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Review article

Lung health in era of climate change and dust storms

Michael D. Schweitzer[a], Andrew S. Calzadilla[b], Oriana Salamo[a], Arash Sharifi[c], Naresh Kumar[d], Gregory Holt[a,e], Michael Campos[a,e], Mehdi Mirsaeidi[a,e,*]

[a] Division of Pulmonary and Critical Care, University of Miami, Miami, FL, United States
[b] Department of Medicine, University of Medicine, Miami, FL, United States
[c] Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, United States
[d] Department of Public Health Sciences, University of Miami, Miami, FL, United States
[e] Miami VA Healthcare System, Miami, FL, United States

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ABSTRACT

Dust storms are strong winds which lead to particle exposure over extensive areas. These storms influence air quality on both a local and global scale which lead to both short and long-term effects. The frequency of dust storms has been on the rise during the last decade. Forecasts suggest that their incidence will increase as a response to the effects of climate change and anthropogenic activities.

Elderly people, young children, and individuals with chronic cardiopulmonary diseases are at the greatest risk for health effects of dust storms. A wide variety of infectious and non-infectious diseases have been associated with dust exposure. Influenza A virus, pulmonary coccidioidomycosis, bacterial pneumonia, and meningococcal meningitis are a few examples of dust-related infectious diseases. Among non-infectious diseases, chronic obstructive pulmonary disease, asthma, sarcoidosis and pulmonary fibrosis have been associated with dust contact. Here, we review two molecular mechanisms of dust induced lung disease for asthma and sarcoidosis. We can also then further understand the mechanisms by which dust particles disturb airway epithelial and immune cells.

1. Introduction

1.1. Dust storms

Climate change has created a wide array of major fluctuations in the environment. Variations in rainfall patterns, rising sea levels, and increased severe weather phenomena such as droughts, floods and dust storms, all have an undeniable implication on human health (Mirsaeidi et al., 2016).

Dust storms, defined as an atmospheric phenomenon triggered by numerous small particles evenly distributed in the air, provide a vital role on Earth (2, 3). Such storms have lasting air quality impact on both a local and global scale in the short and long term (Duncan Fairlie et al., 2007). The majority of dust storms arise from arid and semi-arid regions, frequently referred to as drylands. Drylands are typically formed in the subtropics, where the sinking branch of Hadley cell brings warm and dry air to the land's surface. In meteorology, Hadley cell is defined as a large-scale atmospheric convection in which air rises at the equator and sinks at medium latitudes. Since the air near Earth's surface is dry, the land areas of these regions (approximated as 30°N and 30°S of equator) are the location of world's major deserts (Fig. 1).

These areas are noted to generally be in low-lying terrains (< 1800 m of elevation), with high aerosol index and a low average annual rainfall (Ghio et al., 2014; Goudie and Middleton, 2006). The association between drylands and dust storms is explained by the fact that desiccated, unconsolidated substrates with scarce vegetation cover permit turbulent winds to easily raise particles from the surface (Middleton, 2017). Drylands constitute roughly 40% of the world surface, and are home to approximately 30% of the world's population (Safriel et al., 2005). It is important to note that the impact of dust storms is able to exceed these boundaries, transporting particles out to areas thousands of kilometers away from their origins (Claiborn et al., 2000; Kim et al., 2005). In this paper, we review the impact of particle inhalation and its association with pulmonary diseases, with a specific focus on asthma and sarcoidosis.

1.1.1. Areas of origin

The most important dust source along the dust belt is located in the Sahara-Sahel region in Northern Africa. This region is home to the largest source of atmospheric desert dust on the planet, contributing to almost half of the world's total dust budget. Meanwhile, China and Central Asia contribute around 20%; followed by Arabia and Australia.

* Corresponding author at: Division of Pulmonary and Critical Care, Miller School of Medicine, University of Miami, 1600 NW 10th Avenue #7060A, Miami, FL 33136, United States.
E-mail address: msm249@miami.edu (M. Mirsaeidi).

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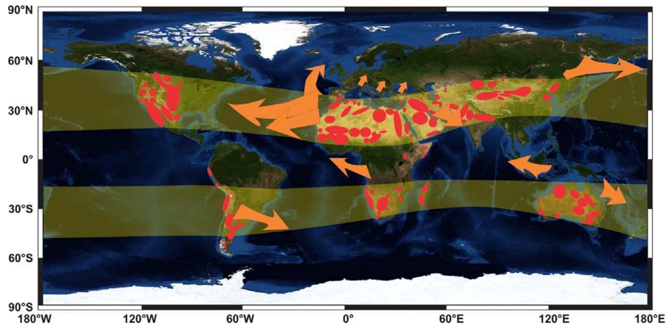

Fig. 1. Schematic map of dust belt and dust transportation pathways. Dust source regions (red) are based on daily measurements of dust optical depth using Moderate Resolution Imaging Spectroradiometer Deep Blue (MODIS DB) Level 2 (Ginoux et al., 2012). The orange arrows denote the dust transport paths over the ocean based on the composite of monthly mean of Total Ozone Mapping Satellite (TOMS) absorbing aerosol index (AAI) (Maher et al., 2010). The pale yellow bands show the approximate locations of the global dust belt. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Both Southern Africa and the North and South America contribute a lesser yet significant amount, calculated at no more than 5% of the planet's dust production. (Miller et al., 2004) The latter estimates are based on models, as actual chronological and geographical measurements are sporadic (Middleton, 2017). In the United States, data from the National Weather Service indicates that the largest number of dust storms occur in the Arizona, California, Washington and Nevada during the spring and summer months. July has been documented as the month with the highest activity of dust storms. These storms occur more frequently in the early afternoon hours (Crooks et al., 2016). To further quantify the effects of dust exposure on Earth, scientists have begun to use satellite data as a means to determine regional air pollution and identify areas of high dust exposure. This technology is increasingly being used to estimate airborne dust around the world, especially in areas where direct measurements are unavailable (Chudnovsky et al., 2017).

