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Review

Desert dust and human health disorders

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ABSTRACT

Dust storms may originate in many of the world's drylands and have an effect not only on human health in the drylands themselves but also in downwind environments, including some major urban centres, such as Phoenix, Kano, Athens, Madrid, Dubai, Jedda, Tehran, Jaipur, Beijing, Shanghai, Seoul, Taipei, Tokyo, Sydney, Brisbane and Melbourne. In some parts of the world dust storms occur frequently throughout the year. They can transport particulate material, pollutants, and potential allergens over thousands of km from source. The main sources include the Sahara, central and eastern Asia, the Middle East, and parts of the western USA. In some parts of the world, though not all, the frequency of dust storms is changing in response to land use and climatic changes, and in such locations the health implications may become more severe. Data on the PM_{10} and $P_{2.5}$ loadings of dust events are discussed, as are various pollutants (heavy metals, pesticides, etc.) and biological components (spores, fungi, bacteria, etc.). Particulate loadings can far exceed healthy levels. Among the human health effects of dust storms are respiratory disorders (including asthma, tracheitis, pneumonia, allergic rhinitis and silicosis) cardiovascular disorders (including stroke), conjunctivitis, skin irritations, meningococcal meningitis, valley fever, diseases associated with toxic algal blooms and mortality and injuries related to transport accidents.

Contents

1. Introduction

The purpose of this paper is firstly to review recent studies on the nature of desert dust storms (e.g. their main sources areas, frequencies,

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changing frequencies, durations, and particulate contents), and secondly to consider some of the empirical evidence that is now accumulating to relate these characteristics of dust storms to various human health disorders. It does not seek to review in detail the underlying biological processes that lie behind such disorders.

2. Desert dust

Dust storms play an important role in the Earth system (Goudie and Middleton, 2006; Ravi et al., 2011; Shao et al., 2011). They are in most cases the result of turbulent winds, including fronts and convective *haboobs* (Miller et al., 2008), which raise large quantities of dust from desert surfaces and reduce visibility to less than 1 km. Dust reaches concentrations in excess of 6000 μg m^{-3} in severe events (Song et al., 2007). It can be transported over thousands of kilometres and is deposited downwind by wet and dry processes, sometimes in appreciable quantities. Much of this load consists of silt. The silt comes finer with distance from source, and in the case of the Sahara, the coarsest dust (over 70 μm) occurs close to the Sahara itself, whereas dust that has travelled further tends to be finer silt, with a diameter of 5 to 30 μm or less. Saharan dust collected in the eastern USA may be finer than 1 μm (Perry et al., 1997). Aeolian dust is dominated by SiO_2 and Al_2O_3, but other significant components are Fe_2O_3, CaO and MgO. It may also have a large salt content, an organic content (Zaady et al., 2001), and, crucially from the health point of view can transport pathogens and anthropogenic pollutants.

2.1. Source areas

The health impact of dust storms will depend on where human populations are located with respect to the source areas of dust storms and the downwind direction of dust transport from them. Some areas are major generators of dust to the atmosphere. Other areas are, however, much less active. Analysis of Total Ozone Mapping Spectrometer (TOMS) data (Prospero et al., 2002; Varga, 2012; Washington et al., 2003) and other satellite borne sensors such as MODIS (Ginoux et al., 2012) has demonstrated the primacy of the Sahara, and the importance of large basins of internal drainage as dust sources (Bodélé, Taoudenni, Tarim, Seistan, Eyre, Etosha, Mkgadikgadi, Etosha, Uyuni, and the Great Salt Lake) (Engelstädter, 2001). Also, many sources are associated with alluvial deposits (Prospero et al., 2002) or piedmont alluvial fans (Tegen and Schepanski, 2009). Furthermore, TOMS data indicate that many of the world's major dust source areas, with high Aerosol Index (AI) values, are very arid (Table 1). Estimates of the relative strength of dust emissions for different parts of the world are variable but in general they demonstrate the importance, firstly of the Sahara (with over half of the global total), secondly of China and Central Asia (with about 20% of the global total), thirdly of Arabia and fourthly of Australia. Southern Africa and the Americas are relatively minor sources, together accounting for less than about 5% of the total (see, for example, Miller et al. (2004) and Tanaka and Chiba (2006) (Fig. 1)).

Table 1
Maximum mean aerosol index (AI) values for major global dust sources determined from TOMS (from Goudie and Middleton, 2006, Table 4.2).

