International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 977-985 www.ijaem.net ISSN: 2395-5252

Analyzing the Influence of Sahara Dust on Meningitis Outbreaks in North Central Nigeria

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Date of Submission: 20-04-2024 Date of Acceptance: 30-04-2024

ABSTRACT
Meningiis disease outbreaks in Sahelian areas, particularly during harmattan periods characterized by dusty conditions, is alarmingly increasing. Limited studies have assessed the impact of dust on meningitis seasonality in Nigeria, and to the best of our knowledge, none of these studies included north central Nigeria despite the fact that meningitis diseases incidences are being reported in the hospital in this region of the country. This research investigates the influence of a crucial factor associated with meningitis outbreaks, namely dust, in selected parts of north-central Nigeria, specifically Minna, Lokoja, and Ilorin. We utilized epidemiological data obtained from the study areas, dust samples collected during harmattan periods, and Aerosol Optical Depth (AOD) retrieved from NASA's MODIS website as a proxy for dust. Dust samples were measured using Bettersizer 2600B at the Central Research Laboratory, Federal University of Technology, Akure. Pearson correlation analysis was employed to assess the quantitative relationship between meningitis cases and AOD. Our findings reveal the presence of both $PM_{2.5}$ and PM_{10} particles in the dust samples collected from different regions, with Minna exhibiting the highest proportion in both particle size categories. A statistically significant weak positive correlation between meningitis cases and AOD was observed in Minna, the region with the highest proportion of PM2.5 and PM10. However, no statistically significant correlation was found between meningitis and AOD in the remaining two areas. Hence, it is crucial to direct focus not just to the mentioned areas but also to the north-central region of the country, considering Minna's geographical connection. This conclusion underscores the importance of expanding the geographic scope when applying preventive measures and interventions against meningitis.

Key words: airbone, particulate matter, meningitis, bettersizer climate variability.

I. INTRODUCTION

Most often occurring from December to March, the harmattan is a dry wind that originates in the northeast and spreads large amounts of Saharan dust over Sahelian regions (Yarber et al., 2023). The dust, which is annually transported from North Africa, affects both regional and global climates in a variety of ways. It modifies ocean carbon budgets and the balance of atmospheric radiation (van der Does et al., 2021). Additionally, mineral dust that has been deposited in oceans and contains vital nutrients like phosphorous (P) and iron (Fe) has an impact on terrestrial and marine ecosystems, affecting the climate, the atmosphere-ocean carbon cycle, and primary productivity (Jickells and Moore 2015). Approximately 30% and more than 70% of the total aerosol mass load and optical thickness, respectively, are mostly contributed by dust, a prominent component of atmospheric aerosols in the Earth system (Kinne et al., 2006). Based on Ginoux et al. (2012), North Africa is the primary worldwide dust source region, contributing over 50% of the world's dust emissions. According to Solomon et al. (2012), Bristow et al. (2010), Evan et al. (2006), Braun (2010), and others, African dust is essential for controlling rainfall in West Africa, supplying nutrients to the Amazon rainforest, and having an effect on public transportation, health, and Atlantic cyclogenesis. According to Hsu et al. (2000), dust

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Volume 6, Issue 04 Apr. 2024, pp: 977-985 www.ijaem.net ISSN: 2395-5252

aerosol can affect the radiation budget directly as well as indirectly because it demonstrates both scattering and absorption properties throughout the solar and atmospheric radiation spectrum. Numerous factors are affected by dust, including human health and the local and global climate (Pandey et al., 2017; Tiwari et al., 2019; Pérez et al., 2006). The meteorological, agricultural, transportation, energy, and social sectors are all disrupted during extreme African dust episodes. This causes school closures, social event cancellations, and problems with emergency response systems (Alexandra et al., 2022). Dust episodes are also linked to health problems like dyspnea, exacerbations of Chronic Obstructive Pulmonary Disease (COPD), poor visibility that interferes with aircraft traffic, and decreased solar energy generation.

