FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 4 No. 3, September, 2020, pp 481 – 488
DOI: https://doi.org/10.33003/fjs-2020-0403-415

IMPACT OF DUST PARTICLES ON AIR QUALITY AND ASSOCIATED HUMAN HEALTH IN ILORIN NIGERIA

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ABSTRACT

To improve our understanding of the impact of desert dust on human health, there is need to constantly monitor and examined the dust related phenomena. Therefore, twenty 20 year's (1998–2018) data of visibility for Ilorin Nigeria were used to estimate the concentrations of the Total Suspended Particles (TSP) and Particulate Matter PM_{10} as usually used to monitor air quality on international level. The results established the threshold for daily concentration of TSP (254) and PM_{10} (186) μgm^{-3} at the study sites. It also identified months (November-March) of the following year with the greatest number of days having low air quality (high concentration of TSP and PM_{10}). These months are responsible for 47% of the annual air pollution and number of days above the US EPA-NAAQSTSP, US EPA-NAAQS PM10 as well as the 24-hour EU-LVAQ regulations, respectively. Furthermore, some considerable numbers of days were found to experienced hazardous atmospheric condition for the total number of days, Harmattan and summer respectively. The concentrations of PM_{10} (0-54 μgm^{-3}) showed absence of good air quality throughout the period of study. Even though, there were significant number of days associated with moderate air quality most of which occurs during summer. Consequence of which can lead to increased respiratory symptoms and aggravation of lung diseases. It was also observed that, the concentrations of TSP and PM_{10} start of build up in the atmosphere by October, reaching peak in December and January before it decline by April and remain low with almost uniform values until September.

Keywords: Harmattan, Human health, Ilorin, Particulate matter, Summer.

INTRODUCTION

In recent years, mineral dust aerosol has become one of the major topics in environmental studies (Balarabe et al., 2015). The locations of the key regions of dust aerosol, emission into the atmosphere and their distributions are not evenly distributed over the surface of the earth (Prospero et al., 2002). The areas of intense dust aerosol production, emission as well as their characteristics have been previously identify (Prospero et al., 2002; Washington et al., 2003; Ginoux et al., 2004 & 2012; Tanaka & Chiba, 2006; Goudie, 2014). Globally, Sahara-Sahel region of Africa was identified as the biggest and most active dust sources. The region is characterised by the highest mean Total Ozone Mapping Spectrometer Aerosol Index (TOMS AI) value which revealed high concentration and active dust emission. The global dust emission ranges between 1000 and 3000 $Tgyr^{-1}$ in which Sahara-Sahel contribute between 500 to 1000 $Tgyr^{-1}$ and more than half originates from West-Africa (Li et al., 2005; Kellogg and Griffin, 2006; Goudie, 2014). The authors also revealed that the Bodele Depression is the world's largest and active source of dust particles not only in the Sahara but globally (Balarabe et al, 2015).

Dust aerosols are injected into the atmosphere and its major concentration is found in the troposphere (Balarabe et al., 2016; Karimian et al., 2016). The dust particles have been regarded as the most abundant aerosol in the atmosphere globally (Balarabe et al., 2016). It is also the largest contributor of aerosol particles in the western Sahel (Nigeria inclusive) (N'TchayiMbourou et al., 1997). The aerosol is usually uplifted into the atmosphere and travel hundreds of kilometres from their sources, before falling to the ground. The transportation of dust aerosol from Sahara is a function of the season (Harmattan and summer). During Harmattan (November-March), dry wind is one of the major atmospheric phenomena in West Africa (Uduma and Jimoh, 2013) which is later replaced by Summer (April-October) that is characterized by the wet wind which comes along with rainfall and reduced the aerosol concentrations from the atmosphere (Balarabe et al., 2015, 2016 and 2019). During Harmattan, dust storm activities in the FayaLargeau (the Bodele depression) in Chad Basin and Bilma area uplift large amounts of dust into the atmosphere (Uduma and Jimoh, 2013), which is then carried by the North-easterly trade winds. Such aerosols particles cause a serious health threat in its capacity to promote cardiopulmonary diseases, cardiovascular disease, pulmonary inflammation, respiratory infection, cancers of the lung, and other ailments (Pierre et al., 2006), it also affects visibility and climate of a region. High concentrations of mineral particulate matter (PM_{10}) and Total suspended particles (TSP) are associated with morbidity and mortality. An increased in respiratory diseases and mortality of 7.77% and 4.92% had been reported by Chen *et al.* (2004) during Mongolian dust outbreaks in Taipei, Taiwan where 10 μgm^{-3} increase in PM_{10} was associated with 1.12% increase in respiratory diseases and 0.72 increase in mortality. Furthermore, African dust has also been associated with increased pediatric asthma, and emergency admission in the Caribbean island of Trinidad (Gyan*et al.*, 2005).

