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The Analysis of Influence of Weather Conditions on Atmospheric Extinction Coefficient over Bauchi, North Eastern Nigeria

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Abstract Weather conditions are natural causes of visibility deterioration and increase in atmospheric extinction coefficient at a place. A 10- year dataset (1998-2007) of visibility and meteorological parameters such as Relative Humidity, Temperature and Atmospheric Pressure measured every 3-hour daily were analysed to examine the dependence of Atmospheric Extinction Coefficient, β_{ext} on seasonal meteorological conditions and synoptic weather patterns in Bauchi, a City in the North-eastern-Nigeria. From the visibility data obtained, the corresponding atmospheric extinction coefficient (β_{ext}) for the period under review was computed by using the Koschmieder relationship. In year 2000, when the Relative Humidity and atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ are highest, the temperature and visibility values are lowest. In 2003, when temperature (29.82°C) is highest, the Relative Humidity (42.52%) is lowest, although, the atmospheric coefficient was not at its lowest neither was the visibility (18.49km) at its highest. Of the years considered, year 2000 has the highest estimated atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ for both raining season and harmattan season. The raining season (June-September) has β_{ext} of 0.267 while the harmattan season has β_{ext} of 0.689. Their respective decadal mean for both raining season and harmattan season for the period under review are 0.205 ± 0.036 and 0.689±0.133.

Keywords: *atmospheric extinction coefficient, weather, visibility, Bauchi*

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1. Introduction

Visibility impairment has become a major public concern in most metropolises in Nigeria, including Bauchi, Bauchi State capital in North-eastern Nigeria. This is usually caused by weather phenomena such as precipitation, fog, mist, haze and dust that are associated with hydrometeor and lithometeor. The term weather describes the state of the atmosphere in terms of air pressure, temperature, humidity, clouds, wind, and precipitation [12]. Meteorological phenomena such as relative humidity and temperature are known to be natural causes of changes in aerosol extinction coefficient and decrease in atmospheric visibility. These meteorological parameters influence visibility through dispersion of aerosols, or by changing their properties or formation and removal rate. Visibility reducing weather phenomena caused by aerosols include precipitation, fog, mist, haze and dust storm. Precipitation is defined as any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground [1], so that it can be easily identified by the observer. Fog is defined as a hydrometeor suspended in the atmosphere near the earth’s surface [1]. Fog reduces visibility below one kilometer. However, the criterion of the relative humidity for fog is not well defined [13]. Mist is defined as a hydrometeor consisting of an aggregate of microscopic and more-or-less hygroscopic water droplets suspended in the atmosphere. Mist produces a thin, greyish vein over the landscape and reduces visibility to a lesser extent than fog. The relative humidity with mist is often less than 95%. Mist is intermediate in all respects between haze and fog [1]. On the other hand, haze is defined as fine dust or salt particles dispersed through a portion of the atmosphere; a type of lithometeor. The particles are so small that they cannot be felt or individually seen with the naked eye, but they diminish horizontal visibility and give the atmosphere a characteristic opalescent appearance that subdues all colors. Haze formations are caused by the presence of an abundance of condensation nuclei which may grow in size to become mist, fog or cloud [1].

The hygroscopicity of atmospheric aerosol represents how particles will behave when exposed considerably to varying relative humidity, RH. [11] proposed that the hygroscopic behavior could be attributed entirely to inorganic content of the aerosol, such as sulfate, nitrate, and ammonium ions. However, less is known about the hygroscopic characteristics of organic aerosols and mixtures of inorganic and organic aerosols. Other factors are the refractive index and shape of the particles, although their effect is harder to measure and is less well understood.

Many Authors have lend credence to the over whelming influences of weather conditions on aerosols' size growth and their contributions to increasing extinction coefficient, as yet, not much research has been done into the relation between weather and visibility deteriorations in Nigeria.

In the study of [9], the growth factor for aerosol diameter varied from 1 to 5.

Also, at a macro level, a temperature is one of factors, which affect the extinction coefficient of aerosol particle. Infact, [5] showed that the temperature, relative humidity and wind speed have an important effect on the extinction of the atmosphere at Qena (Egypt). In their work,

[15] studied air pollutants concentration, meteorological parameters and atmospheric visibility in Delhi during 2006-2011 peak winter season of the years.

In order to study the impact of air pollutants on visibility at IGI airport of Delhi during the winter season (December and January), the daily data of visibility and meteorological parameters like dry bulb temperature, humidity, wind speed, Dew point temperature were collected and a study is carried out to correlate these parameters and air quality in terms of the concentration of CO, NOx, SO_2 and O_3 with the observed visibility. The regression analysis of daily averaged visibility using empirical model demonstrates that higher the concentration of air pollutants (CO, NOx, SO_2, O_3), lower the visibility. Because air pollutants have a significant impact on atmospheric visibility, it is also observed that a targeted reduction of air pollutants in Delhi would improve the visual range. [16] estimated the extinction coefficient due to aerosol by Pyrheliometric and Gorgie type Actinometric measurements in the industrial, urban areas and compared with agricultural areas. The measurements distributed over one year from June 1992 to May 1993 were made under clear sky for five spectral bands. The results show two maxima in hot wet and spring months and minimum in winter months, but there is a fluctuation in urban area. Diurnal variations show maximum at noon especially in the industrial area. Level of extinction coefficient in the industrial and urban area is greater than that of the agricultural area, except for hot wet months is due to the increase of water vapour content in agricultural area. They observed that the temperature and water vapour content have important rules in increasing the extinction coefficient of aerosols.

