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World News of Natural Sciences

An International Scientific Journal

WNOFNS 57 (2024) 119-130 EISSN 2543-5426

Assessment of the Correlation between Aerosol Optical Depth and Respiratory Diseases over Zaria, Kaduna, Nigeria, for 10 Years

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ABSTRACT

Atmospheric Aerosols are highly abundant in windblown dust events originating in arid and semi-arid areas. Aerosols are dangerous to human health when the emission rate is presumably high. Harmattan dust is considered to be amongst the most harmful of all air pollutants due to the toxic effect of the dust constituents. Respiratory infections make up more than 20% of the causes of human mortality and morbidity. This study was carried out to assess the correlation between aerosol loading and respiratory diseases at Zaria, Kaduna State in North-Central Nigeria. The aerosol data were accessed from the National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectra-radiometer (MODIS) platform, while data on respiratory diseases were obtained from Ahmadu Bello University (A.B.U) Teaching Hospital Shika, Zaria, Nigeria from Jan 2009 – Dec 2018. Within that period, 2022 patients were diagnosed with different ranges of respiratory diseases. Out of 2022 516 (25.52%) were adult male, 455 (22.5%) were female, while teenagers were constituted 290 (14.34%), children were 385 (19.04%), and infants were 376 (18.6%). The correlation between aerosol optical depth and the number of cases of respiratory ailments was evaluated. A correlation coefficient of 0.65 was evaluated in the dry season, while in the rainy season the correlation coefficient was -0.55, overall correlation for an inter-annual variation is 0.27 while for the seasonal variation is 0.49. These results

(Received 25 August 2024; Accepted 28 September 2024; Date of Publication 30 September 2024)

suggest that there is a positive correlation between aerosol loading and respiratory cases at Zaria. It also shows that the correlation between the dry seasons is high compared to the rainy season.

***Keywords*:** Aerosol, AOD, respiratory, disease, Zaria, Kaduna, hospital, data, relationship, Nigeria

1. INTRODUCTION

Aerosols are microscopic and submicsroscopic[1] solid or liquid particles suspended in the atmosphere[2]. Aerosols are pollutants[3] that can be either natural or anthropogenic[4]. Examples of aerosols include; windblown dust, sea salts, volcanic ash, smoke from wildfires, pollutions from factories, and so on[5]. Aerosols' sizes, type, or location can determine if they cool or warm the surface of the earth[6]. Aerosol optical depth (AOD) measures the extinction of the solar beam by dust and haze[7]. That is to say, particles in the atmosphere can block sunlight by absorbing or scattering light[8]. It tells us how much direct sunlight is prevented from reaching the ground by this aerosol particles[9]. Aerosol is defined as a stable suspension of solid and liquid particles in the atmosphere[10].

Atmospheric aerosols contain also the medium in which particles are suspended, which is the air[11]. Aerosol particle sizes range from 0.001 μm to 100 μm, hence, the particle sizes span over several orders of magnitude, ranging from almost macroscopic dimensions down to near molecular sizes[2,12]. Aerosols are very important for public health[13] and understanding of their dynamics is important for quantification of their effects on humans[14]. Human exposure to aerosols occurs both in outdoor and indoor environment[15]. In humans, the respiratory tract is the part of the anatomy of the respiratory system involved with the process of respiration[16]. Air is breathed in through the mouth or nose[17]. In the nasal cavity, a layer of mucous membrane acts as a filter and traps pollutants and other harmful substances found in air[18]. Next, air moves into the pharynx, a passage that contains the intersection between the esophagus and the larynx[18].

The opening of the larynx has a special flap of cartilage[18], the epiglottis that opens to allow air to pass through but closes to prevent food from moving into the airway[19]. Diseases of the respiratory system may affect any of the structures[21] and organs that have to do with breathing, including the nasal cavities, the pharynx (or throat), the larynx, the trachea (or windpipe), the bronchi and bronchioles, the tissues of the lungs, and the respiratory muscles of the chest cage[21].

The respiratory tract is the site of an exceptionally large range of disorders[22] for three main reasons: (a) it is exposed to the environment and therefore may be affected by inhaled organisms, dusts, or gases[23]; (b) it possesses a large network of capillaries through which the entire output of the heart has to pass, which means that diseases that affect the small blood vessels are likely to affect the lung[24]; and (c) it may be the site of "sensitivity" or allergic phenomena that may profoundly affect function[25].