The effects dust aerosols causes is generally a function of the size distribution of the particles. Adeyefa et al. (1995) has shown that during the Harmattan of 1976-1979, the median size of aerosol decreased from the source region (around Lake Chad) from 74.3 µm to 8.9 µm in Kano. Oluwafemi (1988) had shown that in Lagos during Harmattan, the concentration of dust particles ranging from 0.1 to 1 µm in size is about six times higher than the size range > 1 µm. In contrast closer to the Sahara, bigger particles (diameter > 1 µm) are more predominant and account for 75% or more of the extinction of solar radiation. Despite the position of Nigeria in sub-Sahara West Africa (Balarabe et al., 2015), where dust aerosol pollution is a familiar phenomenon, with increased occurrence of hazy days which require global and regional attention. Surprisingly, very little number of studies was carried out on air pollution in Nigeria largely due to a lack of data of ambient air quality levels near the Saharan dust sources regions (Pierre et al., 2006). Therefore, based on the available horizontal visibility data, this work aimed at estimating the Total Suspended Particles (TSP) and particulate matter (PM_{10}) concentration at Ilorin Nigeria and also to compare with air quality standards from various sources. This will helps to assess the environmental effects of air pollution in the study region. Considering the fact that Ilorin located in the Northern zone of Nigeria with a rapid increase in population which may likely be confronted with severe challenges of air quality management.

DATA AND METHODOLOGY

Data

The hourly visibilities and 18 other meteorological data for 20 years (1998–2018) were downloaded from the NOAA-NCDC database. According to Hussar et al., (2000), NOAA-NCDC managed about 8000 stations worldwide. The Ilorin meteorological station is one of the 33 out of about 54 operational stations in Nigeria with at least 75% continue observations for the period under study (Engelsteadter et al., 2003). The downloaded data file was in simplified and advanced format.

Data processing

The meteorological data files were originally in ASCII and then imported into Excel spreadsheet for analysis. Visibility data was documented in miles and was converted to kilometres in accordance with the international standard. For the study station, the hourly visibility was arranged January–December, and the series of daily average was computed. It was filted and spurious values were removed after which the Total Suspended Particles (TSP) was estimated from the visibility data using the equations

$C_{TSP} = 1897VV^{-0.91}$ Bertrand, (1976) (1)

$C_{TSP} = 1339.84VV^{-0.67}$ Ben mohamed et al., (1992) (2)

Here, C_{TSP} represent the concentration of TSP in μgm^{-3} and VV represent the horizontal visibility in km. Bertrand, (1976) established the first relationship between TSP and visibility using visibility data in the range of 1.5 to 12 km for three years (1973 to 1975) at Niamey Niger. The other equation was later introduced using 17 months visibility data in the range of 100 meters to 20 km from seven stations in Niger Ben Mohamed et al., 1992 .