In this paper, some meteorological parameters such as relative humidity, temperature, pressure and visibility are analysed to ascertain their influence on aerosol scattering extinction coefficients.

1.1. Geographical Location of Bauchi

Bauchi is a city in northeast Nigeria, the capital of Bauchi State, of the Bauchi Local Government Area within that State, and of the traditional Bauchi Emirate. It is located on the northern edge of the Jos Plateau, at an elevation of 616 m and lies on latitude 10.17° North and longitude 09.49° East of equator. The city has a population of 301,284 (2012). The Local Government Area covers an area of 3,687 km2 and had a population of 493,810 at the time of the 2006 Census. It is bordered by seven states, Kano and Jigawa to the North, Taraba and Plateau to the south, Gombe and Yobe to the East, and Kaduna to the West. The State occupies a total land area of 49,359 square kilometers, representing about 5.3 percent of the land area of Nigeria. The state spans two vegetation zones namely the Sudan savannah and the Sahel savannah, rainfall in the state ranges between 600mm and 1000mm per annum in the Sahel savannah. Effective rainy season starts from mid-May or sometime in early June and ends late October. The dry season starts in October and ends in May. This period is characterized by dryness and the presence of harmattan dust haze especially between December and March of the preceding year. In this city, much of the aerosols deposit arises from the dust plume from the Sahara Desert and very little from anthropogenic sources due to very few available and/or operating industries.

1.2. Mathematical Treatment

The extinction coefficient b_{ext} is dependent on the presence of gases and molecules that scatter and absorb light in the atmosphere. The extinction coefficient may be considered as the sum of the air and pollutant scattering and absorption interactions is given as [6]:

$$b_{ext.} = b_{rg} + b_{ag} + b_{scat} + b_{ap} \tag{1}$$

where b_{rg} is scattering by gaseous molecules (Rayleigh scattering), b_{ag} absorption by NO_2 gas, $b_{scat.}$ scattering by particles, and b_{ap} absorption by particles NO_2 gas. Of these, extinction coefficient due to scattering of particle is dominant. However, these various extinction components are a function of wavelength.

The visual range is a function of the atmospheric extinction, the albedo and visual angle of the target, and the observer's threshold contrast at the moment of observation. Values of visual range usually are estimated from the appearance of buildings and special targets at differing distances against the skyline. The formula for the visual range R_V is given as [2]:

$$R_V = \frac{1}{\beta_{sc}} \frac{\ln C}{\varepsilon} \tag{2}$$

where C is the inherent contrast of the target against the background, and ε is the threshold contrast of the observer. To limit the subjective factors and the optional target choice involved in the formula, a black target in specified; its inherent contrast against the background is unity. However, the basic assumptions and limitations are that the sky lightness at the observer is similar to the sky brightness at the object observed, that the pollutants are homogeneously distributed, the viewing distance is horizontal, that the object is large and black and that there is a threshold contrast of 0.02. In 1924, Koschmieder, followed by Helmholtz, proposed a value of 0.02 for ε . Other values have been proposed by other authors. They vary from 0.007 7 to 0.06, or even 0.2. The smaller value yields a larger estimate of the visibility for given atmospheric conditions. The value of ε is selected as 0.02 from [2] contrast thresholds for the human eye. The use of β_{ext} rather than β_{sc} finds justification in that, the amount of attenuation in the atmosphere is often stated in terms of the quantity known as the transmittance T defined by the Lambert- Beer law as

$$T = \exp\left(-\beta_{ext} x\right) \quad (3)$$

where x is the path length and β_{ext} is the total extinction (scattering + absorption).

A simplified relationship developed by Koschmeider which relates visual range and extinction coefficient is given by [6]

$$V_r = \frac{3.92}{\beta_{ext}} \quad (4)$$

where V_r is the distance at which the object is just barely visible.

2. Materials and Methods

2.1. Data Measurement

Visibilty dataset from the Bauchi Airport for a period of ten years, 1998-2007, was obtained and analysed. The method that was used to obtain visibility readings for the period under review was human identification of target objects and landmarks, most especially hills and buildings at known distances in a full 360 degrees circle around the observation point.

The visibility ranges were measured every three hours daily by looking at the target objects and land marks such as: the Warenge hill runway (a location at a distance of 6km from the Bauchi Airport and height 887m), Guru hill runway (2.47 km from Bauchi Airport and of height 687m), Gudun hill runway (3.0 km from Bauch Airport and of height 730m), Zaranda hotel runway (1.6km from Bauchi Airport and of height 678m), and Central Bank of Nigeria building (0.5km and of height 663m). These are the directions which the aircraft takes up or when landing which are at different distances from Bauchi Airport. Figure 1 show the geographical map of Bauchi town.