Dust also has the ability to affect tropical cyclones and ocean biogeochemistry (Jickells et al., 2005; Pan et al., 2018). According to Milford et al. (2019), there are also consequences for local and distant air quality during periods of desert dust outbreaks. Remarkably, estimates of the annual amount of Saharan dust exported from Africa range from 136 to 222 Tg. The dust is exported from Africa across the Atlantic Ocean and ends up in the Caribbean (Yu et al., 2019). It is noteworthy to mention that these estimations may be conservative, as stated by Adebiyi and Kok in 2020. This air dust acts as ice nuclei and cloud condensation (Twohy et al., 2009), as well as modifying radiation budgets (Ryder et al., 2019). Dust brings vital nutrients to the ocean floor, where it encourages the growth of phytoplankton, which in turn improves the carbon cycle (Pabortsava et al., 2017). Larger dust particles, in particular, have the ability to increase carbon export to the ocean floor by functioning as mineral ballast particles that hasten the settling of organic matter aggregates (Pabortsava et al., 2017; Van der Jagt et al., 2018).

The 1970s and 1980s saw a significant increase in dust transport to the Caribbean after a severe drought in the Sahel, which established a link between dust transport and the African climate (Prospero et al., 2021). Northwest African dust emissions vary significantly from year to year, and the amount of dust deposited decreases with increasing distance from the source (Van der Does et al., 2020). The removal of dust particles from the atmosphere is facilitated by both wet and dry depositional processes (Bergametti and Forêt, 2014). The availability of nutrients carried by dust may be increased by wet deposition in particular, which would increase the fertilizing effect of dust deposition in oceans (Meskhidze et al., 2005; Ridame et al., 2014). The presence of dust sources, wind speed, erosion threshold, and soil particle size are among the factors that affect the size of the dust particles released at the source (Marticorena, 2014). Dust deposited nearer the source tends to have coarser grains than dust deposited at farther locations, so the particle size of dust deposited over the ocean is correlated with the distance from the source (Van der Does et al., 2016). Several research works have suggested a strong correlation between the climate, the Saharan dust, and the prevalence of meningococcal meningitis in West Africa (Agier et al., 2013; Jusot et al., 2017; Martiny &Chiapello, 2013). Meningococcal meningitis is most common in the "Meningitis Belt," a sub-Saharan African region that stretches from Ethiopia to Senegal (Molesworth et al., 2002). Meningococcal meningitis is a serious infection that causes inflammation of the meninges around the brain and spinal cord. It is very common in this area and is a worldwide health problem (WHO, 2022). The 50% fatality rate for meningococcal meningitis if treatment is not received highlights the vital significance of beginning antibiotic therapy as soon as possible (WHO, 2022). As a result of the mucous membrane being weakened by dust and dry air, bacteria can more easily enter the bloodstream, as Mueller and Gessner (2010) found. Meningitis usually occurs in the latter part of the dry season, which is when warm, dusty Harmattan trade winds blow (Adetunji et al., 1979). The meningitis season runs from February to May. In order to fully quantify the effects of atmospheric dust on human health, air quality monitoring stations are hard to come by in Africa, especially in areas that are major sources of dust (Petkova et al., 2013). Because of this, remote measurements of aerosol optical depth (AOD) from satellites and sun photometers are frequently used to assess the seasonality of mineral dust.