While the particulate matter PM10 was calculated using

$CPM10 = 914.06VV^{-0.73} + 19.03$ (D'almeida, 1986) (3)

D'almeida the only researcher to have established a relationship between horizontal visibility and PM10 concentration using visibility data in the range of 200 m to 40 km at eleven synoptic stations mainly located in southern Sahara for the period of two years (1981 and 1982). It was observed that for a given visibility, the estimated concentrations of TSP using these two equations show slight variability ranging from 642 to 698 µg.m3 for horizontal visibility reduced to 3 km, and from 439 to 456 µg.m3 for horizontal visibility reduced to 5 km (Ozer et al., 2002). These small variations was associated with the different methods of sampling of concentrations in TSP and the number of data used to establish relationships.

Using the two equations, both the TSP and PM_{10} were calculated for the daily (average corresponding days (366) in a year for 20 years), Harmattan and summer over the entire study period. The percentage frequency of occurrence of TSP and PM_{10} were analyzed and compared with the USA standard provided in Table 1.

Table 1 US EPA Air Quality Index (AQI), 24-hour PM_{10} (μgm^{-3}) concentration, and health effects

AQI category	AQI values	PM10 (μgm^{-3})	Health effects
Good	0–50	0-54	None
Moderate	51−100	55-154	None
Unhealthy for sensitive groups	101-150	155-254	Increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma
Unhealthy	151-200	255-354	Increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma; possible respiratory effects in general population
Very Unhealthy	201-300	355-424	Significant increase in respiratory symptoms and aggravation of lung disease, such as asthma; increasing likelihood of respiratory effects in general population
Hazardous	>300	>424	Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population

RESULT AND DISCUSSION

The concentrations of daily particulate matter due to dust particles

Figure 1 shows the mean daily TSP and PM_{10} concentrations at Ilorin Nigeria for 20 years (1998–2018). It is observed that even when the two equations for estimating TSP were applied for the estimation of the parameter over a longer period (20 years) involving large data set, the two equations produced results of significant relationship. This is also true with what is observed in the PM_{10}. The dark and light green horizontal lines show the established threshold for daily concentration of TSP(254) and PM_{10}(186) μgm−3 at the study sites inline with Bertrand, 1976 and Ben Mohamed et al., 1992 for TSP and D`Almeida, 1986. This implies that each can be adopted as the perfect criteria for monitoring air quality in the study region. The results established that, the maximum number of days with low air quality occurred from November to March of the following year. These months are responsible for 47% of the annual air pollution and number of days above the US EPA-NAAQSTSP, US EPA-NAAQS PM10 as well as the 24-hour EU-LVAQ regulations, respectively. The concentrations of TSP and PM_{10} were extremely high on January 3rd, 12thand 13th as well as December 23rd – 29th ranging from 379.4-465.1 μgm−3 and250.2-307.6 μgm−3, respectively. Such very high concentrations are in line with what was previously observed in different regions of the world during thick dust storms. Daily atmospheric particulate concentrations of 13,735μgm−3 were reported during a thick dust haze in the inland Niger delta region of central Mali (Gillies et al., 1996). Chung *et al.*, (2003a) reported a daily TSP concentration greater than 4000 μgm−3 in an explosive dust storm in Beijing, China. In another development, Chung et al., (2003b) recorded a daily PM_{10} concentration of 1779 μgm−3 in Chongwon-Chongju, Korea. Furthermore, PM10 concentrations above 1000 μgm−3 were recorded during dust storms in Beijing (Fang *et al.*, 2003). Finally, PM_{10} air concentrations exceeding 1800 μgm−3 was measured in Kuwait during severe dust storms (Draxler*et al.*, 2001).

