ISSN: 2634 - 8845

Journal of Earth and Environmental Sciences Research

SCIENTIFIC Research and Community

Review Article

Open Access

The Impact of Saharan Dust on Visits to Clinics in Antigua and Barbuda for Acute Respiratory Infections

Adelle AC Blair

Lightfoot West, St. George's Parish, Antigua, West Indies

ABSTRACT

At present there is no assessment of the health impacts of Saharan dust in Antigua and Barbuda. A retrospective study was conducted to determine the association between Saharan dust particles along with other climatic variables and visits to the clinics for acute respiratory infections. All visits to the clinics on both islands (*n*=8851) over 14 years (1999-2003, 2005, 2011-2018) were compared to the dust haze observations and climatic variables using regression analysis. A negative correlation was observed between visits to clinics for acute respiratory infections (ARIs) and the presence of dust haze in the atmosphere (R^2=0.339, p=0.029). Visits for ARIs had positive correlations with wind speed (R^2=0.373, *p*=0.020), mean sea level pressure (R^2=0.094, *p*=0.286), relative humidity (R^2=0.203, *p*=0.106) and rainfall (R^2=0.040, *p*=0.493). A significant inverse relationship was found between visits and the study years (R^2=0.666, *p*=<0.001). Saharan dust impacts the residents of Antigua and Barbuda causing an increase in visits to clinics for ARIs with a lag or latency interval between the dust events. These findings provide good evidence which should aid governments in planning their strategic response to this serious public health issue.

***Corresponding author**

Adelle AC Blair, Lightfoot West, St. George's Parish, Antigua, West Indies. E-mail: aacblair@gmail.com

Received: July 06, 2022; **Accepted:** July 11, 2022; **Published:** July 18, 2022

Keywords: Saharan Dust, Acute Respiratory Infections, Health Impact, Clinic Visits, Dust Haze

Introduction

Air pollution, both ambient (outdoor) and household (indoor) – is one of the biggest environmental risks to human health [1]. Globally, ambient air pollution, which is the focus of this paper, was responsible for approximately 4.2 million premature deaths in 2016 [1]. By 2019, 99% of people worldwide were inhaling air that was below the air quality guidelines set by the World Health Organization [1]. Air pollution causes a number of diseases including stroke, heart disease, as well as both chronic and acute respiratory illnesses [1,2]. However, this paper will focus on acute respiratory infections. In 2016, it was estimated that 18% of deaths worldwide were due to acute lower respiratory infections [1].

The deaths associated with ambient air pollution are due to exposure to fine particulate matter (PM) with diameters of 2.5 microns or less (PM2.5) [1,3]. Particulate matter is one of the main proxy indicators for air pollution. It is made up of solid and liquid particles, organic and inorganic substances main of which are silicate minerals, sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust, organic nitrogen, oxides and water [1,4]. The impact of these inhalable particles can be summarized as follows:

Diameter of 10 microns or less (≤PM10) (small) – may enter and embed deep inside the lungs;

Diameter of 2.5 microns or less (≤PM2.5) (fine) – may breach the lung barrier and enter the blood system [1,5].

Generally, the inhalation of PM has various pathological effects based not only on size and shape but length of exposure, chemical and mineralogical composition, lung function and seasonality [6,7]. In humans, PM of these small sizes even at very low concentrations, cause cardiovascular and respiratory diseases and cancers, especially lung cancer as well as diseases affecting the reproductive and nervous systems as they can be entrained in the atmosphere over a long period time and travel long distances [3,8].

The solid particles that make up PM include bits that have been detached from rock, fine mineral aggregates and fine volcanic mineral particles [7]. One of these main components, mineral dust, has received increased attention as it is a serious threat to health with the Sahara Desert (SD) as the world's main source [5,6]. The focus here is on dust naturally entrained from land surfaces around the SD and its impact across the Atlantic in the Caribbean nation of Antigua and Barbuda.

The SD located in North Africa contains a major dried-out former lake bed, the Bodélé depression, which is the largest source of fine mineral dust in the world [6,9]. Approximately 70% of the global dust comes from Africa and 25% of the total emissions is transported over the Atlantic in the Saharan Air Layer (SAL) [10]. The SAL is dynamic and during the summer in the Northern Hemisphere, it is elevated to altitudes of 5 km and 7 km because of its interactions with cool marine air masses [11-13].