Recognizing the acknowledged impact of dust on meningitis incidence, recent research emphasizes the need for more studies to enhance our understanding of the connection between dust influence and meningitis. This research aims to fill this gap by conducting a detailed analysis of the influence of Saharan dust on meningitis outbreaks. The investigation involves collecting dust samples and measuring particle sizes, with a primary emphasis on establishing a correlation between meningitis incidences and Aerosol Optical Depth (AOD), used as a proxy for dust particles

II. MATERIAL AND METHOD

2.1 Dust Sample Collection

Following the dust sampling methodology developed by Falaiye and Aweda (2018), we systematically positioned clean Petri dishes on elevated platforms at secure locations in each station (Minna, Lokoja, and Ilorin). Jalala Estate, Natako, and London Street were specifically chosen as the designated sampling locations for Ilorin, Lokoja, and Minna respectively. Local dust interference was minimized by strategically choosing elevated platforms for sampling. These elevated platforms included the top of an uncompleted building in Jalala, and the second floor of a two-story building for both Lokoja and Minna. To further mitigate local dust input, precautions were observed during the collection process, such as ensuring the sample containers were kept away from untarred public roads and highways, aligning with the approach outlined by Falaiye et al. (2013). Each Petri dish was exposed for a minimum of one month to accumulate a representative sample. To prevent contamination, the collected samples were stored in desiccators before analysis. Subsequently, the samples from each Petri dish were combined to create a single sample, ensuring a sufficient quantity for analysis. Elemental and particle size measurements were conducted on each combined sample.

2.2 Dust Particle Size Measurement

To assess the significant role played by dust particles of various sizes, particle size measurements were conducted at each location using the Bettersizer 2600E machine located at the Central Research Laboratory, University of Technology, Akure (FUTA), Nigeria. Half of the collected samples from each station were used for this measurement, and the machine has the capability to measure particle size ranging from 0.1 to 2600 micrometers. The Bettersizer 2600E operates as a laser diffraction particle size analyzer, adopting laser scattering and Fraunhofer diffraction principles. The instrument features a laser diode as a coherent light source, emitting a beam of light that passes through the sample containing particles. Interactions occur between the laser light and particles, and the instrument measures scattered light at specific scattering angles. The detector, positioned accordingly, collects the scattered light, with adjustable angles based on measurement requirements and sample characteristics.

As the laser light interacts with particles, it undergoes diffraction following Fraunhofer diffraction principles. The diffraction pattern contains information about the particle size distribution, and Fourier transform techniques are used to convert the scattered light intensity pattern into a frequency domain representation. This representation is then reversed to the particle size domain using inverse Fourier transform, allowing determination of the particle size distribution based on scattered light intensity data. The instrument's software analyzes scattered light intensity data and calculates various particle size distribution parameters, including mean particle size, size distribution width, and cumulative distribution. Calibration is essential to establish a correlation between measured scattered light intensity and known particle sizes, typically accomplished using reference standards. During analysis, the software utilizes calibration data to convert scattered light intensity into particle sizes.

The Bettersizer 2600E provides multiple options for data presentation, such as graphical representations of particle size distribution, cumulative distribution curves, and statistical parameters.

2.3 Aerosol Optical Depth (AOD) data

The Aerosol Optical Depth (AOD) at 550 nm was assessed using the Deep Blue Algorithm for land-only areas on a monthly basis with a spatial resolution of 1 degree, utilizing MODIS-Aqua MYD08_M3 v6.1 data spanning from January 2009 to December 2018. The data extraction encompassed three distinct study regions. The selection of MODIS data for this research is justified by its capability to effectively capture the spatial distribution of aerosols across the entire country. This is particularly relevant during the dry season when Saharan dust, a significant aerosol source, reaches the surface. The choice of MODIS is supported by its synoptic nature, which ensures the detection of Saharan dust storms, as highlighted by Knippertz and Todd (2010). Furthermore, MODIS provides a comprehensive view of aerosol spatial variability, a crucial factor for a thorough understanding of aerosol dynamics in relation to national meningitis.

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Volume 6, Issue 04 Apr. 2024, pp: 977-985 www.ijaem.net ISSN: 2395-5252

III. RESUL AND DISCUSSION

3.1 Results

Table1: Correlation Analysis result between meningitis and AOD

Stations	Ilorin	Lokoja	Minna
Corr coeff.	0.06	0.08	0.21
P value	0.56	0.40	0.04

Table 1 shows the Correlation of Aerosol Optical Depth (AOD) and meningitis disease incidences in the study area.