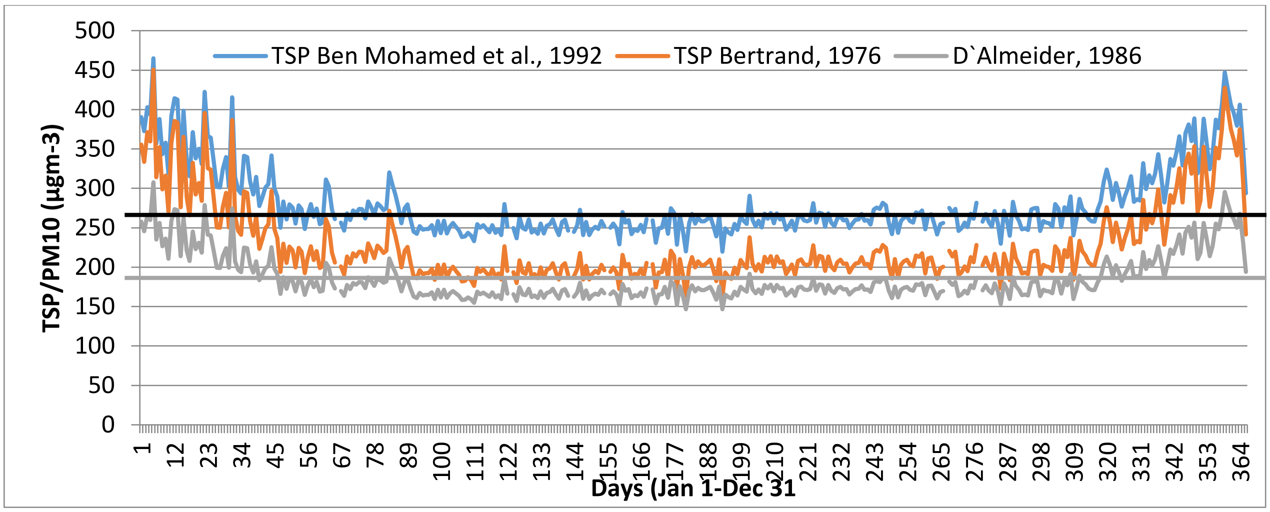
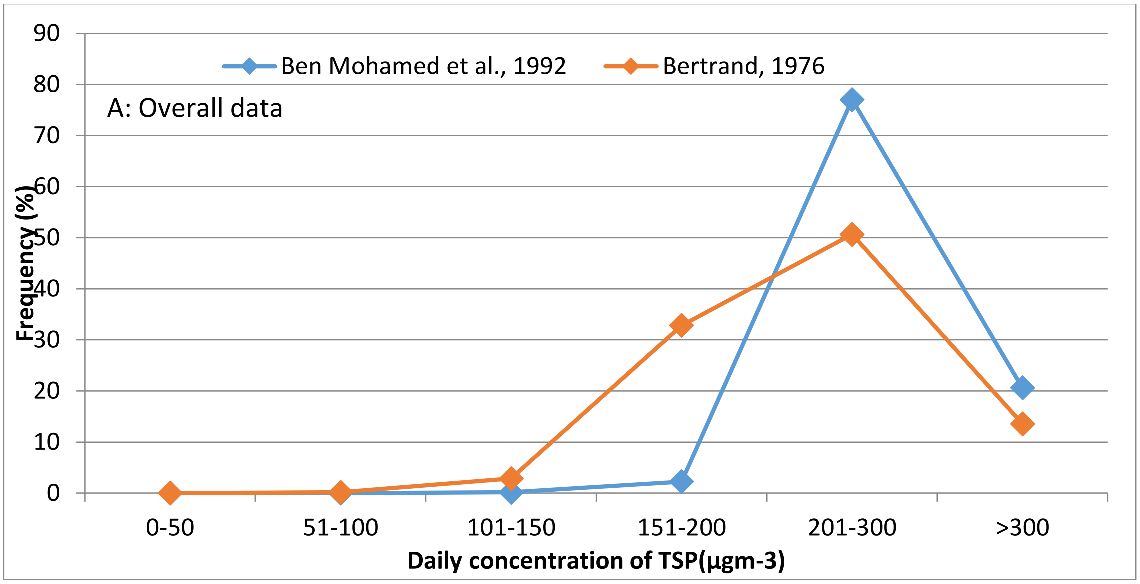
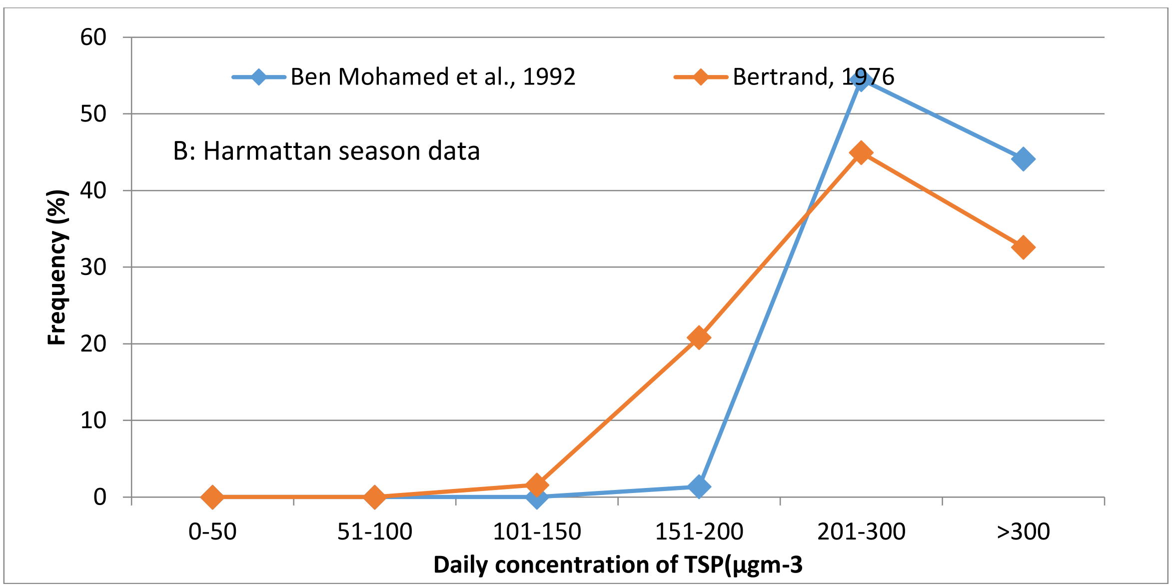