Once entrained (around 5000 m), dust from the Sahara is driven across the Atlantic Ocean by the northeast trade winds, reaching the Caribbean in approximately 5-7 days' time, mainly in Summer and early Autumn [6,14-16]. This time period coincides with the Hurricane or rainy season in the Caribbean.

The monitoring of atmospheric mineral dust in the Caribbean began in Barbados in 1965 and in Miami, Florida in 1974 [17]. Approximately 50% and 90% of PM2.5 and PM10, respectively, present in Barbados, is made up of African dust [18,19]. Mainly during the Summer months, mineral dust concentrations in Miami and Puerto Rico were found to range between 10 µg m-3 and 100 µg m-3 and in excess of 70 µg m-3, respectively [20]. In Guadeloupe, the mass of dust transported during a 3-day event ranged between 2.5 – 5 Mt and most of the mineral particles ranged between PM1 to PM8 with a modal size of PM4 [14]. In Grenada, the daily mineral dust concentrations ranged between 12.13 µg/m3 and 18.68 µg/m3 over a 5-year period [21]. Another Saharan dust (Sd) study conducted in Trinidad found that the mean levels of PM10 ranged between 46-88 µg/m-3 [22].

Exposure to high concentrations of respirable mineral dust as noted earlier can negatively affect human health and has been widely studied [13,23]. Saharan dust has also been found to carry viable bacteria and fungi over the United States Virgin Islands (USVI), also located in the Caribbean [24]. Mobilized top soils from the Sd are laden with viable and diverse bacteria, fungi and viruses which are capable of affecting humans [25]. The fungi *Aspergillus* from the Sahara, for example, commonly found in soil, organic detritus and indoors in Barbados and the USVI, causes a number of allergen-related diseases [25]. Also from the Sahara, *Cladosporium* outdoor fungus as found in both Barbados and the USVI causes serious allergen-related disease.

Kotsyfakis et al specifically researched the health impact of Sd exposure between 1966 to 2019 and found 2 Caribbean studies [26]. The Grenadian study did not state the PM size but found that variation in asthma was associated with change in the dust concentration [21]. The study in Guadeloupe was based on PM10 and PM 2.5 – 10 and found that the pollutants contained the Sd increased the risk of children with asthma visiting the emergency department [27]. Similar findings were made in Trinidad by Gyan et al [28]. Further, in Guadeloupe, an association was found between intense Sd episodes (PM10 concentration) and preterm birth with adjustments for medical risk and other factors [29]. Viel et al conducted another study in Guadeloupe and found that Sd (≤PM10) had a negative impact on placental sufficiency during early pregnancy, influencing the weight of the head at birth [30].

This paper is unique as no research of this nature has been conducted on Antigua and Barbuda which sits at the northern end of the Eastern Caribbean arc with Trinidad being the furthest south, Barbados mostly easterly and the USVI most westerly. This research adds new evidence to the health impacts of Sd on the Caribbean region. The objective therefore is to determine whether there is a link between variability in Sd levels and the number of visits to health clinics for acute respiratory illnesses in Antigua and Barbuda. Further, as there are no known studies in the region which examine the relationship between ARI visits to clinics and specific weather parameters, this paper will explore associations with mean sea level pressure (MSLP), rainfall, wind speed, relative humidity and dust haze in the atmosphere over time. The limited number of reports which exist focus on pediatric asthma visits to hospitals and these climate variables were found to exacerbate emergency room visits [21,31,32].

Data and Methods

The retrospective study relied on primary data obtained from the Health Information Department and the Meteorological Services in Antigua and Barbuda.

Meteorological Data

The Antigua and Barbuda Meteorological Services (ABMS) is located in Antigua at the V.C. Bird International Airport on the island's northeast. The ABMS conducts hourly weather observations every day of the year checking, inter alia, wind speed and direction, sky conditions, visibility, relative humidity, pressure and precipitation. In addition to automated weather stations, human observers also estimate horizontal visibility and sky conditions.

In its hourly observations, the ABMS makes a distinction between dust haze by source which means that dust from the Sahara has a different code to dust haze from unknown origin [33]. The reddish-brown colour of Sd is what distinguishes it from other possible sources of haze when there is poor visibility (Gyan et al., 2005). Poor visibility refers to those hazy days when visibility is less than 15 km [33].