The focus of this paper is on the effects of air pollutants on human respiratory system using Zaria, Kaduna State, as a case study. The data used for this paper were collected from NASA MODIS (for aerosol optical depth) platform and Ahmadu Bello University Teaching Hospital, Zaria, Nigeria (for the hospital data). During the period of this research, aerosols were found to have effect on the respiratory system. Furthermore, measures to manage and control aerosol distributions were discussed.

2. MATERIALS AND METHODS

2. 1. The study area is Zaria, Kaduna State in North-Central Nigeria. It is within latitude 11.09°N and longitude 7.72°E and situated at elevation 644 m above sea level.

2. 2. Zaria is a major commercial city in Kaduna state in Northern Nigeria. Formerly known as Zazzau, it is occupies the total area of 563 km^2 and as at 2006 census has a population of 975,153 people with a density of 730 km^2.

2. 3. It also operates on the West Africa Time (WAT) zone. Figure 1 shows the location of Zaria on the map of Kaduna state, Nigeria.

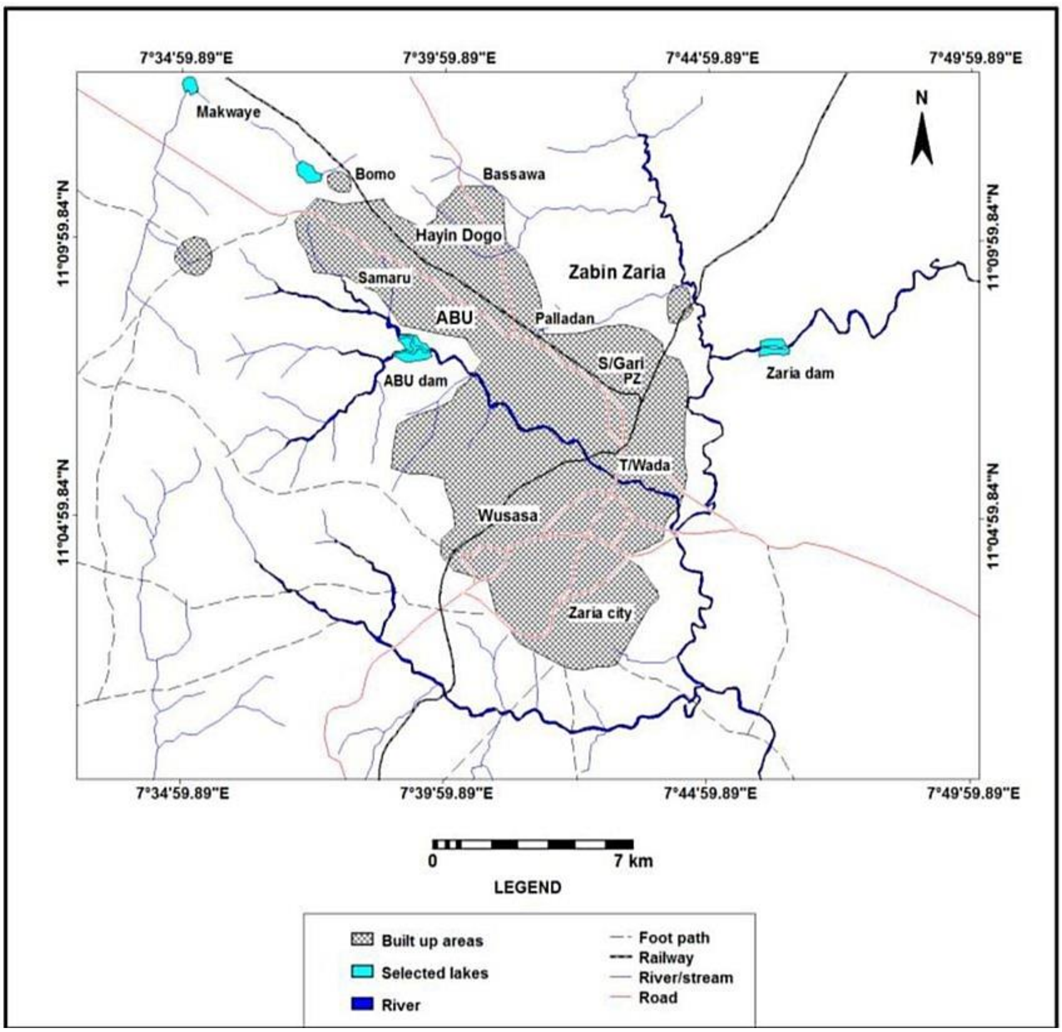

Figure 1. Map of Zaria, Kaduna Nigeria, Showing ABUTH

2. 4. The climate of Zaria is tropical. In winter, there is less rainfall in Zaria compared to summer. In Zaria, the average annual temperature is 24.9 °C. The rainfall here averages 1050 mm. The driest month is January. There is almost 0mm of precipitation in January. With an average of 273 mm, the most precipitation falls in august. With an average of 28.6 °C, April is the warmest month. January has the lowest average temperature of the year. It is 22.6 °C. Zaria has a tropical Savanna climate with warm weather year-round, a wet season lasting from April-September, and a drier season from October-March.