Location	AI value	Average annual rainfall (mm)
Bodélé Depression of south central Sahara	>30	17
West Sahara in Mali and Mauritania	>24	5–100
Arabia (southern Oman/Saudi border)	>21	<100
Eastern Sahara (Libya)	>15	22
Southwest Asia (Makran coast)	>12	98
Taklamakan/Tarim Basin (China)	>11	<25
Etosha Pan (Namibia)	>11	435–530
Lake Eyre Basin (Australia)	>11	150–200
Mkgadikgadi Basin (Botswana)	>8	460
Salar de Uyuni (Bolivia)	>7	178
Great Basin (USA)	>5	400

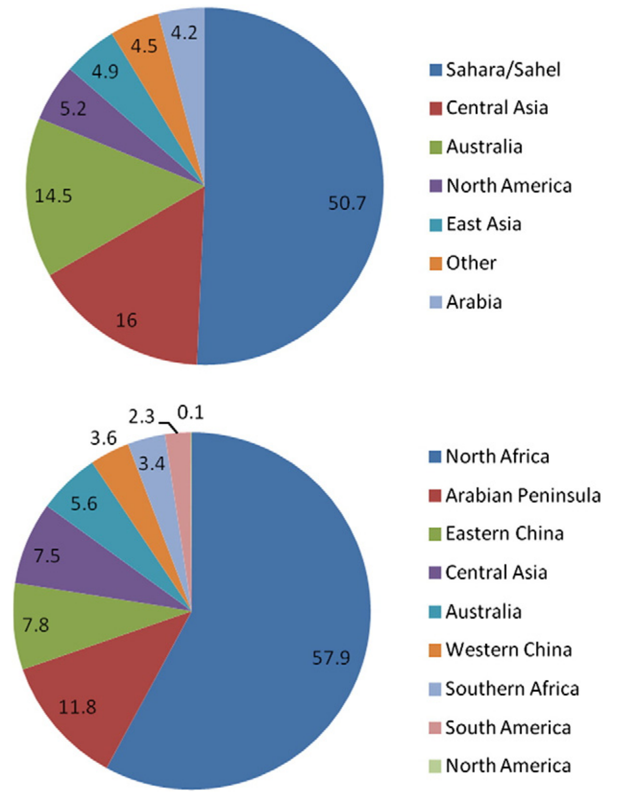

Fig. 1. Estimates of the relative strength of dust emissions for different parts of the world (from data in Miller et al. (2004) (top) and Tanaka and Chiba (2006) (bottom).

With regard to individual source regions, in the USA the greatest frequency of dust events occurs in the Great Plains and the Great Basin. These areas combine erodible materials with a dry climate and high wind energy (Gillette and Hanson, 1989). With regards to the arid south west, Bach et al. (1996) discuss the spatial and temporal variabilities of dust storms in the Mojave and Colorado Deserts and identify the Coachella Valley as being the dustiest region. Dust blown from the desiccated Owens Valley in California has been a cause of local health concerns. Dust has also been a major health issue in cities such as Phoenix in Arizona (Leathers, 1981), and pneumonia, called 'Haboob Lung Syndrome', has been reported after dust events in Lubbock, Texas (Panikkath et al., 2013).

The main source areas for Saharan dust (Goudie and Middleton, 2001) include: the Bodélé Depression (Bristow et al., 2009; Washington et al., 2006a, 2006b); an area that comprises southern Mauritania, northern Mali and central-southern Algeria (Knippertz and Todd, 2010); southern Morocco and western Algeria; the southern fringes of the Mediterranean Sea in Libya (O'Hara et al., 2006) and Egypt (Koren et al., 2003); and northern Sudan (Brooks et al., 2005). Much dust is moved by the north easterly trades over Nigeria and the Guinea zone to give the Harmattan haze (Breuning-Madsen and Awadzi, 2005) which may play a role in the timing and severity of meningococcal meningitis outbreaks. The Tokar delta of the Sudan, an arid, silty region across which high velocity winds are funnelled by a gap in the Red Sea Hills, is a frequent source of dust over the Red Sea (Hickey and Goudie, 2007) — dust which often moves into Arabia and may lead to air quality deterioration in cities like Jedda.

Dust storms in the Middle East itself (Middleton, 1986a) are frequent on the alluvial plains of southern Iraq and Kuwait, and concerns have been expressed about their possible health implications (Thalib and Al-Taiar, 2012). In Tehran the great bulk of particulates appear to be derived from the deserts of Iraq and Syria (Givehchi et al., 2013). The Wahiba Sands (Pease et al., 1998) of Oman and the Oman–Saudi Arabia border are other large dust generation areas (Middleton and