Health Data

The health data is the total number of cases treated at community health clinics at Browne's Avenue, Bishop Gate's Street, Northern, Southern and Eastern areas, All Saints, St. John's Health Centre, Gray's Farm on Antigua and Hanna Thomas on Barbuda.

Acute respiratory infection restricts normal breathing, which usually starts as a serious viral infection in the nose windpipe or lungs which untreated may spread to affect the whole respiratory system [34]. Patients presenting with the following signs are considered to have acute respiratory infection: fever ≥37.8°C, abnormal white blood cell count or differential, and one of the following: cough, sore throat, wheezing, sputum production, rapid abnormal breathing, chest pain, spitting blood, shortness of breath, crepitations or stridor [35-38].

Statistical methods

The datasets were obtained for the period 1999-2003, 2005, and 2011-2018 as the complete health data were only available for these years. The daily mean of acute respiratory illness-related visits and selected climatic variables were calculated. The correlation coefficient was determined between clinic visits for acute respiratory illness, dust haze from the Sd, mean sea level pressure, relative humidity and rainfall using and SPSS statistical software package version 28.0.1.0 (142). In addition to SPSS, Microsoft Excel version 2111 was used to conduct regression analysis and extract scatter plots.

Results

Over the 14 years during which this study was conducted 8,851 visits were made to the clinics in Antigua and Barbuda for ARI emergencies. From Table 1, the daily visits ranged from 9 in 2016 to 25 in 1999 during the 14-year period. During the study period on average there were 64 hazy observations per year caused by Sd while the average wind speed was 9.87 kts.

Table 1: Mean daily visits, mean Saharan dust haze days in a year, annual mean wind speed (kts) measurements

Year	Mean daily clinic visits	Mean SD haze days in the year	Mean Wind Speed (kts)
1999	24.99	35.13	10.47
2000*	17.19	60.04	12.21
2001	24.88	33.75	11.42
2002	16.13	31.04	11.71
2003	16.75	28.71	11.55
2005	29.96	45.75	9.54
2011	12.64	116.67	9.28
2012*	11.52	78.63	10.03
2013	13.16	90.21	8.24
2014	10.55	137.75	8.40
2015	11.45	76.21	9.07
2016*	8.93	52.46	8.38
2017	12.28	44.58	8.55
2018	14.48	62.33	9.32

* Leap year

Highly significant correlations were found between ARI- related visits to clinics and three weather parameters. Figure 1 shows a negative correlation between ARI cases reported and presence of dust haze observed in the atmosphere (R2=0.339, *p*=0.029). Figure 2 shows a positive association between the number of ARI visits and wind speed (R2=0.373, *p*=0.020). Figure 3 shows the inverse relationship between ARI visits and the study years (R2=0.666, *p*=<0.001). Further, there was a positive relationship between clinic visits for ARI and mean sea level pressure (R2=0.094, *p*=0.286) in addition to ARIs visits and the relative humidity (R2=0.203, *p*=0.106). There was also a positive correlation between the number of ARI-related visits to clinics and rainfall (R2=0.040, *p*=0.493).

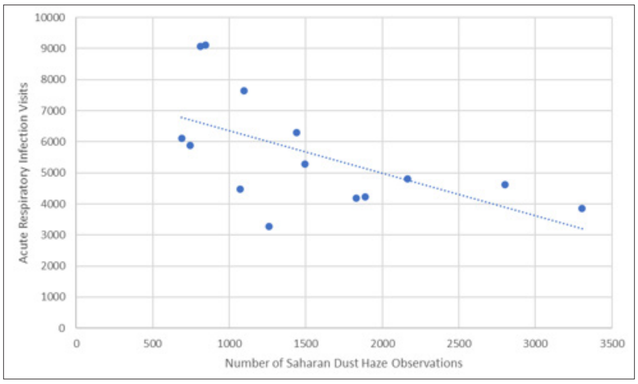

Figure 1: Annual ARI visits and annual Saharan dust haze observations (R2=0.339, *p*=0.029)

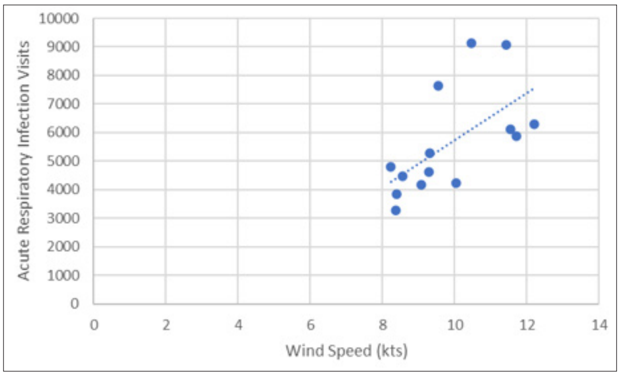

Figure 2: Annual ARI visits and average annual wind speed (R2=0.373, *p*=0.020)