2. 5. The study data can be regarded as a secondary data since it was collected from an already processed data base. I assessed my aerosol data from National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer MODIS platform.

2. 6. Data for respiratory ailments were collected from Ahmadu Bello University Teaching Hospital (ABUTH) Shika, from January 2009 to December 2018. All case folders of affected patients were retrieved from the central library of health information management department of the hospital.

2. 7. All data where subjected to statistical and mathematical analysis such as measures of central tendency and measure of spread and the statistical correlations were determined and compared with results from other studies. The data was subjected to demographical segregation in order to assess influence of gender, occupation and age on the results.

3. RESULTS AND DISCUSSION

3. 1. Analysis of Aerosol Loading

The aerosol loading is high and almost constant at about 0.96 throughout the ten years survey. This is evidence that the source of the aerosol loading is sustainably influencing the risk of human to respiratory dysfunction. The sources of pollution are Sahara dust and anthropogenic pollution[26].

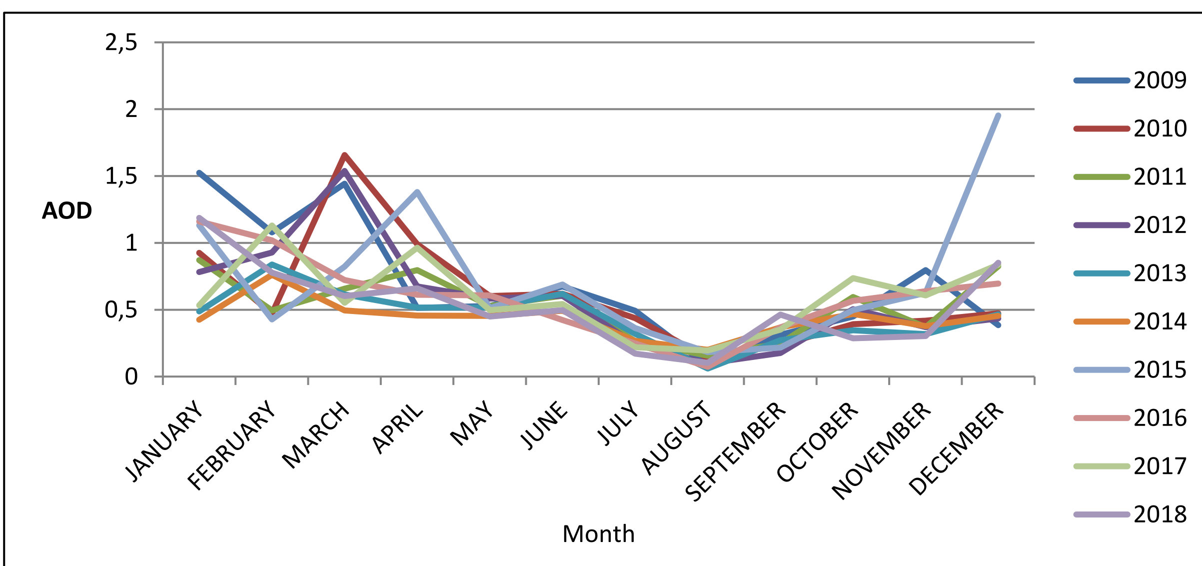

Figure 2. Time Series of Aerosol Optical Depth (2009-2018)

The anthropogenic sources include bush burning, automobile gas emission, domestic fuel burning (e.g. fire wood, charcoal, kerosene etc.)[27] and industrial emission[28]. In Figure 2, the highest aerosol loading for ten years was found to occur in December 2015 while the lowest was found to occur in August 2013.