Figure 1: Variations of estimated daily mean concentrations of TSP and PM10 (μgm−3) due to Saharan dust events at Ilorin Nigeria from (1998–2018)

Frequency distribution daily TSP and PM_{10}

The frequency of occurrence of the number of days with TSP for overall, Harmmatan and Summer is presented in Fig. 2 A B, and C. While figure 3 revealed the distribution of the number of days with PM_{10}. From the result, and for the twenty years under study, there is no any day with TSP concentration from 0 to 100 μgm−3 range which could represent good and moderate air quality without any health effects. This implies that Air quality deteriorated during the entire 20 years corresponding to different health effects.There were only 5 (0.2%) days when the concentration of the TSP ranged between 101-150 μgm−3,which is considered unhealthy for sensitive groups, 75 (2.3%) days in the range of 151-200 μgm−3 unhealthy. The greater number of days (77% of the total days) (Fig. 2A), (55% of the Harmattan days) (Fig. 2B) and (91.3% of the summer days) (Figure 2C) fall within the range (201-300) μgm−3 of which the concentration is considered as very unhealthy. Consequence of which can lead to increased respiratory symptoms and aggravation of lung diseases. Furthermore, some considerable number of days was found to experienced hazardous atmospheric condition and these constitute 21% (Fig. 2A), 44% (Fig. 2B) and 6% (Figure 2C) for the total number of days, Harmattan and summer respectively. Under these conditions, people might be exposed to serious risk of respiratory and lung disease, such as asthma.