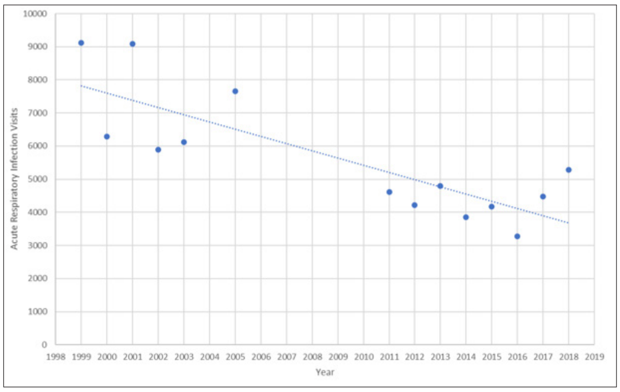

Figure 3: Annual ARI visits by Years (R2=0.666, *p*=<0.001)

Discussion

This study investigated whether the presence of Saharan dust (Sd) in the atmosphere was associated with increased visits to the clinics in Antigua and Barbuda for acute respiratory infections. It also assessed the influence of certain weather parameters on the frequency of the visits as these have been found to have significant impact [39].

This research found a highly significant inverse relationship between the number of persons who visited the clinics for ARIs and the number of days on which the Sd haze was observed. This means that the visits were higher not on the dusty days but sometime after. This result is in line with Merrifield et al who found that a dust storm period in Australia was associated with a decrease in hospital admissions for respiratory issues and posited that is could have been because of increased media awareness during the event period [40]. Blades et al investigated the same relationship and found no discernable association [41]. However, Gyan et al noted that they did not factor into their analysis a possible "lag or latency interval" between the dust period and the hospital visits. In their study, however, Gyan et al assessed possible lagged effects up to 7 days positing that the incubation period could delay the manifestation by a number of days causing a lag in the hospital visits [28].

Similarly because the effects of exposure to aerosols and other environmental pollutants can lead to same day or later admissions, Souza et aland Belleudi et al factored in a two-day delay in their investigations into respiratory admissions in Brazil and Rome, respectively [42,43]. Others found latency intervals in admissions for respiratory tract infection and pneumonia between 3 to 6 days after dust events [44,45].

The results showed an inverse relationship between an increase in the number of visits and the barometric pressure. This finding is similar to those of Akpinar-Elci et al (2015), Gyan et al (2005) and Prospero (2006). It follows on that during rainy periods the number of visits would also increase, as found in this research as well as Akpinar-Elci et al, Ivey et al and Khot et al [21,28,46]. Low barometric pressure is usually associated with inclement weather events such as rain showers, depressions and hurricanes or cyclones [47]. Therefore, the results of both variables were no surprise.

The study revealed an increase in the number of visits when the relative humidity increased. These findings were consistent with Mireku et al, Hervas et al and da Silva et al [31,48,49]. The more saturated the air is with water vapour the higher the possibility of rain. Therefore, this finding is consistent with those associated with rainfall and barometric pressure.

In this study, it was found that visits to the clinics were higher when the wind speed increased. Similar findings were made by Nastos et al, Hervas et al, Weiland et al [31,50,51]. Higher wind speed favours higher entrainment of pollutants into the atmosphere, increasing the chances of exposure of those with ARIs.

This study found that the number of visits to clinics decreased considerably as the years progressed. This was by far the most significant finding. Foltz & McPhaden as well as Kim et al found that concentrations of Sd decreased significantly over the Tropical Atlantic between 1980 to 2008 due to increased rainfall in the Sahel [52,53]. Shao et al discovered that between 1984-2012, there was reduced global dust due mainly to reduced dust from the Sahara [54]. Since the 2000s, there has been a persistent reduction in African dust emissions and this trend is projected to continue over the twenty-first century [55,56].