Aerosol loading varies in its occurrence in months over the years, this may due to climate change and it is an evidence of a dismal rainfall pattern over the area. It is also observed that aerosol loading occurrence over the years is high between January and March with a slight high value in December. It was also observed that the transient nature of the aerosol loading over the research area was between July and September. Other observance for the minimum and maximum occurrence of aerosol loading for both months and years are shown in Table 1. These results partly show the period where Sahara dust flow is highest or low. The dominant pollutant can be traced from the aerosol data, which describes the dependency of the aerosol optical thickness or aerosol extinction coefficient on wavelength. AOD describes how much direct sunlight is prevented from reaching the ground by these aerosol particles. It has been proven that precipitation rate lowers the aerosol loading in the atmosphere. A value < 0.4 corresponds to a clean atmosphere, and a value ≥ 0.4 correspond to a very hazy condition. Figure 3 and 4 shows the mean AOD for seasonal variation and inter-annual variation.

Table 1. AOD Statistics over Zaria, Nigeria

Statistics	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NO of Value	12	12	12	12	12	12	12	12	12	12
NO of Missing Value	0	0	0	0	0	0	0	0	0	0
Minimum Value	0.08	1.14	0.17	0.09	0.06	0.2	0.18	0.07	0.19	0.10
Maximum Value	1.52	1.657	0.871	1.54	0.84	0.76	1.95	1.16	1.13	1.19
Mean	0.689	0.61	0.53	0.58	0.45	0.43	0.73	0.59	0.59	0.53
Variance	0.19	0.17	0.06	0.15	0.04	0.02	0.27	0.09	0.08	0.09
Standard Deviation	0.45	0.41	0.24	0.39	0.20	0.14	0.52	0.30	0.28	0.31