The temporal and spatial production of dust is not constant. The Sahara Bodélé Depression, the world's largest desert dust source, is constantly active. However, it has been reported that an increase in activity (affecting West Africa) occurs between the months of October and April. The Middle East is affected particularly between May and August when the northwestern winds of Shamal increase in frequency (Middleton, 2017; Yu et al., 2016). Desiccation of lakes caused by poor water management is seen in Central Asia (Issanova et al., 2015) and the Middle East (AghaKouchak et al., 2015). Land surface erosion, like that seen in the North American Great Plains (McLeman et al., 2014), and deforestation are clear examples of how human activities have made substantial contributions to the creation of new drylands and new potential sources of dust.

1.1.2. Dust transport

Emerging research show that particles can travel long distances through the troposphere. For example, from the Taklamakan Desert in Northwest China and from North Africa can traverse the Pacific and Atlantic Oceans, respectively. These particles can be found in such far-reaching places as North America (McKendry et al., 2001; Pourmand et al., 2014) and Greenland (Bory et al., 2003). In 2007, particles traveled around the globe in a period of just 13 days (Uno et al., 2009). Dust hazards from the Gobi Desert in China have been observed in many cities, including Beijing (Liu et al., 2014), Seoul, and Tokyo (Kashima et al., 2016). Saharan dust has been shown to move across the Atlantic Ocean reaching the Amazon (Swap et al., 1992), the Andes (Boy and Wilcke, 2008) and many other locations in the Americas (Bozlaker et al., 2013; Pourmand et al., 2014). They have also been identified to head northbound into Europe (Varga, 2012) and the Arctic (Barkan and Alpert, 2010). The Sahara is known as a principle source of dust deposition in the Mediterranean Sea. Saharan dusts have been seen in many cities including Madrid, Barcelona, Rome and Athens (Salvador et al., 2014). Mid-East dust has been shown to reach all over the region including Iran (Givehchi et al., 2013) and India (Badarinath et al., 2010). Global dust transport paths over the ocean are shown in Fig. 1.

1.1.3. Dust composition

Dust composition is influenced by a wide range of natural and anthropogenic factors. Particle size and conformation are largely determined by the structure and composition of source rocks and physical and chemical weathering processes. Additionally, wind velocity and atmospheric conditions can greatly influence the dust mixing process during transportation. Particles found near dust storms are comprised of weathering resistant minerals such as quartz, titanium bearing minerals and zircon, those found at long distances from the storm's origin are comprised of clay minerals and phyllosilicates. Particles generally consist of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron (Fe_2O_3) and titanium (TiO_2) oxides. Other common particles are calcium (CaO) and magnesium oxide (MgO), and oxides of sodium and potassium (Na_2O and K_2O). Based on the composition of source rock and mineralogy of dust, an array of trace elements such as zirconium (Zr), strontium (Sr), rubidium (Rb) and rare earth elements (REEs) are also present. Desert dust also contains large amounts of evaporated minerals (salt), organic content, pathogens and anthropogenic pollutants (heavy metals, pesticides, sulfate, nitric acid, polycyclic aromatic carbons) in its matrix and/or surface (Middleton, 2017). Mineralogy, chemical composition and particle size of mineral dust are widely used to track the dust particles to their source regions (Coudegaussen et al., 1987; Sarnthein et al., 1981). Ultimately, utilizing isotopic tracers (Sr, Nd and Hf) seems to provide more reliable information about dust deposit origins and source contributions (Grousset et al., 1988; Pourmand et al., 2014). The Nd-Sr composition of the world's major dust sources is shown in Fig. 2.

Among dusts, many microorganisms including bacteria, fungi, spores have been described. Even viruses have been described as a part of the microorganisms of those particles (Chen et al., 2010; Griffin, 2007; Maki et al., 2010). These have survived for long periods of time as demonstrated in analysis of dust collected by Charles Darwin from over 150 years ago (Gorbushina et al., 2007). Some of these pathogens, especially those in spore forms (for examples *Bacillus*) have been described to endure UV and gamma-ray radiation, low temperatures and desiccation instigated by transportation at high altitudes (Saffary et al., 2002).

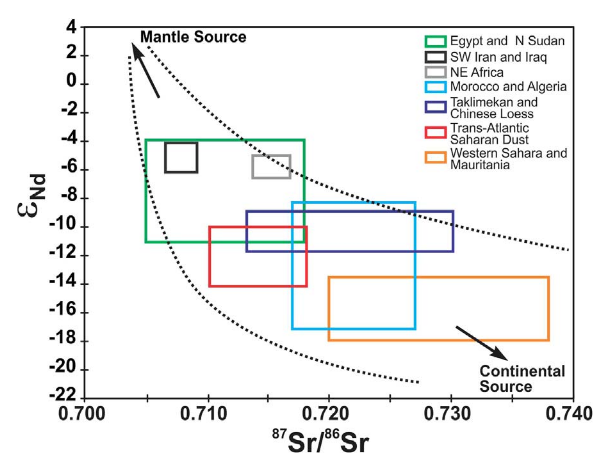

Fig. 2. Radiogenic Sr and Nd isotopes in aerosols from the world's source regions. Colored boxes represent ranges of values measured in surficial samples of North Africa, East Asia and Middle East (Abouchami et al., 2013; Chen et al., 2007; Chen and Li, 2013; Scheuvens et al., 2013) as well as Trans-Atlantic Saharan Dust particles collected in Bahamas (Pourmand et al., 2014).