Table2: Proportion of coarse and fine particle in the sample for various location (micrometer)

Location	PM2.5	PM10	Others
Ilorin	0.08	0.16	<100
Lokoja	0.06	0.21	<100
Minna	11.15	23.45	<70

Table 2 presents the bettersizer 2600B results showing the percent proportion of the various particles sizes found in the dust sample collected from the study locations

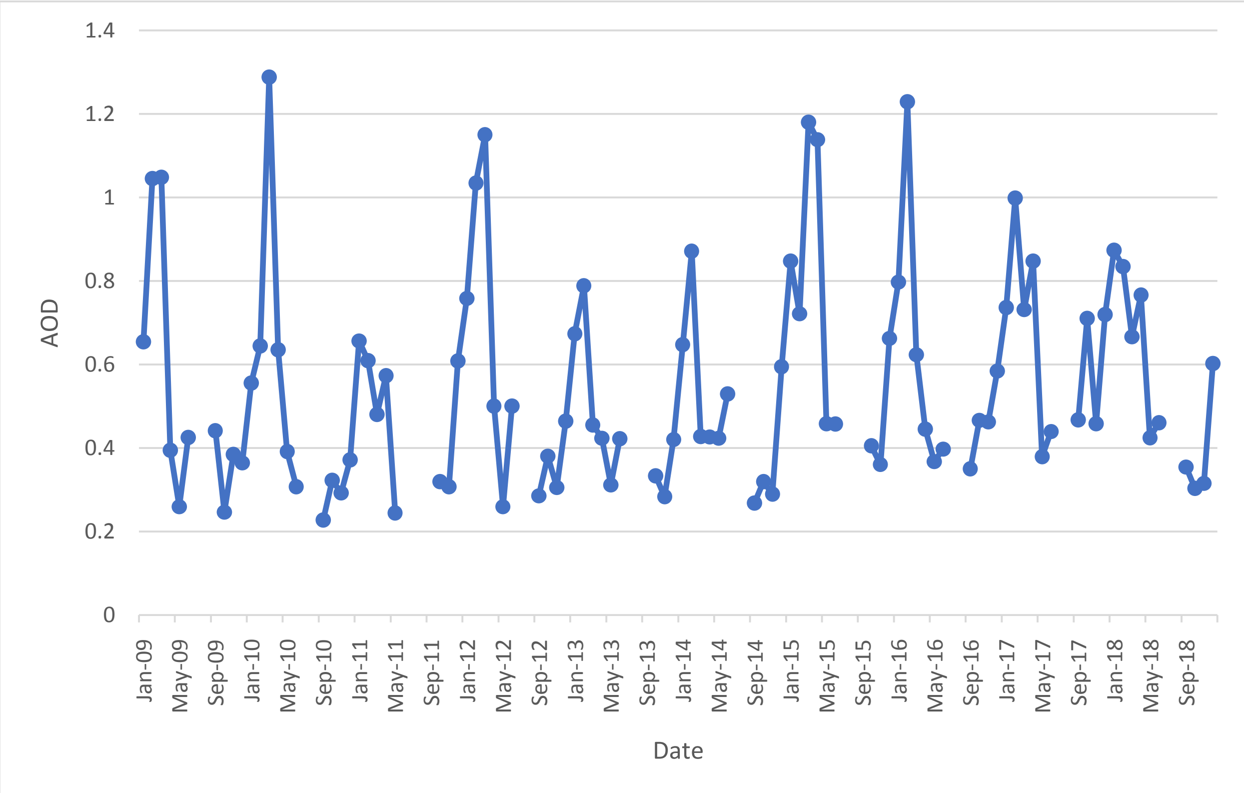

Figure1 : Graph of AOD over the study period in Minna

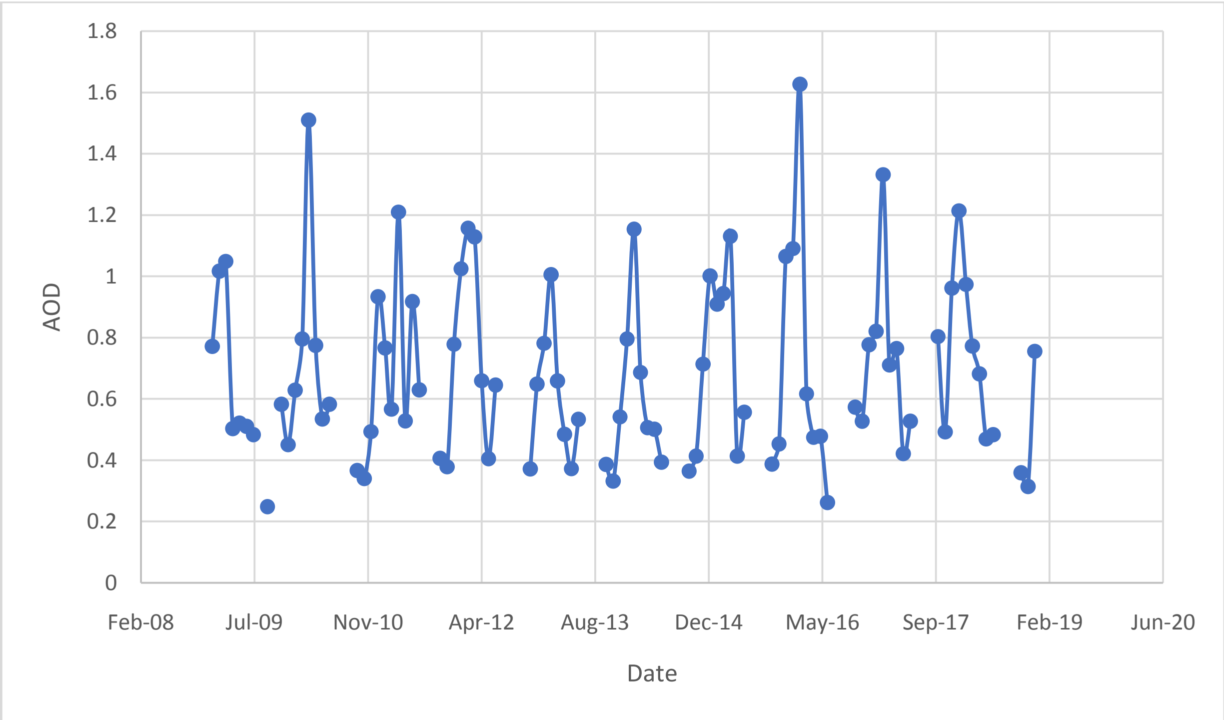