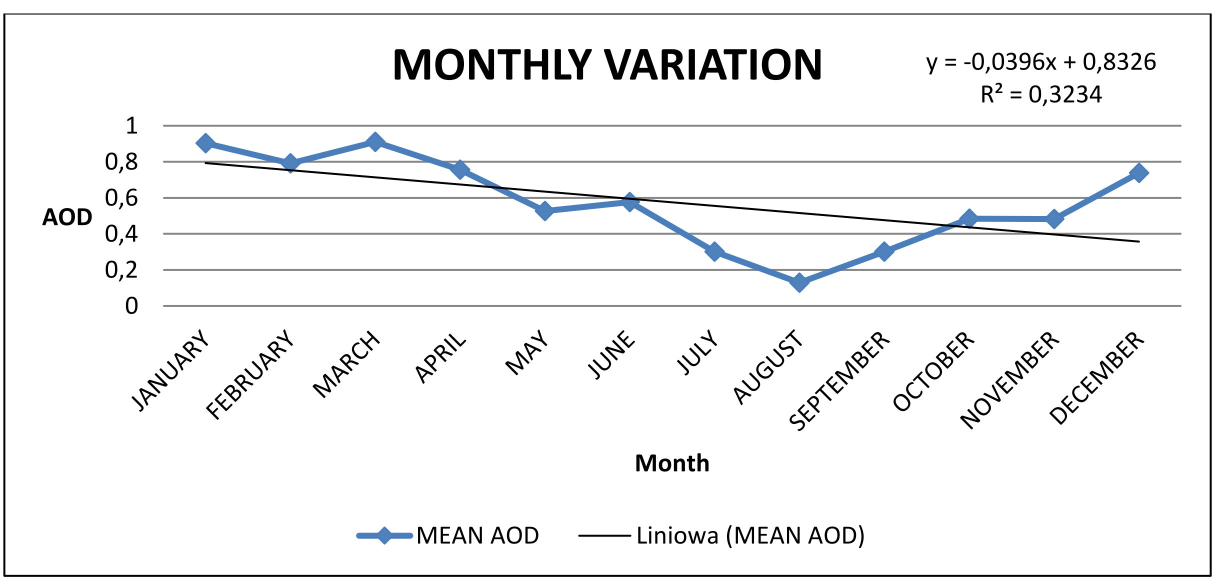

Figure 3. Monthly Variation of AOD

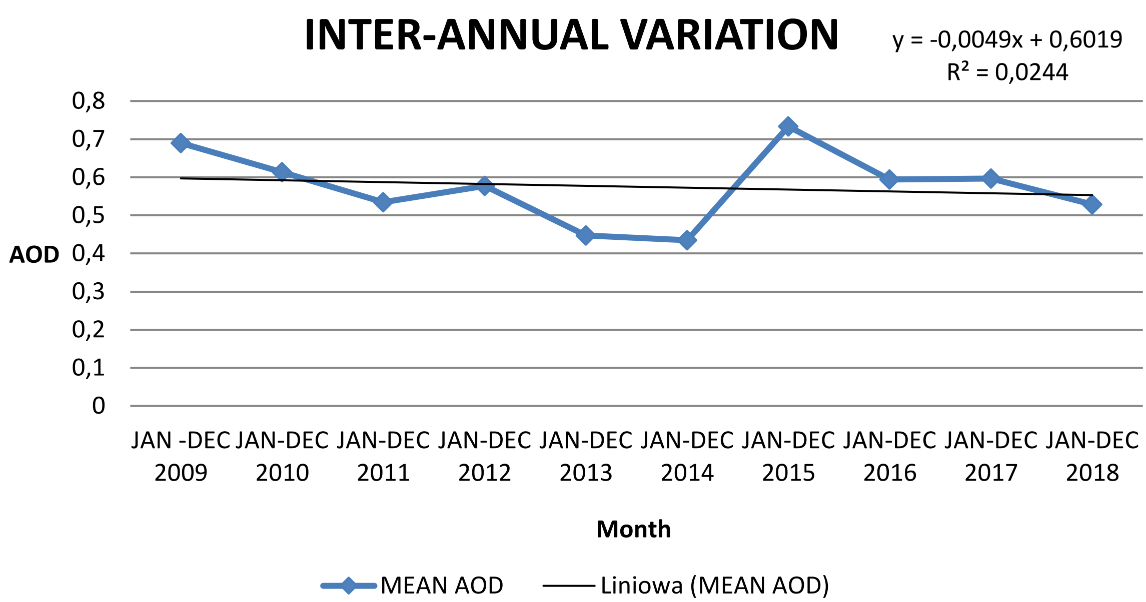

Figure 4. Inter-annual Variation of AOD

3. 2. Analysis for Cases of Respiratory Diseases

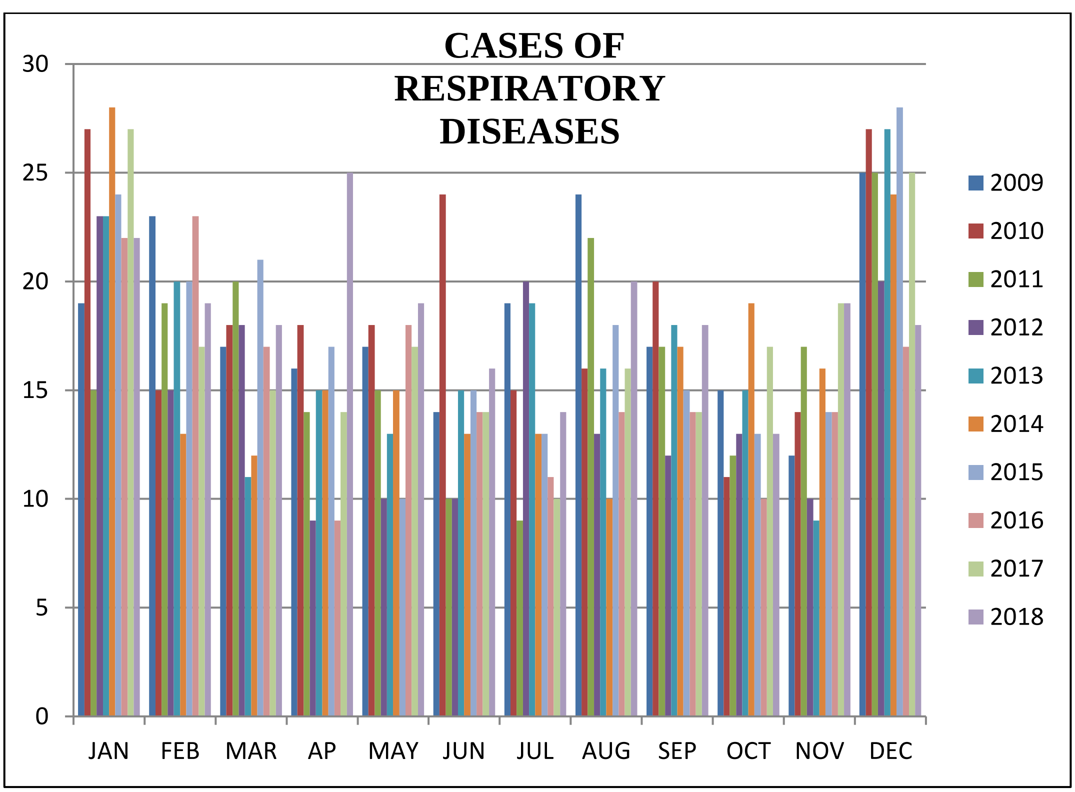

Figure 5. Plot of a Monthly Decadal Value of Cases of Respiratory Diseases (2009-2018)

