Airborne dust: A primer for clinicians

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The material which gave the “Dust Bowl” its name and blows through the Southwest is a geological and meteorological phenomenon now recognized to impact human health, especially through its respiratory effects. Indoor and occupational dust (generated inside buildings) possesses its own different sources, characteristics, and significant human health effects, representing a different material and topic, investigated by environmental engineers and ventilation specialists rather than earth or atmospheric scientists. There is no clear scientific definition for (atmospheric) “dust”; in general, one may describe it as a coarse or large-sized aerosol (particle that is or was suspended in air, either by wind or mechanical forces), consisting of mineral matter or soil.

Granulometrically, dust includes only particles smaller than 50 micrometers in diameter (silt-and sand-sized grains); larger particles are classified by soil scientists as sand. Realistically, in the Southwest, strong winds pay no attention to grain-size boundaries, so “dust storms” are also just as much “sand storms” and vice versa. Meteorologists differentiate “haze,” “blowing dust,” “suspended dust,” and “dust storms” based on visibility, wind speed, and the duration of the event; these represent gradations of the same phenomenon, much as a tropical storm is differentiated from a hurricane. Air quality researchers and environmental regulators discern between “windblown” or “natural” dust, raised by atmospheric action generally from natural surfaces and thus a natural event, as opposed to “fugitive” dust, emitted through human actions or human modification of the landscape, such as a truck driving down an unpaved road or a tractor plowing a field. However, human lungs and eyes cannot differentiate them on a hazy, windy West Texas day.

Dust is regulated in the United States under the Clean Air Act as part of PM10 (airborne particulate matter with a mean aerodynamic diameter smaller than 10 micrometers) and PM2.5 (airborne particulate matter with a mean aerodynamic diameter smaller than 2.5 micrometers). These are health-based standards; PM10 can be inhaled sufficiently deeply into the human respiratory tract to cause adverse effects, and PM2.5 is small enough to reach deep into the lungs. In general, most dust particles fall into the “coarse fraction” (larger than PM2.5), but severe dust storms in West Texas have manifested both PM10 and PM2.5 concentrations more than an order of magnitude higher than EPA standards, and recent research shows that some dust is shattered into “ultrafine particles” (a fraction of a micrometer in diameter) which may be able to pass directly into the bloodstream. Actual concentrations of airborne dust are difficult to exactly quantify, as they ebb and flow with turbulent gusts and small-scale shifts of wind, but can be reasonably estimated. Measurement methods range from simple sediment traps—basically, containers set out in the air collecting dust as if it were precipitation in a rain gauge—to sophisticated optical sensors measuring aerosol scattering of a light beam, oscillating microbalances weighing specks of entrained air, and impactor and cyclone samplers pumping ambient air and collecting entrained particles through a filter or onto a plate. They all lose accuracy under heavy particulate loadings and/or high winds (i.e., dusty conditions) but seem to be reasonably precise as a standard of comparison.

Dust, and almost all atmospheric aerosols, are complex mixtures of materials; the reddish color of South Plains dust comes from iron and manganese oxides sandblasted off “rust-coated” silica grains. The mineral component of dust is primarily quartz (SiO2, silica); crystalline silica in itself is a recognized health hazard. Silicosis has long been identified as a respiratory disease, and the accompanying Regional Medicine Review article discusses “haboob
lungs syndrome. Additional components of mineral dust include other complex silicates, salts including sodium compounds from dry saline lakes, calcium carbonate (caliche), and calcium sulfate (gypsum), the aforementioned oxides and other naturally-occurring metal compounds, and rarely minerals which by themselves are cytotoxic, such as asbestos. Almost never is an aerosol completely mineral in nature; especially in urban or cropland regions, such as the Great Plains, natural mineral surfaces are coated with anthropogenic substances, such as motor vehicle or industrial emissions, soot from smoke, agricultural chemicals, and a myriad of biological substances, especially viruses, bacteria, and fungi. Winkler (1973) stated, “The same net composition of an aerosol can be caused by an infinite variety of different internal distributions of the various compounds”; this clearly holds for dust aerosols, and must be kept in mind for its medical implications. Still, research has shown that in dry-climate cities, such as Lubbock, the atmospheric aerosol is predominantly mineral (i.e., dust) in composition, even on clear calm days.