To understand the effects of weather conditions on atmospheric extinction coefficient, meteorological parameters such as temperature, relative humidity, atmospheric pressure and visibility were measured every 3 hours from an automatic weather station in Bauchi, North-eastern Nigeria for a period of ten years (1998-2008) and these data are employed in this paper.

Temperature data was obtained by using maximum and minimum thermometers, and the daily mean values were recorded in degree centigrade (°C). To get accurate records, a combined maximum and minimum thermometers kept in Stevenson screen raised above the ground to a height of 1.2m was used.

On the other hand, the data of relative humidity was obtained by using a hygrometer. This consists of wet and dry bulb thermometers placed side by side in the Stevenson screen. To take the reading, the dry bulb which is an ordinary thermometer measures the shade temperature. The wet bulb, which is kept wet by a wick that is dipped in a container of distilled water. When the air is not saturated, evaporation, which produces a cooling effect, takes place from the moist wick. The wet bulb always shows a lower reading than the dry bulb. If the difference in the two readings is high, it indicates low humidity. If there is no difference in their readings, it means that the air is saturated and therefore, the relative humidity would be 100%.

The pressure of the study area was measured in millibars by using an instrument called barometer. The barometer works by balancing the weight of mercury in the glass tube against the atmospheric pressure just like a set of scales. If the weight of mercury is less than the atmospheric pressure, the mercury level in the glass tube rises. If the weight of mercury is more than the atmospheric pressure, the mercury level falls.

From the visibility data obtained, the corresponding atmospheric extinction coefficient (β_{ext}) for the period under review was computed by using the Koschmieder relationship as given by equation (4).

The method of data analysis in this work is a common one usually applied to periodic variations of meteorological parameters to show cyclic variations, means and trends [3,7]. To depict the periodic pattern of variation in visibility values the data set was plotted as a time series. The annual values of visibility for Bauchi were obtained from monthly averages which in turn were derived from daily data. The atmospheric extinction coefficient values generated for the various seasons of the years (1998-2007) under review were evaluated for some atmospheric parameters that indicate weather condition such as temperature, relative humidity, air pressure and visibility. The extinction coefficient β_{ext} derived from the use of equation (4) was processed the same way as the visibility in terms of means, seasonal and annual means, and trends.

3. Results

Daily mean values of temperature, relative humidity, pressure and visibility were recorded for each month for the period under review and the corresponding mean monthly values were evaluated and shown respectively in Table 1- Table 4. From these tables, the mean annual temperature, relative humidity, pressure and visibility for Bauchi was evaluated from tables and shown in Table 5.

Table 1. Mean Monthly Temperature for Bauchi in degree Celsius (°C)

Month	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
JAN	22.2	27.3	23.5	21.0	20.5	29.3	26.8	26.0	27.4	25.5
FEB	23.2	30.3	22.0	23.5	24.5	31.5	27.0	29.3	28.7	28.7
MAR	27.9	34.0	27.0	28.0	28.0	32.3	29.0	31.3	29.5	29.1
APR	32.0	34.7	26.0	30.0	29.9	35.3	31.5	31.5	30.8	31.9
MAY	29.0	29.5	31.0	29.5	29.5	34.8	29.8	29.8	28.6	30.5
JUN	29.5	28.5	27.0	26.9	29.0	29.7	27.5	28.0	29.0	28.8
JUL	27.6	26.3	26.0	25.6	26.8	27.7	25.5	25.5	27.0	26.1
AUG	25.3	25.0	25.2	25.0	25.0	27.0	25.8	25.3	25.6	25.0
SEPT	38.1	25.6	26.1	25.4	25.5	29.4	26.5	27.0	26.0	26.1
OCT	31.6	25.5	26.0	26.0	25.5	27.5	28.6	27.3	27.4	27.8
NOV	31.9	24.9	24.6	25.1	25.0	27.9	28.0	26.0	25.7	26.8
DEC	27.5	26.5	27.0	26.9	26.6	25.4	27.0	25.8	20.1	25.3

Table 2. Mean Relative Humidity for Bauchi in Percentage (%)

Month	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
JAN	21.5	29.0	34.5	47.0	27.0	12.9	26.5	20.0	24.5	27.0
FEB	26.0	33.5	32.5	33.5	21.0	17.5	19.0	21.0	26.0	25.5
MAR	28.5	36.0	34.5	19.5	22.0	11.0	18.5	19.5	21.5	24.5
APR	37.5	35.0	44.5	25.5	37.0	32.0	36.0	26.0	27.5	39.5
MAY	50.5	38.0	54.5	34.0	41.5	29.3	52.0	49.0	53.0	47.5
JUN	65.5	50.0	61.5	49.0	55.0	68.0	52.0	62.0	63.5	58.0
JUL	69.0	63.5	72.5	65.0	66.5	72.5	71.0	75.0	71.5	67.5
AUG	72.0	74.5	80.5	72.0	74.5	77.0	75.5	79.0	79.5	73.5
SEPT	70.5	70.5	77.5	65.5	81.0	73.0	73.0	72.0	75.5	66.0
OCT	61.0	60.5	66.5	47.0	68.5	58.5	48.0	54.0	62.5	44.5
NOV	43.5	40.0	61.5	38.0	56.0	34.5	40.0	32.5	37.0	29.5
DEC	34.0	34.0	42.5	29.0	40.1	24.0	22.0	26.5	29.5	23.0