From the data collected for cases of respiratory diseases from 2009-2018 it was 2022 cases where recorded. It was recorded that adult male has the highest number of cases with 516 cases (25.52%) compared to adult females with 455 cases (22.50%). The hospital also recorded cases for teenagers of age grade from 14-17 to be 290 cases (14.34%), children 7-13 to be 385 cases (19.04%), infants 0-6 with 376 cases (18.60%). It was observed that asthma occurred more in the rainy season compared to the dry season, while pneumonia has more incidence in the dry season compared to the rainy season. More cases of pneumonia were recorded compared to other respiratory diseases follow suit by asthma. More cases of asthma were observed in infants and children compared to adults. From Figure 5 it can be observed that more cases occurred in 2010 and the least was 2012. January and December were recorded with higher incidence while October had the least.

3. 3. Analysis of the Relationship between AOD and Cases of Respiratory Diseases

Correlation between aerosol optical depth and the number of cases of respiratory ailments were evaluated. A correlation coefficient of 0.65 was evaluated in the dry season as shown in Figure 6, while in the rainy season the correlation coefficient was -0.55 as shown in Figure 7, overall correlation for an inter-annual variation is 0.27 as show in Figure 8, while for the seasonal variation is 0.49 as shown in Figure 9.

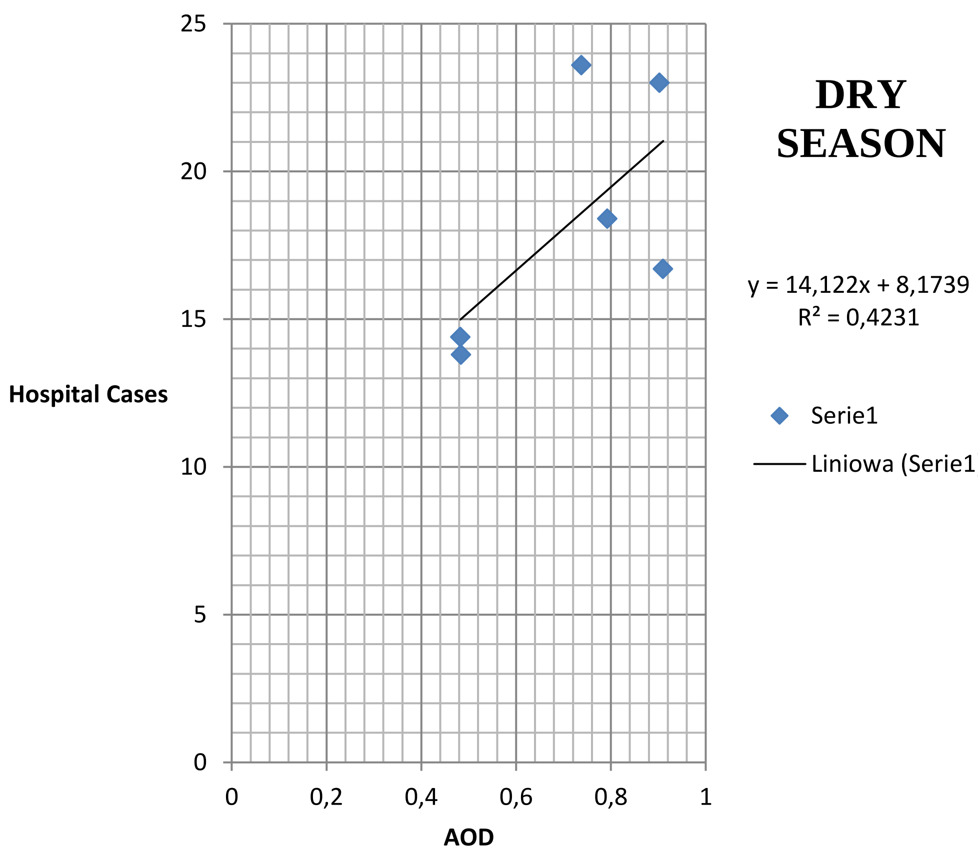

Figure 6. Correlation between Mean of Cases of Respiratory Diseases versus Mean Aerosol loading

Figure 6 shows that there is a positive linear relation between the cases of respiratory diseases recorded in ABUTH and aerosol loading within the region during the dry season or harmattan period.