There were several limitations to this retrospective study. First, there was limited access to medical data. This meant that only the years with full data could be selected. Second, the format in which the medical data was received meant that it could not be analyzed by season. Third, climatic variables were collected from the country's lone meteorological office on Antigua. Micro-climatic conditions on Barbuda were not assessed. Fourth, optical visibility rather than the actual dust level measurements limited data analysis and comparison with some previous studies. Fifth, the small dataset meant that there could be no analysis of the data inter alia by location, sex or age.

This study provides more evidence of the global impact of Sd on public health. It contributes to the body of work from the Caribbean region and the first of its kind in Antigua and Barbuda. For the Caribbean, this study is unique in that, to date, it is the only one found which did not focus on asthma but ARIs. The findings in this study underscore the fact that Sd is a significant risk factor in the prevalence of ARIs in the region as Antigua and Barbuda, like Grenada, is not as industrialized as Trinidad and Barbados [21].

Although the trend is toward a reduction in Sd in the future, the findings will bring awareness to the need for resources to implement measures to address chronic respiratory diseases in the twin-island nation. These measures include the establishment of early warning systems for children and the elderly on days when the Saharan dust would be present in the atmosphere. Further, on the flip-side of a reduction in African dust emissions is the stark prediction of enhanced warming of the Tropical North Atlantic, making it more susceptible to the formation and growth of hurricanes [55,57].

Acknowledgements
I thank the Meteorological Services and the Health Information Division of the Government of Antigua and Barbuda as well as Mr. Keithley Meade for the data.

References

1. WHO (2021) WHO global air quality guidelines: particulate matter (PM2. 5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide: executive summary.
2. Landrigan PJ (2017) Air pollution and health. The Lancet Public Health 2: e4-e5.
3. Zhang X, Zhao L, Tong DQ, Wu G, Dan M, et al. (2016) A systematic review of global desert dust and associated human health effects. Atmosphere 7: 158.
4. Esmaeil N, Gharagozloo M, Rezaei A, Grunig G (2014) Dust events, pulmonary diseases and immune system. American journal of clinical and experimental immunology 3: 20.
5. Karanasiou A, Moreno N, Moreno T, Viana M, de Leeuw F, et al. (2012). Health effects from Sahara dust episodes in Europe: literature review and research gaps. Environment international 47: 107-114.
6. Derbyshire E (2007). Natural minerogenic dust and human health. AMBIO: A Journal of the Human Environment 36: 73-77.
7. Farina F, Sancini G, Mantecca P, Gallinotti D, Camatini M, et al. (2011) The acute toxic effects of particulate matter in mouse lung are related to size and season of collection. Toxicology letters, 202: 209-217.
8. Kim KH, Kabir E, Kabir S (2015) A review on the human health impact of airborne particulate matter. Environment international 74: 136-143.
9. Heft-Neal S, Burney J, Bendavid E, Voss K K, Burke M (2020) Dust pollution from the Sahara and African infant mortality. Nature Sustainability 3: 863-871.
10. Ramírez-Romero C, Jaramillo A, Córdoba MF, Raga GB, Miranda J, et al. (2021) African dust particles over the western Caribbean–Part I: Impact on air quality over the Yucatán Peninsula. Atmospheric Chemistry and Physics 21: 239-253.
11. Adams AM, Prospero JM, Zhang C (2012) CALIPSO-Derived Three-Dimensional Structure of Aerosol over the Atlantic Basin and Adjacent Continents. Journal of Climate 25: 6862-6879.
12. Chouza F, Reitebuch O, Benedetti A, Weinzierl B (2016) Saharan dust long-range transport across the Atlantic studied by an airborne Doppler wind lidar and the MACC model. Atmos. Chem. Phys 16: 11581-11600.
13. Korte LF, Pausch F, Trimborn S, Brussaard CPD, Brummer GJA, et al. (2018). Effects of dry and wet Saharan dust deposition in the tropical North Atlantic Ocean. Biogeosciences Discuss 1-20.
14. Petit RH, Legrand M, Jankowiak I, Molinié J, Asselin de Beauville C, et al. (2005) Transport of Saharan dust over the Caribbean Islands: Study of an event. Journal of Geophysical Research: Atmospheres 110.
15. Prospero JM, Nees RT (1986) Impact of the North African drought and El Nino on mineral dust in the Barbados trade winds. Nature 320: 735-738.
16. Schepanski K (2018) Transport of mineral dust and its impact on climate. Geosciences 8: 151.
17. Prospero JM, Mayol-Bracero OL (2013) Understanding the Transport and Impact of African Dust on the Caribbean Basin. Bulletin of the American Meteorological Society 94: 1329-1337.
18. Reid JS, Jonsson HH, Maring HB, Smirnov A, Savoie DL, et al. (2003) Comparison of size and morphological