Table 3. Mean Monthly Pressure for Bauchi in Millibars (mb)

Month	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
JAN	946.8	943.5	1010.5	1012.8	1011.5	1010.5	1012.8	1013.7	1012.8	1009.2
FEB	946.2	942.3	1013.5	1010.5	1013.0	1013.0	1010.2	1008.5	1010.0	1009.0
MAR	944.4	940.5	1008.5	1008.6	1009.5	1008.8	1008.7	1007.8	1008.6	1005.6
APR	941.6	939.5	1006.3	1009.0	1007.0	1006.4	1008.4	1005.6	1010.0	1004.4
MAY	942.9	942.3	1008.3	1010.0	1007.8	1008.0	1008.5	1007.8	1007.3	1005.4
JUN	945.0	947.0	1009.4	1009.5	1008.5	1009.2	1009.0	1011.3	1006.1	1012.1
JUL	946.5	949.0	1010.8	1010.4	1009.5	1010.8	1009.6	1012.5	1009.2	1012.6
AUG	947.0	949.5	1010.4	1011.0	1010.4	1010.4	1010.1	1011.7	1009.2	1008.9
SEPT	947.3	950.0	1010.0	1010.0	1011.0	1010.0	1010.4	1012.3	1013.3	1008.9
OCT	943.0	951.0	1010.7	1010.5	1011.3	1010.9	1010.7	1010.8	1007.6	1007.1
NOV	944.8	951.0	1010.3	1011.0	1011.5	1010.7	1012.6	1010.3	1006.1	1007.1
DEC	942.9	954.0	1012.1	1011.5	1010.0	1011.3	1013.1	1012.1	1011.5	1014.9

Table 4. Mean Monthly visibility for Bauchi in kilometres (km)

Month	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
JAN	5.20	14.5	5.20	5.50	5.50	20.0	10.0	9.60	11.5	11.0
FEB	10.5	10.5	5.50	5.20	10.4	9.70	9.50	9.70	11.0	10.5
MAR	10.5	14.5	6.00	9.80	10.5	9.70	9.70	24.5	9.70	10.0
APR	20.0	15.0	14.5	19.5	16.5	25.0	14.5	35.0	20.5	11.0
MAY	20.0	24.0	14.5	19.0	14.5	24.5	29.0	34.5	29.0	14.5
JUN	20.0	16.0	19.0	24.3	20.0	24.0	29.0	29.0	27.0	16.0
JUL	21.5	15.0	14.5	24.0	23.5	23.0	24.0	21.5	24.0	19.5
AUG	15.0	14.5	1.50	23.3	14.5	14.5	10.9	16.0	14.5	15.5
SEPT	15.3	15.0	14.5	24.0	19.5	24.0	21.0	23.0	24.5	17.0
OCT	15.0	19.5	19.5	16.3	19.0	19.5	19.5	20.5	19.5	11.5
NOV	14.5	11.5	0.60	16.5	11.0	17.5	20.5	20.0	16.0	10.5
DEC	9.60	5.20	0.60	16.5	10.5	10.5	15.0	16.5	10.5	10.3

Table 5. Mean Annual temperature, relative humidity, pressure and visibility for Bauchi.

YEAR	**Temp.**	**Humidity**	**Pressure**	**Visibility**
1998	28.78	48.29	944.87	14.76
1999	28.18	47.04	946.63	14.60
2000	25.95	55.25	1010.07	9.66
2001	26.08	43.75	1010.40	16.99
2002	26.32	49.18	1010.08	14.62
2003	29.82	42.52	1010.00	18.49
2004	27.75	44.46	1010.34	17.72
2005	27.73	44.71	1010.37	21.65
2006	27.15	47.63	1009.31	18.14
2007	27.63	43.83	1008.77	13.11

To more clearly show the influence of temperature, relative humidity, pressure and visibility on atmospheric extinction coefficient, Figure 2 - Figure 5 were plotted from their respective annual data. These depict variations that can be compared with the graph of annual variation in atmospheric extinction coefficient which is shown in Figure 6. The annual mean visibility and standard deviation data are shown in Table 6. This table present years 2000 and 2007 as having the yearly mean visibility values of 11.35 and 13.11 with respective standard deviation of 5.38 and 3.23. The values for the yearly mean standard deviation and variance for the period under consideration is shown in Table 6. However, for deeper understanding of the yearly standard deviation and variance of visibility, analysis were carried out for the two prevalent seasons of the year which are the raining season (June- September) and the dry season (November-February) and are presented respectively in tables 7a and 7b. The June-September season of 2004 has the maximum standard deviation of 7.63 while the November-February season of 2000/2001 has the minimum standard deviation of 0.04. Table 8 and Table9 show the computed values of atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ from measured visibility data by applying equation 4.From these Tables, year 2000 has the highest estimated atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ for both raining season and harmattan season. The raining season (June-September) has β_{ext} of 0.267 while the harmattan season has β_{ext} of 0.689. Figure 7 show the variation of atmospheric extinction coefficient for the raining season months of June to September. Their respective decadal mean for both raining season and harmattan season for the period under review are 0.205 ± 0.036 and 0.689±0.133.

