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Review Article

The role of airborne mineral dusts in human disease

Suzette A. Morman *, Geoffrey S. Plumlee

U.S. Geological Survey, Denver, CO 80225, USA

A R T I C L E I N F O

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A B S T R A C T

Exposure to fine particulate matter (PM) is generally acknowledged to increase risk for human morbidity and mortality. However, particulate matter (PM) research has generally examined anthropogenic (industry and combustion by-products) sources with few studies considering contributions from geogenic PM (produced from the Earth by natural processes, e.g., volcanic ash, windborne ash from wildfires, and mineral dusts) or geoanthropogenic PM (produced from natural sources by processes that are modified or enhanced by human activities, e.g., dusts from lakebeds dried by human removal of water, dusts produced from areas that have undergone desertification as a result of human practices). Globally, public health concerns are mounting, related to potential increases in dust emission from climate related changes such as desertification and the associated long range as well as local health effects. Recent epidemiological studies have identified associations between far-traveled dusts from primary sources and increased morbidity and mortality in Europe and Asia. This paper provides an outline of public health research and history as it relates to naturally occurring inorganic mineral dusts. We summarize results of current public health research and describe some of the many challenges related to understanding health effects from exposures to dust aerosols.

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1. Introduction

The study of dust has expanded in recent decades and there are many reviews on the importance of dust in the framework of the Earth ecosystem from a variety of disciplinary perspectives (Shao et al., 2011). But, until recently little work has sought to elucidate links between inorganic mineral dusts (IMD) and population health. This may be due in part to the focus early air pollution regulations may have indicated for research (the goal of limiting mobile and industrial sourced pollutants) and epidemiological study design, which requires amongst other criteria, a large population sample size to demonstrate association with health related effects. Additional difficulties that limit research on mineral dusts include: identifying etiological mechanisms responsible for disease, characterization of the sample and source, and quantifying exposure.

* Corresponding author. Tel.: +1 303 236 1205.
E-mail address: smorman@usgs.gov (S.A. Morman).

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2. Overview

In recent decades, numerous adverse health effects have been associated with what is broadly identified as air pollution. These effects include exacerbation of existing cardiovascular and respiratory illnesses, an increased risk of stroke and death. An estimated 1.3 million deaths are attributed to urban outdoor air pollution annually according to the World Health Organization (WHO). Particulate matter (PM) according to WHO, affects more people than any other pollutant and is composed of sulfates, nitrates, ammonia, sodium chloride, carbon, mineral dust and water (WHO, 2012a). Particulate matter may be directly emitted into the atmosphere (primary) or produced by atmospheric chemical reactions between gases or particles and gases (secondary). Sources may be natural (volcanic ash, forest fires, and dusts) or anthropogenic (fossil fuel combustion). Although it is estimated that 2000 Mt of dust is emitted into the atmosphere every year (Shao et al., 2011, though this value varies by author and model), health related studies of particulate matter have generally focused on urban areas and anthropogenic sources.

Occupational studies throughout history have contributed significantly to our knowledge of health effects and toxicology. Publications dating back to the 15th century, by Agricola and Paracelsus, describe etiology of miner's disease, treatment and prevention (Gallo, 2008). Epidemiology studies examining health risks from exposures for communities have primarily focused on industrial sources of air pollution. Famous examples include the great smog of 1952 in London, a five day period reported to have caused 4000 deaths and made thousands ill and the Donora, Pennsylvania incident (1948) where a temperature inversion and air stagnation kept sulfuric acid, nitric oxide and fluorine gases from dispersing killing 20 people and hundreds of animals (over 7000 people experienced acute illness).

Another historical event, the Great American Dust Bowl of the 1930s, provided unparalleled community exposures to IMD (Fig. 1). Yet this event, producing illness (dust pneumonia – related to excessive and prolonged inhalation of dust resulting in inflammation of the alveoli) and death, seems to have received less attention in terms of health related studies. Rates of illness were difficult to determine, not well documented, or easily found. One public health report from 1935, states that many health officers in Kansas reported a 50–100% increase in pneumonia cases as compared to the same months in prior years and a marked increase in sinusitis, laryngitis, bronchitis, corneal ulcers, and eye infections. Death rates in Kansas, according to Brown et al. (1935), increased from 70 to 99 deaths per 100,000 (people) and infant mortality increased from 62.3 to 80.5 deaths per 100,000. Characterization of the dusts found high silica content, on average greater than 72%, but no pathogenic organisms (Brown et al., 1935). The role of quartz dust in occupational silicosis had been identified by this time so there was an awareness of risk related to dusts with high silica content (McClellan, 2000).

2.1. Respiratory exposure pathway

To familiarize the reader with the lung physiology needed to understand PM or IMD exposure through an inhalation pathway and terms and concepts presented, we begin with a superficial summary of the respiratory tract. For a more detailed description of this complex system readers are encouraged to review the references provided or other available resources. The respiratory tract includes: the nasopharynx, the tracheobronchial and pulmonary regions or compartments (McClellan, 2000) and serves as a portal of entry into the body, deposition site and target organ (Fig. 2). It is a complex system providing basic needs such as olfaction (sense of smell) and gas exchange (providing oxygen to red blood cells and removing carbon dioxide). It also meets other important physiological needs such as controlling the acid–base balance of the blood and body, serving as a blood reservoir, and assisting in the body's immune system, and the metabolism of many compounds.

The nasopharyngeal region consists of the nose, mouth and larynx. In addition to housing olfactory cells (which provide our ability to smell) it humidifies and equilibrates the incoming air temperature and operates as an initial barrier to larger particles. The tracheobronchial compartment consists of conducting airways

Fig. 1. Dust storm approaching Stratford, Texas, 1935. NOAA George E. Marsh Album.