measurements of coarse mode dust particles from Africa. Journal of Geophysical Research: Atmospheres 108.
19. Reid EA, Reid JS, Meier MM, Dunlap MR, Cliff SS, et al. (2003) Characterization of African dust transported to Puerto Rico by individual particle and size segregated bulk analysis. Journal of Geophysical Research: Atmospheres 108.
20. Akpinar-Elci M, Martin FE, Behr JG, Diaz R (2015) Saharan dust, climate variability, and asthma in Grenada, the Caribbean. International journal of biometeorology 59: 1667-1671.
21. Rajkumar WS, Chang AS (2000) Suspended particulate matter concentrations along the east–west corridor, Trinidad, West Indies. Atmospheric Environment 34: 1181-1187.
22. Venero-Fernández SJ (2016) Saharan dust effects on human health: a challenge for Cuba's researchers. MEDICC review 18: 32-34.
23. Griffin DW, Kellogg CA, Shinn EA (2001) Dust in the Wind: Long Range Transport of Dust in the Atmosphere and Its Implications for Global Public and Ecosystem Health. Global Change and Human Health 2: 20-33.
24. Griffin DW (2007) Atmospheric movement of microorganisms in clouds of desert dust and implications for human health. Clinical microbiology reviews 20: 459-477.
25. Kotsyfakis M, Zarogiannis SG, Patelarou E (2019) The health impact of Saharan dust exposure. Int. J. Occup. Med. Environ. Health 32: 749-760.
26. Cadelis G, Tourres R, Molinie J (2014) Short-term effects of the particulate pollutants contained in Saharan dust on the visits of children to the emergency department due to asthmatic conditions in Guadeloupe (French Archipelago of the Caribbean). PloS one 9: e91136.
27. Gyan K, Henry W, Lacaille S, Laloo A, Lamsee-Ebanks C, et al. (2005) African dust clouds are associated with increased paediatric asthma accident and emergency admissions on the Caribbean island of Trinidad. International Journal of Biometeorology 49: 371-376.
28. Viel JF, Mallet Y, Raghoumandan C, Quénel P, Kadhel P, et al. (2019) Impact of Saharan dust episodes on preterm births in Guadeloupe (French West Indies). Occupational and environmental medicine 76: 336-340.
29. Viel JF, Mallet Y, Raghoumandan C, Quénel P, Kadhel P, et al. (2019) Impact of Saharan dust episodes on preterm births in Guadeloupe (French West Indies). Occupational and environmental medicine 76: 336-340.
30. Hervás D, Utrera JF, Hervás-Masip J, Hervás JA, García-Marcos L (2015) Can meteorological factors forecast asthma exacerbation in a paediatric population? Allergologia et immunopathologia 43: 32-36.
31. Prospero JM, Blades E, Naidu R, Mathison G, Thani H, et al. (2008) Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. International Journal of Biometeorology 52: 823-832.
32. Paige O (2021) How Visibility is Recorded by the ABMS.
33. Insani M, Permana D (2020) Use of Antibiotics for acute respiratory infection (ARI) in Puskesmas Karang Rejo, Tarakan. Yarsi Journal of Pharmacology 1: 15-21.
34. Mulholland K (2003) Global burden of acute respiratory infections in children: implications for interventions. Pediatric pulmonology 36: 469-474.
35. Rowlinson E, Dueger E, Mansour A, Azzazy N, Mansour H, et al. (2017) Incidence and etiology of hospitalized acute respiratory infections in the Egyptian Delta. Influenza and other respiratory viruses 11: 23-32.
36. Tazinya AA, Halle-Ekane GE, Mbuagbaw LT, Abanda M, Atashili J, et al. (2018) Risk factors for acute respiratory infections in children under five years attending the Bamenda Regional Hospital in Cameroon. BMC pulmonary medicine 18: 1-8.
37. Zaman K, Baqui AH, Sack RB, Bateman OM, Chowdhury HR, et al. (1997) Acute respiratory infections in children: a community-based longitudinal study in rural Bangladesh. Journal of tropical pediatrics 43: 133-137.
