for each parameter studied. The results of the plots show that aerosol both fine and coarse plays a minimum role in visibility reduction hence they all have a negative slope. The values of the slope shows that coarse aerosols reduces visibility much faster than fine aerosols judging by the steepness of the slopes and the corresponding slope values. The implication of this result is that every particle emitted in Ikeja has the potential to inhibit visibility. There is the likelihood that coarse particles in Ikeja may not be just dust but sea salt as well (based on the city's proximity to the Atlantic Ocean) and industrial nature.

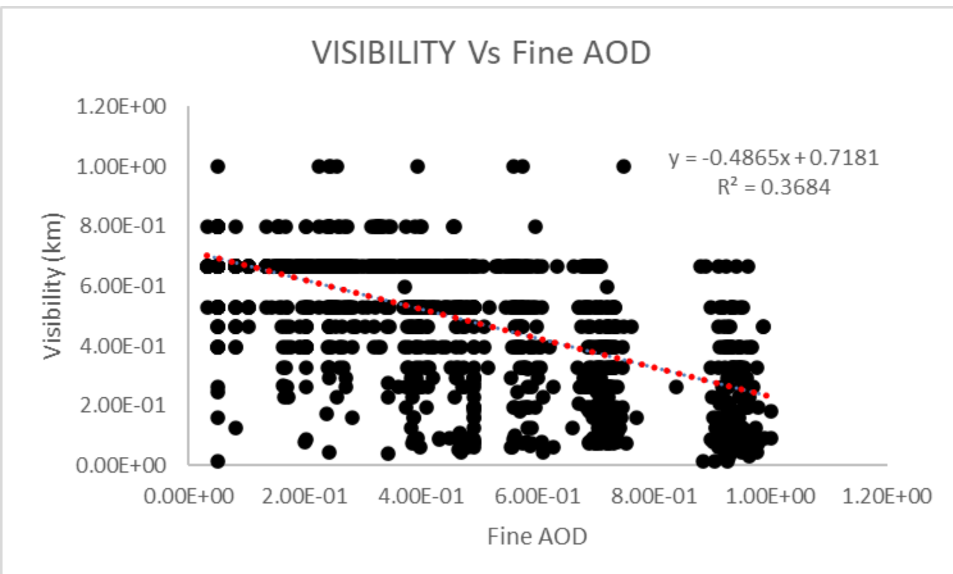

Figure 8: Scatter plot of Fine AOD versus Visibility for the entire study period

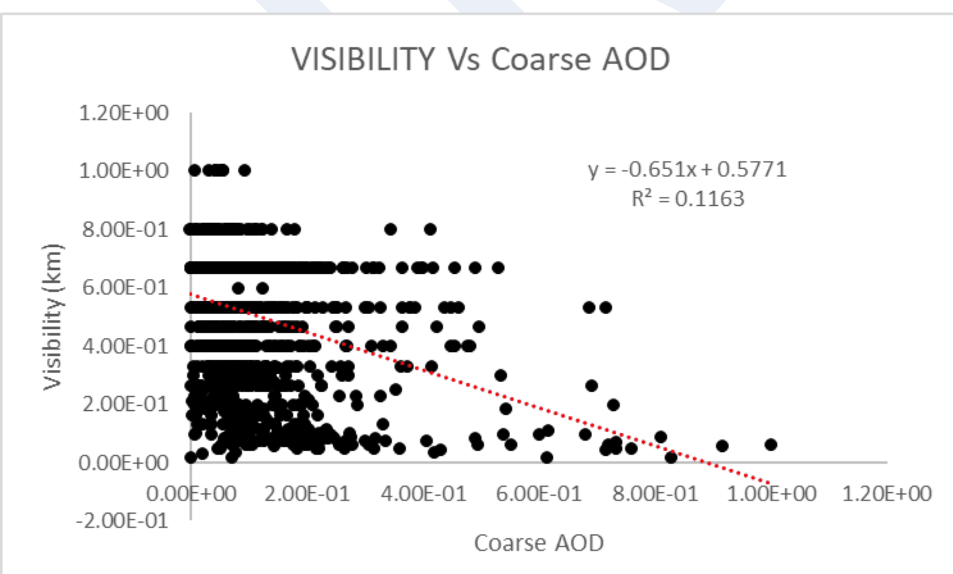

Figure 9: Scatter plot of Coarse AOD versus Visibility for the entire study period

Seasonal Analysis of AOD Versus Visibility

The result in figure 10 and 11 shows the seasonal plots of the various aerosol species, it could be deduced from the graphs that during the dry season all aerosol species inhibits visibility while during the rainy season the aerosols does not. From the slope values it showed that the dry season aerosol loading exerts greater influence on visibility than the rainy season values due to the steepness of the slope. Basically the dry season slope values were negative with weak correlation of R^2=0.1972, during the rainy season R^2=0.00 , as such, no relationship between visibility and AOD existed.