Ben Mohamed et al., 1992
Bertrand, 1976
A: Overall data
Frequency (%)
0
10
20
30
40
50
60
70
80
90
0-50
51-100
101-150
151-200
201-300
>300
Daily concentration of TSP(µgm-3)


Ben Mohamed et al., 1992
Bertrand, 1976
B: Harmattan season data
Frequency (%)
0
10
20
30
40
50
60
0-50
51-100
101-150
151-200
201-300
>300
Daily concentration of TSP(µgm-3

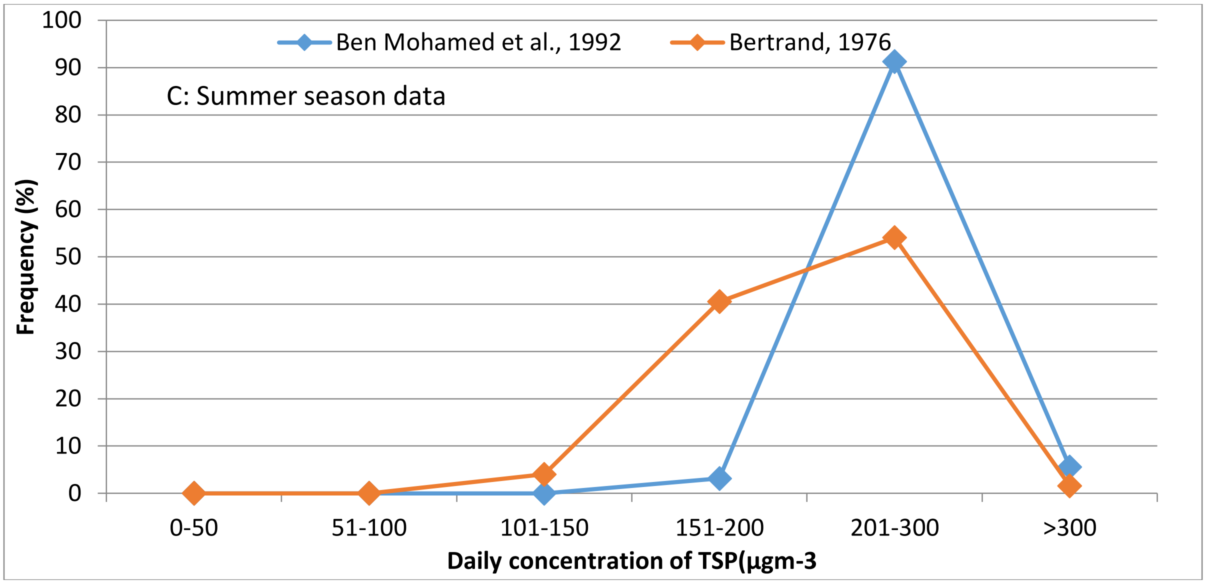


Fig. 2: Distribution of the number of days with selected pollution gradients (μgm−3) in TSP (A: Overal; B: Harmattan; C: Summer)