Figure2: Graph of AOD over the study period for Ilorin

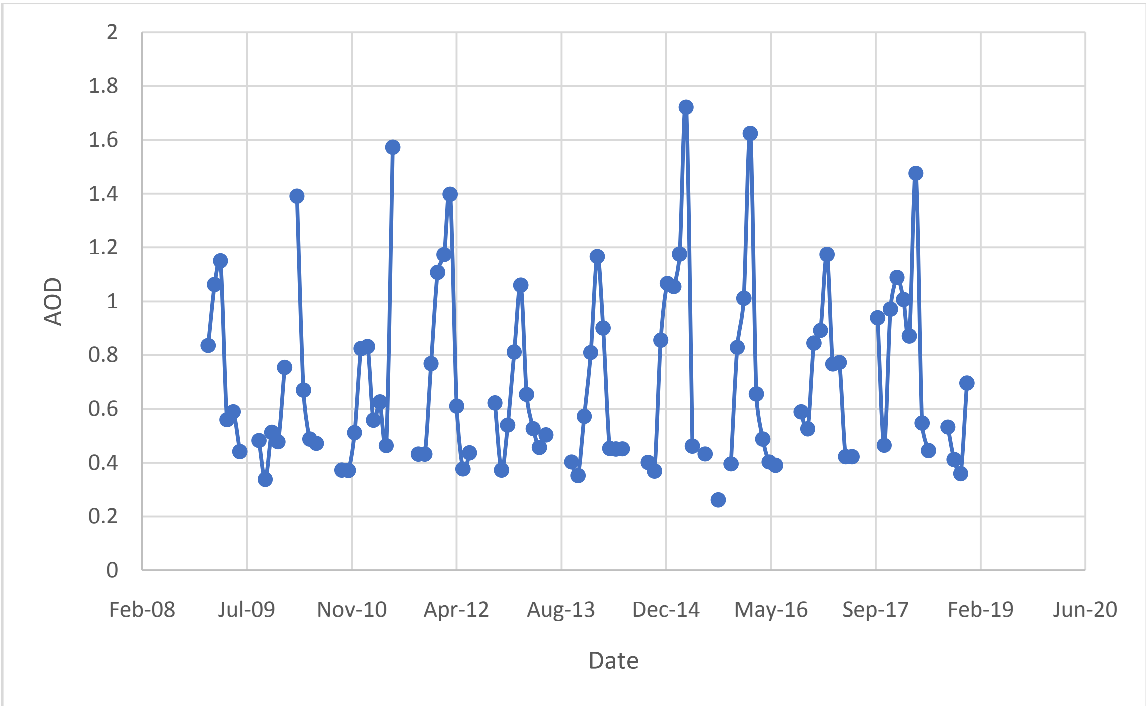

Figure3: Graph of AOD over the study period for Lokoja

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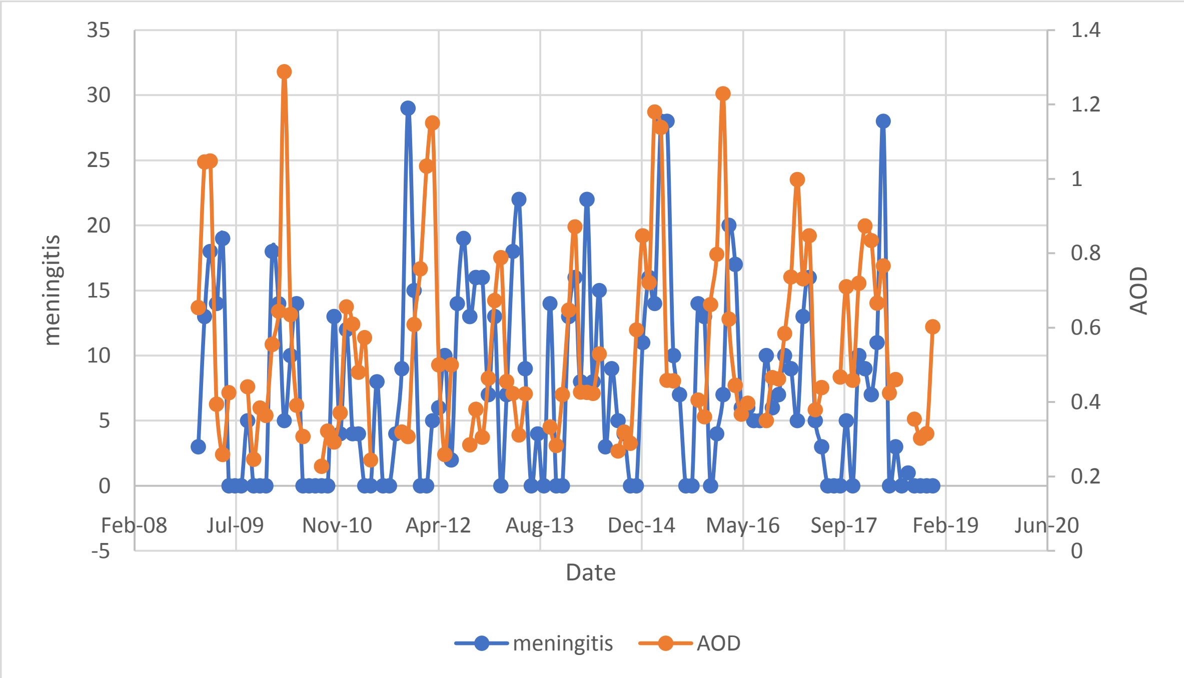