Figure 8 show the trend analysis of the visibility for years 1998-2007.

Table 6. Yearly Mean and Standard Deviation of Visibility, V_r

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Average (mean)	14.76	14.60	11.35	16.70	14.62	16.98	16.76	20.15	18.06	13.11
Standard Deviation (S)	5.07	4.57	5.38	6.98	5.24	5.84	5.96	6.54	6.98	3.23
Variance (S^2)	25.71	20.89	28.94	48.72	27.46	34.11	35.52	42.77	48.72	10.43

Table 7a. June-Sept Mean and Standard Deviation for Visibility, V_r

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Average (mean)	17.95	15.13	14.63	23.90	19.38	21.38	21.23	22.38	22.50	17.00
Standard Deviation (S)	3.29	0.63	3.47	0.42	3.71	4.53	7.63	5.34	5.49	1.78
Variance (S^2)	10.84	0.40	12.06	0.18	13.73	20.50	58.27	28.56	30.17	3.17

Table 7b. Nov-Feb. Mean and Standard Deviation for Visibility, V_r

Year	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Average (mean)	9.80	12.28	6.85	5.68	11.35	10.30	11.88	13.08	14.50	12.00
Standard Deviation (S)	3.62	2.60	3.10	0.04	4.45	0.57	2.64	4.14	4.56	2.68
Variance (S^2)	13.10	6.76	9.61	0.16	19.80	0.33	6.33	17.14	20.79	7.18

Table 8. Variability in atmospheric extinction coefficient, β_{ext} (June-sept) in Bauchi

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	decadal	mean
β_{ext}	0.218	0.259	0.267	0.164	0.202	0.183	0.184	0.175	0.174	0.230	0.205±	0.036

Table 9. Variation in Harmattan season (November- February) Atmospheric extinction coefficient, β_{ext} in Bauchi (97/98-06/07)

Year	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	decadal	mean
β_{ext}	0.399	0.319	0.571	0.689	0.345	0.380	0.329	0.299	0.270	0.326	0.393±	0.133