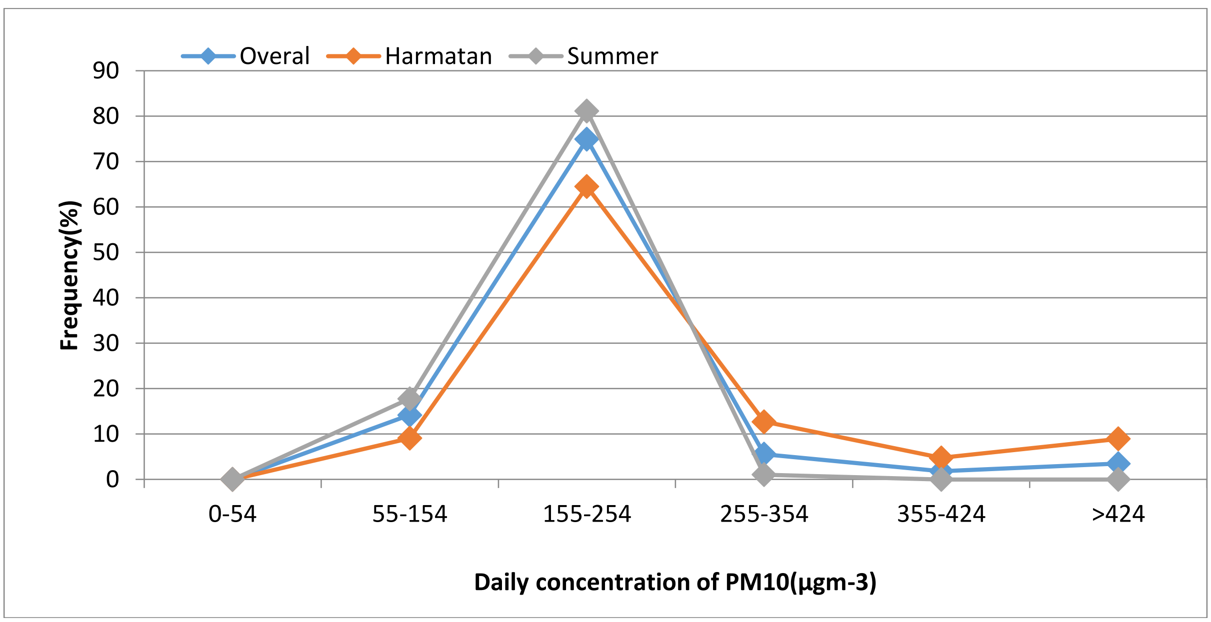


Fig. 3: Distribution of the number of days with selected pollution gradients (μgm−3) in PM_{10}

Similarly, for PM_{10}, good air quality (0-54 μgm−3) is also absent throughout the period of study (Figure 3). Even though, there were some significance number of days (473 days; 14.2%) with moderate air quality (PM_{10} 55-154 μgm−3) most of which occurs during summer (17.8%) when precipitation has washed down significant amount of particles from the atmosphere. Moreover, most of the days fall under the range (155-254 μgm−3) of values when the concentration is considered as unhealthy for sensitive groups (75, 65, and 81%) for the overall, Harmattan and summer respectively. Even though, some significant numbers of days were found to experienced concentrations for unhealthy, very unhealthy and hazardous conditions of the atmosphere but mostly during Harmattan period. When compared with the threshold of daily PM_{10} concentrations contained in the EU-LVAQ, the number of polluted days is 100% times greater than the number of allowed days with >50 μgm−3, and 100% times higher than the legislation on air quality as there is no day with PM_{10} concentration below 50 μgm−3, and the projected 20 μgm−3, by the year 2010. A total of 86% of the days were therefore likely to affect human health in the study region because of the high frequency of mineral dust processes.

Monthly and seasonal concentration of TSP and PM10 due to dust particles

Figure 3 revealed the results of the mean monthly TSP and PM_{10} concentrations owing to mineral dust processes. From the graph, by October of every year, the atmosphere starts to deteriorate due to the presence of aerosol concentration that begins to build up. From November to February, STP and PM_{10} increases further with peak values in December and January (371.7, 396.6 μgm−3) and (246.0, 262.7 μgm−3) for TSP and PM_{10} respectively. They remain high in the atmosphere through March and start to decline by April (247.3 and 164.1 μgm−3) in TSP and PM_{10}due to the commencement of rainfall. The concentration remains low with almost uniform values until September which correspond to the minimum values (258.4 and 171.2 μgm−3) in TSP and PM_{10} before the cycle repeats itself in October. The maximum number of month with low air quality (high concentration of TSP and PM_{10} occurred from November to March of the following year which constitutes 94.1% of the unhealthy, very unhealthy and hazardous conditions of the region.