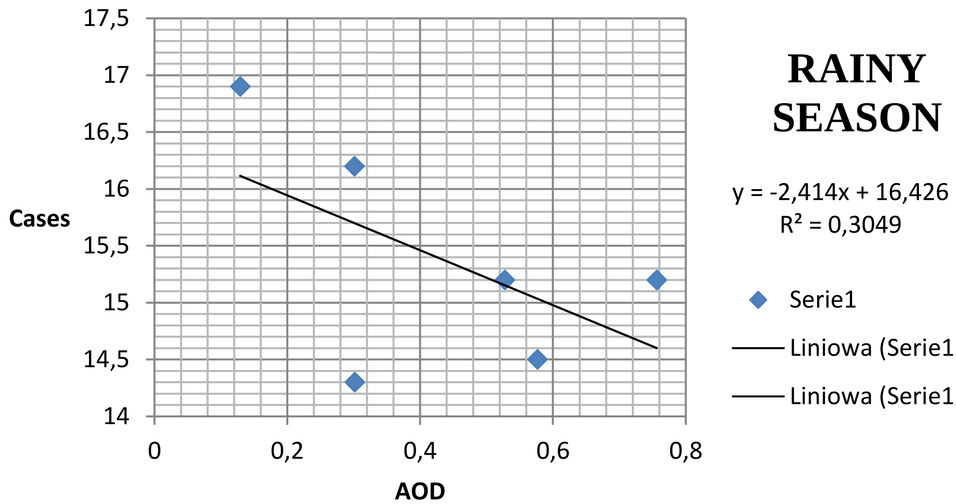

Figure 7. Correlation between Mean of Cases of Respiratory Diseases versus Mean Aerosol loading for Rainy Season

Figure 7 shows that there is a negative relation between Cases of affected patients and aerosol loading in Zaria during the rainy season.

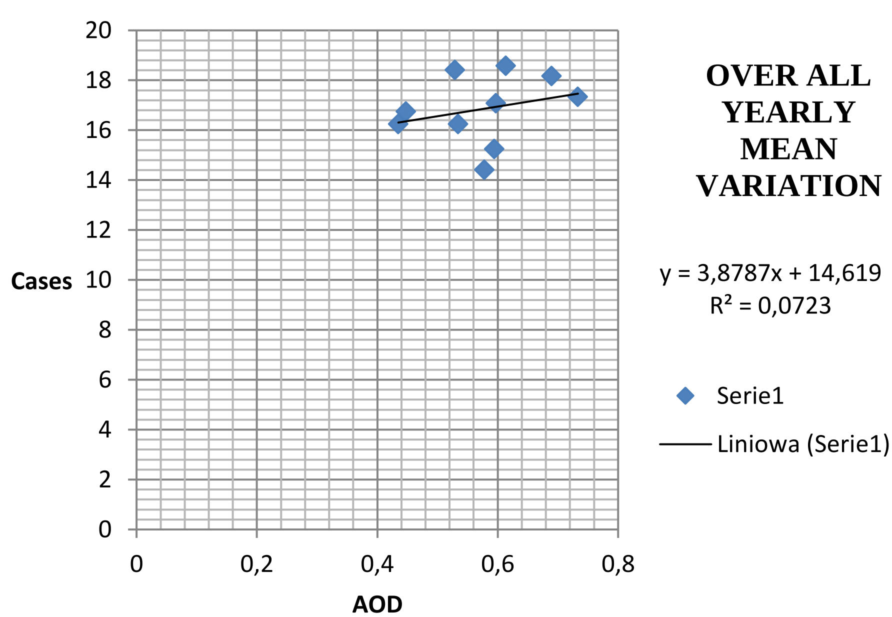

Figure 8. Correlation between the Mean Cases of Respiratory Diseases versus Mean Aerosol loading (2009-2018)