Figure 1. Geographical Map of Bauchi

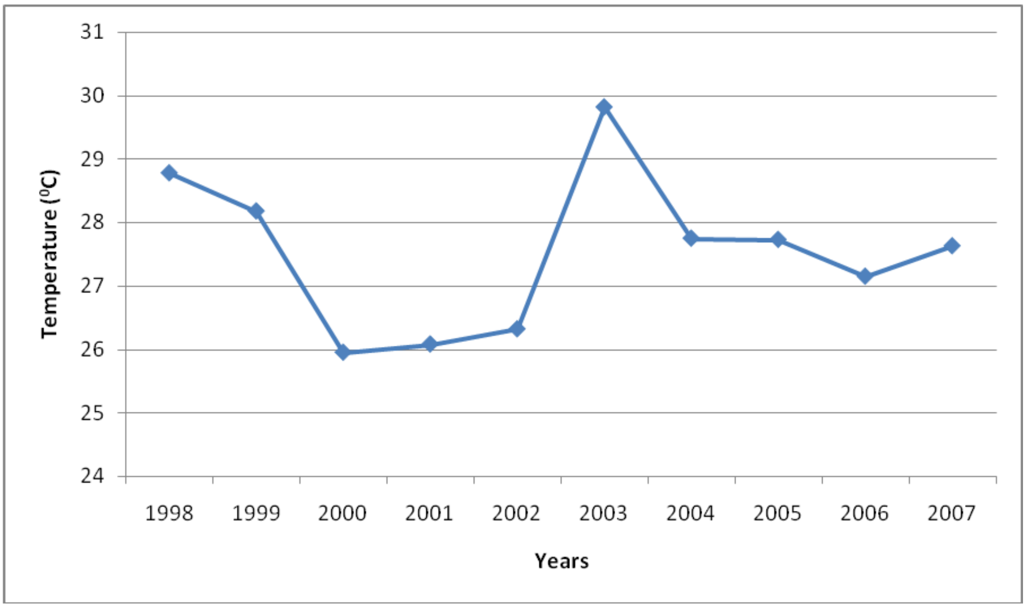

Figure 2. Variation in temperature (^{0}C) in Bauchi for 1998-2007

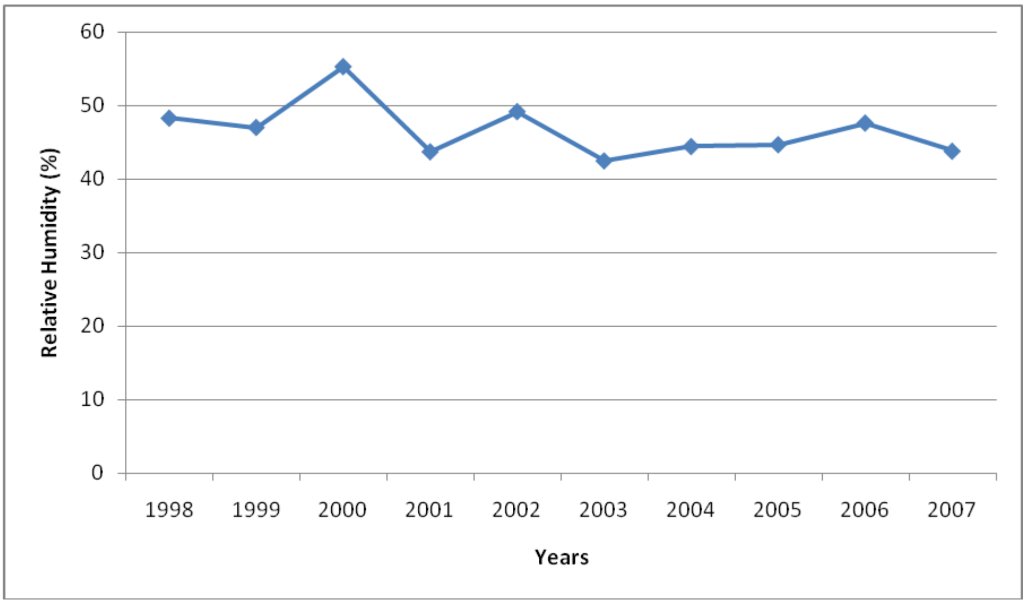

Figure 3. Variation in Relative Humidity (%) in Bauchi for 1998-2007

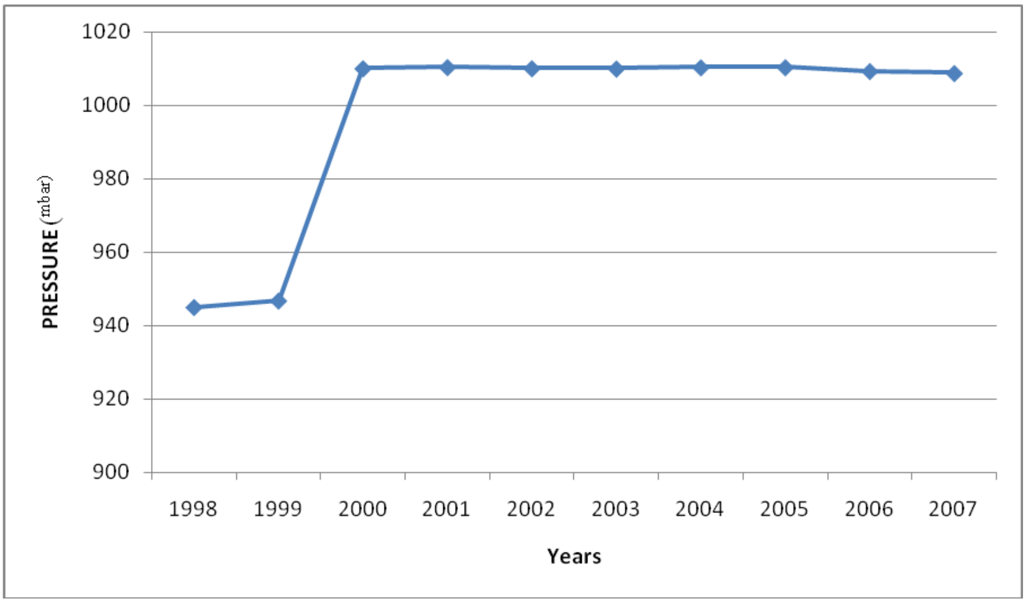

Figure 4. Variation in Pressure (mbar) in Bauchi for 1998-2007