38. Fleming DM, Cross KW, Sunderland R, Ross AM (2000) Comparison of the seasonal patterns of asthma identified in general practitioner episodes, hospital admissions, and deaths. Thorax 55: 662-665.
39. Merrifield A, Schindeler S, Jalaludin B, Smith W (2013) Health effects of the September 2009 dust storm in Sydney, Australia: did emergency department visits and hospital admissions increase? Environmental Health 12: 1-7.
40. Blades E, Naidu RP, Mathison GE (1998) The microbiological analysis of Sahara dust and its association with asthma in Barbados. West Indian med. j 34-35.
41. Souza Ad, Santos DAdS, Ikefuti PV (2017) Association between climate variables, pollutants, aerosols and hospitalizations due to asthma. O Mundo Da Saúde (Cusc. Impresso) 41: 359-367.
42. Belleudi V, Faustini A, Stafoggia M, Cattani G, Marconi A, et al. (2010) Impact of fine and ultrafine particles on emergency hospital admissions for cardiac and respiratory diseases. Epidemiology 414-423.
43. Meng Z, Lu B (2007) Dust events as a risk factor for daily hospitalization for respiratory and cardiovascular diseases in Minqin, China. Atmospheric environment 41: 7048-7058.
44. Rublee CS, Sorensen CJ, Lemery J, Wade TJ, Sams EA, et al. (2020) Associations between dust storms and intensive care unit admissions in the United States, 2000–2015. GeoHealth 4: e2020GH000260.
45. Khot A, Burn R, Evans N, Lenney W, Storr J (1988) Biometeorological triggers in childhood asthma. Clinical & Experimental Allergy 18: 351-358.
46. Heupel MR, Simpfendorfer CA, Hueter RE (2003) Running before the storm: blacktip sharks respond to falling barometric pressure associated with Tropical Storm Gabrielle. Journal of fish biology 63: 1357-1363.
47. Mireku N, Wang Y, Ager J, Reddy RC, Baptist AP (2009) Changes in weather and the effects on pediatric asthma exacerbations. Annals of Allergy, Asthma & Immunology 103: 220-224.
48. da Silva Júnior JLR, de Lima Diniz IT, Nunes LFG, Borges TR (2016) EFEITO DA SAZONALIDADE CLIMÁTICA NAS HOSPITALIZAÇÕES POR DOENÇA RESPIRATÓRIA NA CIDADE DE ANÁPOLIS-GO ENTRE 2002 E 2012 EFFECT OF SEASONALITY IN HOSPITALIZATIONS FOR RESPIRATORY DISEASE IN THE CITY OF ANÁPOLIS-GO BETWEEN 2002 AND 2012. Revista Educação em Saúde 4.
49. Nastos PT, Paliatsos AG, Papadopoulos M, Bakoula C, Priftis KN (2008) The effect of weather variability on pediatric asthma admissions in Athens, Greece. Journal of Asthma 45: 59-65.
50. Weiland SK, Hüsing A, Strachan DP, Rzehak P, Pearce N (2004) Climate and the prevalence of symptoms of asthma, allergic rhinitis, and atopic eczema in children. Occupational and environmental medicine 61: 609-615.
51. Foltz GR, McPhaden MJ (2008) Impact of Saharan dust on tropical North Atlantic SST. Journal of Climate 21: 5048-5060.
52. Kim D, Chin M, Remer LA, Diehl T, Bian H, et al. (2017)

Role of surface wind and vegetation cover in multi-decadal variations of dust emission in the Sahara and Sahel. Atmospheric Environment 148: 282-296.
53. Shao Y, Klose M, Wyrwoll KH (2013) Recent global dust trend and connections to climate forcing. Journal of Geophysical Research: Atmospheres 118: 11-107.
54. Evan AT, Flamant C, Gaetani M, Guichard F (2016) The past, present and future of African dust. Nature 531: 493-495.
55. Palchan D, Torfstein A (2019) A drop in Sahara dust fluxes records the northern limits of the African Humid Period. Nature communications 10: 1-9.
56. Ivey MA, Simeon DT, Monteil MA (2003) Climatic variables are associated with seasonal acute asthma admissions to accident and emergency room facilities in Trinidad, West Indies. Clinical and Experimental Allergy: Journal of the British Society for Allergy and Clinical Immunology 33: 1526-1530.
57. Prospero JM (2006) Saharan dust impacts and climate change. Oceanography 19: 60.