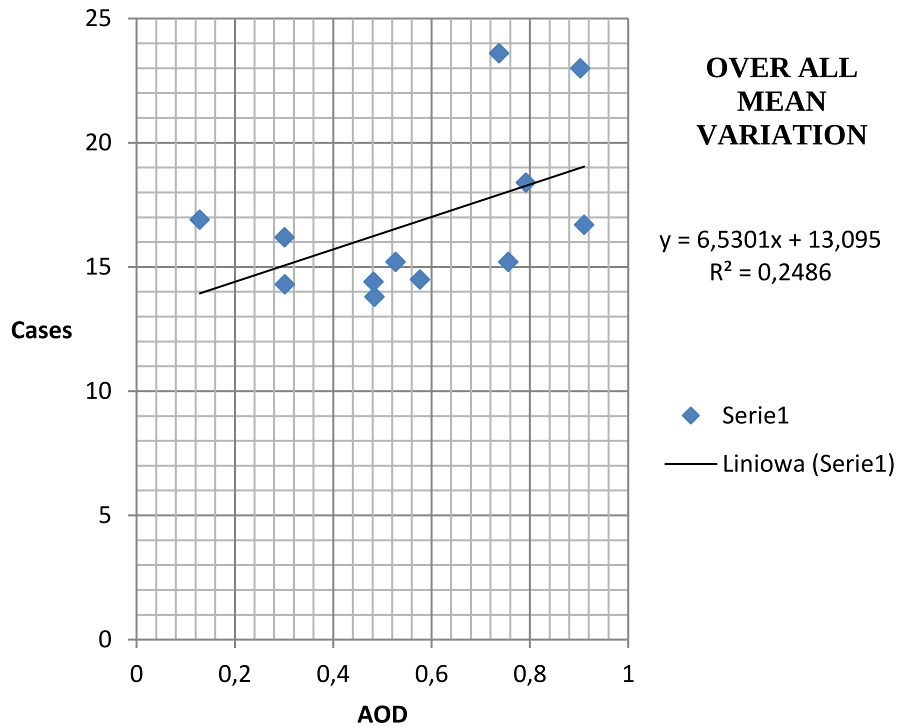

Figure 9. Correlation between the Mean Cases of Respiratory Diseases versus Mean Aerosol loading (Seasonal Variation)

It is shown in Figure 7 that the overall yearly mean variation between aerosol loading and cases has a positive linear relationship. While Figure 9 shows that there exists a positive linear relationship between them.

It can be seen by the above analysis and results that aerosol loading within Zaria is presumably high over the harmattan period compared to the rainy season. It was also shown that for gender, male has higher risk to these respiratory diseases compared to women, while infants, children are more at prevalent to asthma and pneumonia compared to the adults. In terms of the correlation, it can be concluded that these results suggest that there is a positive correlation between aerosol loading and respiratory cases at Zaria. It also shows that the correlation in the dry season is high compared to rainy season. There is a positive correlation between aerosol loading and respiratory ailments in the dry season, while there is a negative correlation between aerosol loading and respiratory cases during the rainy season. Generally, the correlation are weak suggesting possible influences of other parameter order than aerosols in respiratory diseases such may include humidity, temperature, rainfall and so on.

The limitation of this data is due to three main reasons: First, not everybody goes to hospital for treatment because of financial constraint or religious belief. Second, there are patients who prefer private hospital to government hospital. Third, is the issue of authenticity of collected data? Moreover, there are others who use other methods such as traditional herbal medicine and spiritual means for the treatment of their ailments. The information therefore may not represent the true number of respiratory cases in the study area. At the same time, the data were not regarded as worthless, rather it is belief that they at least depict a general pattern of respiratory diseases occurrence in the study area Visibility measurements reflect the aerosol concentration at ground level. The visual range can vary from a few meters to 200 km, depending on the proximity to sources, the strength of the sources, and atmospheric conditions.

Aerosol is prevalent due to desertification. Aerosol can be combat with constant planting and grassing. Reduced incidence of over grazing, improving and encouraging ranching can reduce rise of dust on the atmosphere that can affect respiratory diseases. Precipitation also prevents aerosols from accumulating in the atmosphere. The highly diverse sources and locations of aerosols combined with their short residence times lead to high spatial and temporal variability in global aerosol distribution and the associated forcing. Removal of aerosols by clouds and precipitation is the largest sinks for aerosols with diameters <1 μm. Thus the lifetime of aerosols is strongly linked to that of clouds.

4. CONCLUSION

Aerosols may exist in the form of airborne dusts, sprays, smokes, and fumes. Aerosol particle sizes ranges from 0.001 μm to 100 μm, hence, the particles sizes span over several orders of magnitude, ranging from almost macroscopic dimensions down to near molecular sizes. They originate from either naturally occurring processes or from anthropogenic activity. Respiratory tract infection refers to any of a number of infectious diseases involving the respiratory tract. Deposition of aerosol particles into the respiratory system causes variety of diseases that are harmful to the body. Aerosol prevalence is a major burden both on environment and human life.

This study compares the correlation of cases of respiratory diseases and aerosol loading over Zaria, Kaduna State. The correlation where observed to be rather weak and presumably not sustainable to fully be responsible for respiratory diseases over Zaria. It was also statistically observed that the harmattan season has higher cases of respiratory diseases and aerosol loading compared to the rainy season.

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