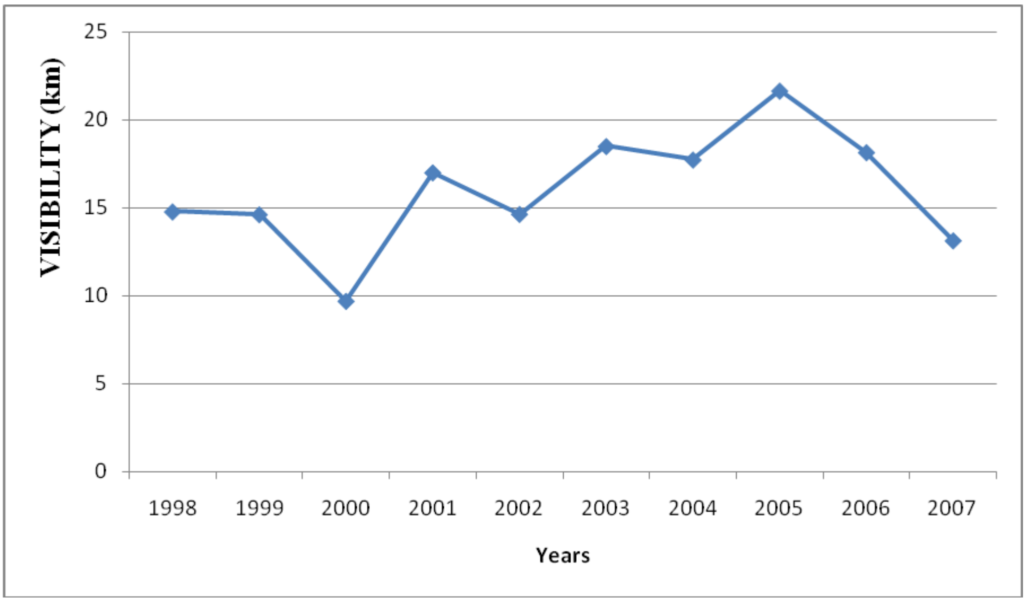

Figure 5. Variation in Visibility (km) in Bauchi for 1998-2007

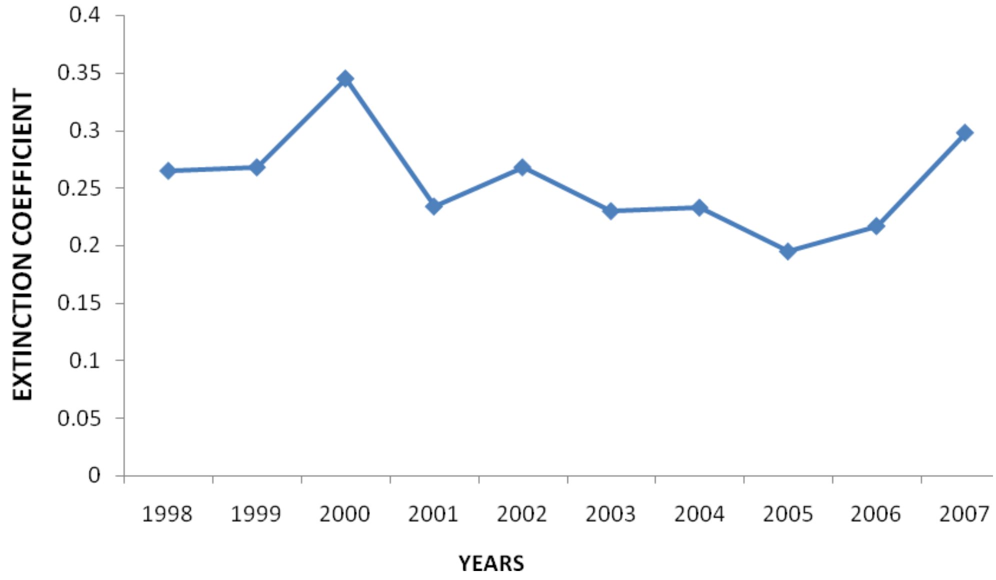

Figure 6. Variation of Atmospheric Extinction Coefficient in Bauchi (1998-2007)

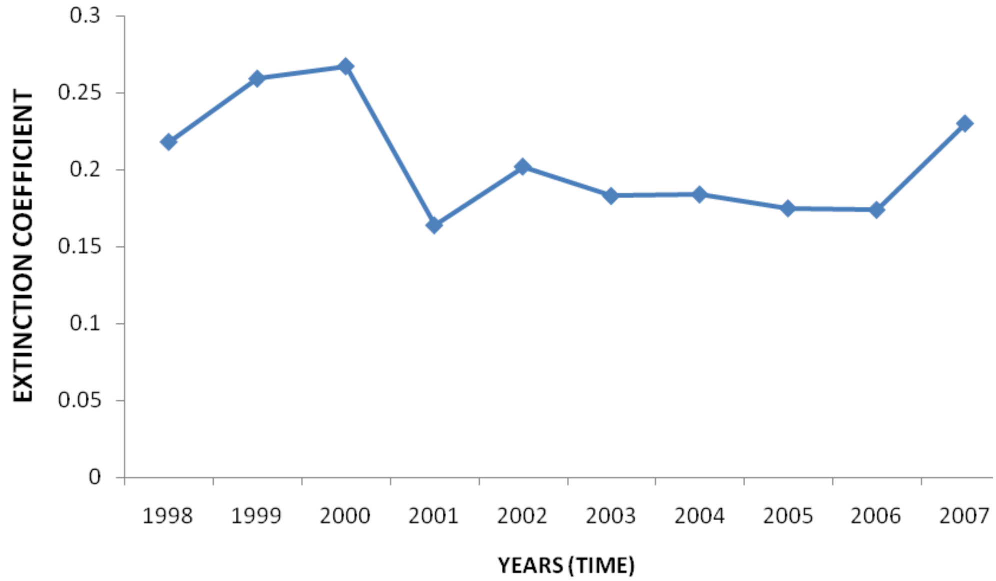

Figure 7. Variation of Atmospheric Extinction Coefficient (June-Sept) in Bauchi (1998-2007).