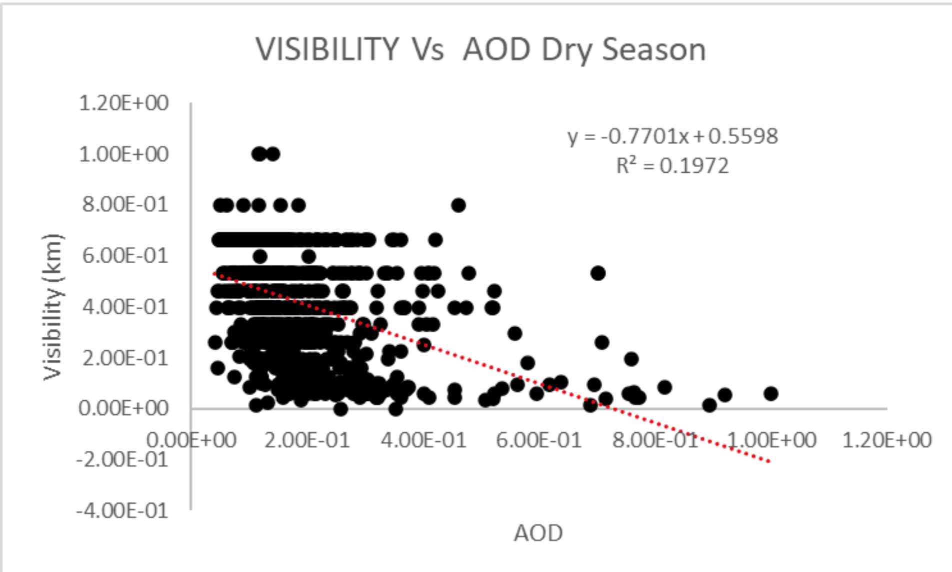

Figure 10: Scatter plot of AOD versus Visibility for the dry season for the entire study period

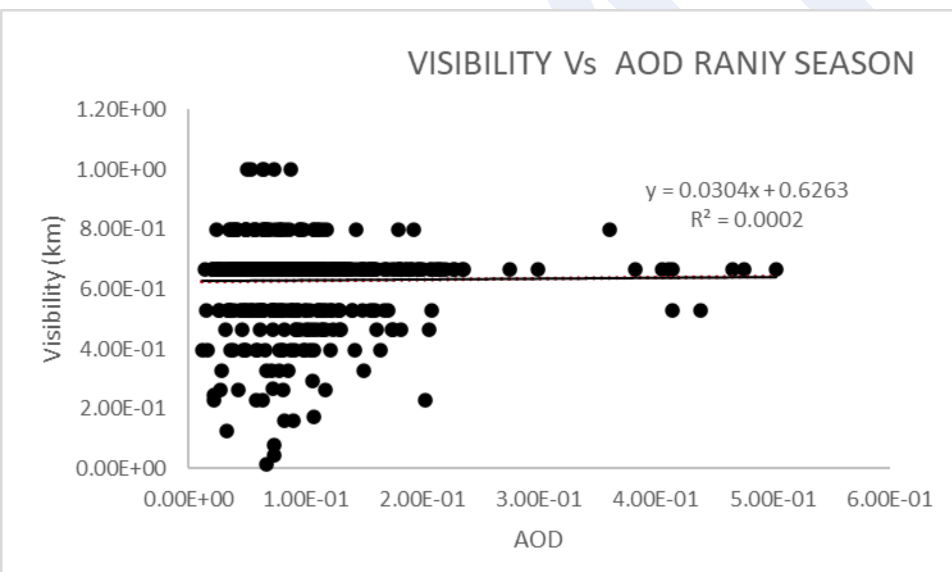

Figure 11: Scatter plot of AOD versus Visibility for the rainy season for the entire study period

4.0 Conclusion

9Both fine and coarse aerosols influence visibility at different but little degrees. During the rainy season, aerosol loading exerts greater influence on visibility reduction than during the dry season. This could be as a result of water vapour in the atmosphere which is absorbed by aerosols as it gives rise to phenomenon such as haze, dews.

Fine aerosols are emitted than coarse aerosols. As the year goes by the incidences of both fine and coarse aerosols reduces giving rise to improved visibility. A further analysis showed that both fine and coarse aerosols reduces visibility but at varying degree. Fine and coarse aerosols play a minimal role in visibility reduction but fine aerosols have a susceptibility to hamper visibility compared to coarse aerosol. During the dry season all aerosol species inhibits velocity while during the rainy season the aerosols do not. It was concluded that this site has economic development, weather, and regional anthropogenic activities leading to homogeneous aerosol emission. Visibility becomes better in the last few years owing to government control strategy to minimize the dust outbreak. Visibility are also found increasing with time, implying decrease in the rate at which aerosol are being re-supplied to or removed from the atmosphere in the recent time. Even though, various study have it that visibility generally increases in rainy season and worse in dry season throughout Nigeria; however, in this study, it was shown that during the dry seasons, visibility was best In Ikeja due to the climate conditions.

5.0 Recommendations

Well spread continuous monitoring of aerosol properties and functional meteorological stations to provide baseline data for visibility forecasting cannot be overstated, given the significant climate changes in West Africa resulting in prolonged drought, aerosol loading is expected to intensify (Nwofor, 2010). Government should pose a strict standard for monitoring visibility level in Nigeria.

The aerosol loading is potentially influential in the observed visibility seasonality at the site. Although many airports in Nigeria are now equipped with visibility monitoring instruments, there is the immense need to keep improving our capacity in the area of visibility forecasting and scenario construction. From this study, inasmuch as AOD affects visibility at certain degrees of seasons, the correlation between visibility and AOD is weak. Further studies on other factors that can inhibit visibility can be made.

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