Figure 4: plot meningitis disease incidences and AOD for Minna

3.2 Discussion

Correlation coefficient of 0.06 and 0.08 for Ilorin and Lokoja respectively indicate a very weak positive linear correlation between meningitis and AOD for both Ilorin and Lokoja. Minna (0.21) Minna shows a weak positive linear relationship, which is somewhat stronger compared to Ilorin and Lokoja.

The p-value for Ilorin, 0.56, is high (greater than the conventional significance level of 0.05), suggesting that the relationship observed could be due to random chance. The predictors in the model may not be statistically significant. Lokoja's p-value, 0.40, is also high, indicating that the relationship observed may not be statistically significant, and the predictors in the model may not be providing meaningful information. The p-value for Minna, 0.04, is below the 0.05 significance level, suggesting that the relationship observed is more likely to be statistically significant. The predictors in the model may have some significance in explaining the variability in the dependent variable.

The accuracy of the outputs of the above correlation results was however affected by too many missing values observed in the aerosol optical data which led to the significant reduction in the data used for the correlation analysis, but the positive and statistically correlation coefficients obtained for Minna is expected as particle size measurement shown that t Minna has the highest volume of both $PM_{2.5}$ and PM_{10} as presented in table 2. Dust has been reported to play a vital role in the transportation of pathogen, and when inhaled y human could lead to infections that are potentially responsible to the microorganism in the dust. When dust particles are also inhaled, they could cause irritation to the respiratory track due to the presence of both PM2.5 and PM10. Heavy metals present in harmattan dust has been linked to an increase in cardiovascular disease and mortality, either alone or in mixes (Flemming et al., 2013; Valdes et al., 2012). Heavy metal detected in my analysis include arsenic, lead. According to WHO, 2013, damage of the nasopharyngeal mucosa in humans as a result of high harmattan winds which often carry a lot of particulate matter, predisposes people to the risk of Meningitis.

Figures 1, 2, and 3 show the trend of AOD over time where it was observed that AOD maintain a relatively higher values during the months of December, January, February, and March, the periods that are characterized by high concentration of Sahara dust. From figure 4, the plot showing the relationship or pattern of meningitis and AOD, it could be observed as well that the meningitis disease incidences usually peaks while the AOD are high in Minna. The graph showing relationship between meningitis disease incidences and AOD was only plotted for Minna location because it is the only location among the three study areas where the correlation between the two variable is statistically significant. Therefore, dust has established a relationship with AOD

IV. CONCLUSION AND RECOMMENDATION

In this study, the relationship between dust and meningitis diseases incidences was assessed by using AOD as proxy for dust, determine the dustparticle sizes with intent to finding the presenceand distribution of the harmful particulate matters such as $PM_{2.5}$ and PM_{10}. Limited studies have assessed the impact of dust on meningitis seasonality in Nigeria, and to the best of our knowledge, none of these studies included north central Nigeria despite the fact that meningitis diseases incidences are being reported in the hospital in this region of the country.

This study shows that harmful particulate matter such as $PM_{2.5}$ and PM_{10} are contained in dust samples collected during harmattan, and unevenly distributed across the study areas with Minna having the highest proportion of both $PM_{2.5}$ and PM_{10}. The Pearson correlation conducted to access the quantitative relationship between dust and meningitis using AOD as proxy for dust shows aweak positive coefficient in Minna, which also has the highest proportion of both $PM_{2.5}$ and PM_{10}, this could be due to the presence of high proportion of dust in the region.

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