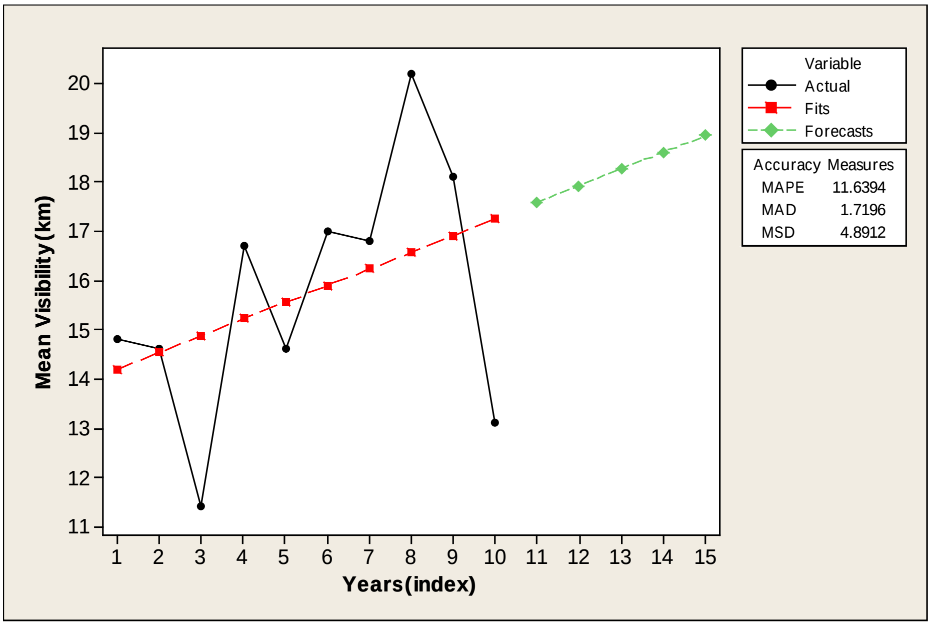

Figure 8. Trend analysis of visibility for Bauchi (1998-2007)

4. Discussion

It is found that high concentration of aerosols in the atmosphere decreases the visibility, which is an important weather indicator. Since ambient aerosol particles experience hygroscopic growth at enhanced Relative Humidity, their microphysical and optical properties especially the aerosol light scattering are also strongly dependent on Relative Humidity. Soluble particles will take up water as Relative Humidity (RH) increases, resulting in increased particle size and mass; this, in turn, affects the aerosol refractive index, light scattering properties, and atmospheric visibility ([8,9]). With increasing RH, an aerosol phase transformation from solid to solution will occur when the Relative Humidity reaches the deliquescence relative humidity, which is governed primarily by the chemical composition of the aerosol particles ([4,14]). Hence, Relative Humidity has important rules in increasing the extinction coefficient of aerosols as clearly depicted by Figure 3. Comparing Figure 2, Figure 3, Figure 5 and Figure 6 shows that in year 2000, when the Relative Humidity and atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ are highest, the temperature and visibility value are lowest. In 2003, when temperature (29.82°C) is maximum, the Relative Humidity (42.52%) is minimum, although, the atmospheric coefficient was not at its minimum neither was the visibility (18.49km) at its maximum. This suggests that although Relative Humidity and Temperature are necessary and indispensible weather parameters in investigating atmospheric extinction coefficient, they are not sufficient since there may be other factors which are equally strong determinant. These parameters may be wind, pressure or cloud cover. In year 2000, the atmospheric pressure (1010.07mbar) was fairly high just as the Relative Humidity (55.25%) and atmospheric extinction coefficient while the corresponding values of temperature (25.95°C) and visibility (9.66km) are lowest. The value of the atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ tends to decrease with increasing air pressure, and increase with increasing air temperature. The highest extinction tends to occur at high temperature and low air pressure.

The role of temperature as a factor influencing the atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ is difficult to perceive because of the many routes by which temperature dependence may be exerted. Even coarse examination of the existing historical database reveals that major qualitative changes have occurred in the temperature dependence of haziness.

5. Conclusion

The Saharan dust laden atmosphere during the harmattan attenuates visible solar radiation much stronger than do hydrometeors in the raining season. The value of the atmospheric extinction coefficient, $\boldsymbol{\beta_{ext}}$ tends to decrease with increasing air pressure, and increase with increasing air temperature. The highest extinction tends to occur at high temperature and low air pressure.

Also, at higher relative humidity, both the strengthened hygroscopic growth and the more efficient oxidization (of the precursor gases and formation of the secondary sulfate and nitrate) contribute to the increase of the mass fraction of the hygroscopic species, which consequently results in the increase of the atmospheric extinction coefficient.

It can be concluded that temperature and humidity have the significant role of increasing the aerosol mass concentration and thus the atmospheric extinction, $\boldsymbol{\beta_{ext}}$. However, the identification of specific aerosol sources of haze over the different parts of the world is inherently a difficult task.

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