Dust is typically not directly “lifted” or “suspended” by the wind (direct aerodynamic entrainment), other than in dust devils or vortexes. Instead, dust emission happens as aeolian forces exceed a threshold wind velocity and cause large sediment particles to creep along the ground and move in saltation, the wind-driven hopping motion of sand grains. Saltating and creeping grains collide with the ground and each other, shattering, dislodging, crushing, spalling, and sandblasting off smaller, dust-sized pieces which become suspended and dispersed in the airstream (Figure 1).

Any sufficiently strong wind over the right surface can cause dust emission, although climatological studies have revealed certain weather patterns most favorable for dust events. In the Southwest, these include dry, fast-moving fronts and drylines, cyclones, and the downdrafts from thunderstorms which produce haboobs, a menacing wall of dust blowing in as a dirty avalanche rolling over the land. In West Texas, fronts are the most frequent dust-producing weather, while cyclones, though rarer, produce the longest-lasting and highest concentrations of dust. In Arizona, thunderstorm-spawned gusts and haboobs are predominant.

The advent of weather satellites revolutionized our understanding of the sources and nature of dust events. Spaceborne sensors, such as TOMS (the Total Ozone Monitoring Spectrometer) and MODIS (the Moderate-resolution Imaging Spectroradiometer), have revealed that dust does not rise equally from throughout a semiarid landscape, but instead flows in

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**Figure 1.** Illustration of the dust emission process, showing how saltation and creep of large grains release dust aerosols transported downwind. (After Dr. Robert Wallace, Ripon College: used with permission.)
discrete plumes emanating from myriad small, intense point sources which spread out downwind and coalesce into a broader shield.\textsuperscript{15} Certain geographical features, such as flat, dry, sandy plains and the desiccated, sand-ringed beds of salt lakes, have been quantified as disproportionately frequent initiation points of these plumes compared to other landforms.\textsuperscript{14,15} Satellite tracking has also shown that dust clouds can traverse the globe. Although minimal in quantity compared to locally-generated particulate matter, dust from the Sahara\textsuperscript{16} and Chinese deserts\textsuperscript{17} falls on West Texas, and Great Plains dust from the Dust Bowl may have been deposited on the Greenland ice cap.\textsuperscript{18} These new understandings of meteorological and geographic patterns favoring dust emission have vastly improved our ability to forecast dust events.

Although quantitative measurements of dust concentrations in the USA have only been made since the implementation of national ambient air quality standards (NAAQS) in the 1970s, multiple lines of evidence suggest that the implementation of soil conservation measures and other agricultural improvements has reduced dust levels in the Plains since the Dust Bowl. The 1950s drought resulted in less wind erosion than the 1930s drought,\textsuperscript{19} and dust levels decreased significantly from the 1960s into the 21\textsuperscript{st} century.\textsuperscript{20}

Compared to the 1930s Dust Bowl days, we now have a much greater scientific understanding of airborne dust, its causes, characteristics, controls, and effects, but many challenges remain. Even under ideal conditions, dust can be raised profusely from one localized part of the landscape while an equivalent adjacent area remains dust-free; one agricultural field will blow a brownout, while the adjacent field will remain stable (Figure 2). Chaos-scale fluctuations of wind and soil probably have a role in this variability.

\textbf{Figure 2.} One of the first known aircraft photos of a dust storm in the USA, eastern Colorado during the Dust Bowl, 1936. Note the emission of dust in linear plumes (from north to south: right to left on the picture) from a limited sector of the landscape, while surrounding areas are not blowing. (NOAA photo archives, public domain).
Equally, only in recent decades have human health hazards from dust been widely realized (see Reed and Nugent in this issue), yet they still are not systematically understood. Clinicians’ diligent awareness and recognition of dust’s role in the cause and exacerbation of illness will improve our understanding of the epidemiology, etiology, and treatment of dust-associated disease.

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## REFERENCES