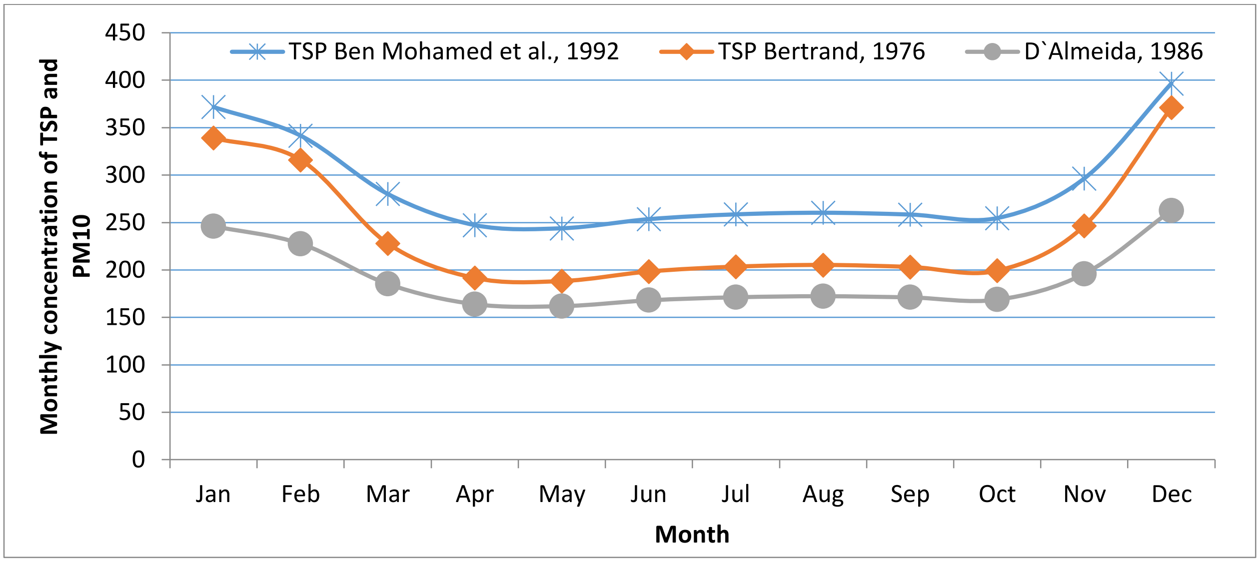


Figure 2: Variations of estimated monthly mean concentrations of TSP and PM_{10} (μgm−3) due to Saharan dust at Ilorin Nigeria from (1998–2018)

Similarly, a monthly pattern of estimated TSP and PM_{10} concentrations has been reported in Niamey, Niger, and Nouakchott-Mauritania in which the January to March period represents 65% of annual mineral dust air pollution, with monthly values in the range of 230 to 330 μgm−3 (TSP) and 160-200 μgm−3 (PM10) (Ozer, 2005). Moreover, high monthly concentration of PM10 (100-200 μgm−3) were recorded in Iraq, Kuwait and Saudi Arabia during the dust season (Draxler*et al.*, 2001). On the Aral Sea shore, the concentration of monthly PM10 (400 μgm−3) were reported in August (Wiggs*et al.*, 2003). The yearly annual average of TSP and PM10 was 289 and 191 μgm−3.

CONCLUSION

In this work, visibility data at Ilorin Nigeria for 20 years (1998–2018) was used to estimate the concentrations of TSP and PM_{10} as usually used to monitor air quality globally. The results were compared with the guideline levels of atmospheric pollutants recommended by the WHO, EU and USA AQI. It was observed that application of Bertrand, 1976 and Ben Mohamed et al., 1992 for TSP for estimating TSP over a longer period (20 years) involving large data set, produced results of significant relationship. Therefore, the threshold for daily concentration of TSP (254) and PM_{10} (186) μgm−3 at the study sites were established. The results also established that, the highest number of days with low air quality (high concentration of TSP and PM_{10}) occurred from November to March of the following year. Furthermore, some considerable number of days was found to experienced hazardous atmospheric condition for the total number of days, Harmattan and summer respectively.

Considering the daily $PM_{10,}$ good air quality (0-54 μgm−3) is absent throughout the period of study. Even though, there were some significance number of days with moderate air quality most of which occurs during summer. Moreover, compared to the threshold of daily PM_{10} concentrations established by the EU-LVAQ, the number of polluted days is 100% times greater than the permitted number of days with >50 μgm−3, as there is no day with PM_{10} concentration below 50 μgm−3, and the projected 20 μgm−3.
Furthermore,it was observed that by October of every year, the atmosphere starts to deteriorate and the aerosol concentration further increases from November to February with peak values in December and January respectively. They start to decline until September.

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