Airborne dust: A primer for clinicians

Thomas E. Gill, PhD

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.

Corresponding author: **Thomas E Gill**
Contact Information: Tegill@utep.edu
DOI: 10.12746/swrccc.v6i22.437

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),[1] 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,[2] and recent research shows that some dust is shattered into “ultrafine particles” (a fraction of a micrometer in diameter)[3] 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.[4] The mineral component of dust is primarily quartz (SiO2, silica); crystalline silica in itself is a recognized health hazard.[5] Silicosis has long been identified as a respiratory disease, and the accompanying Regional Medicine Review article discusses “haboob lung syndrome."[6] 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.[7] 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";[8] 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.[9]

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 sand-blasting 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.[10-12] 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.[10,11] In Arizona, thunderstorm-spawned gusts and haboobs are predominant.[13]

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)[14] and MODIS (the Moderate-resolution Imaging Spectroradiometer), have revealed that dust does not rise equally from throughout a semiarid landscape, but instead flows in

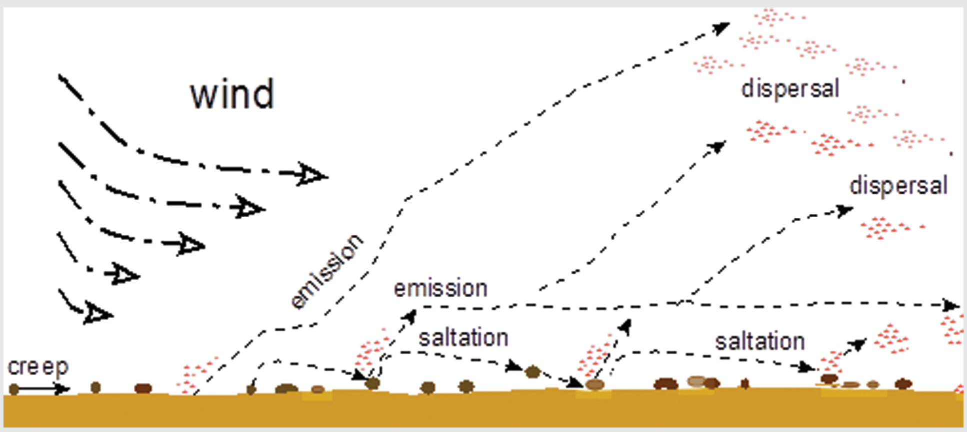

Figure 1. Illustration of the dust emission process, showing how saltation and creep of large grains release dust aerosols transported downwind. (After Dr. Robert Wallace, Ripon College: used with permission.)

discrete plumes emanating from myriad small, intense point sources which spread out downwind and coalesce into a broader shield.[15] Certain geographical features, such as flat, dry, sandy plains and the desiccated, sand-ringed beds of salt lakes, have been quantified as disproportionally frequent initiation points of these plumes compared to other landforms.[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[16] and Chinese deserts[17] falls on West Texas, and Great Plains dust from the Dust Bowl may have been deposited on the Greenland ice cap.[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,[19] and dust levels decreased significantly from the 1960s into the 21st century.[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.

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.

Keywords: dust, aerosol, wind, medical geology, Great Plains, weather

---

From: The Department of Geological Sciences, University of Texas, El Paso, TX.
Submitted: 1/5/2018
Conflicts of interest: none

References

1. Sharratt BS, Lauer D. Particulate matter concentration and air quality affected by windblown dust in the Columbia Plateau. Journal of Environmental Quality 2006;25:2011–2016.
2. Rivera Rivera NI, Gill TE, Bleiweiss MP, et al. Source characteristics of hazardous Chihuahuan Desert dust outbreaks. Atmospheric Environment 2010;44:2457–2468.
3. Kok JF. A scaling theory for the size distribution of emitted dust aerosols suggests climate models underestimate the size of the global dust cycle. Proceedings of the National Academy of Sciences 2011;108:1016–1021.
4. Bullard JE, White K. Dust production and the release of iron oxides resulting from the aeolian abrasion of natural dune sands. Earth Surface Processes and Landforms 2005;30:95–106.
5. Glenn DD. Sandstorm: Current Issues Surrounding Silica: Understanding the latest developments. Professional Safety 2008;53(2):37–42.
6. Panikkath R, Jumper CA, Mulkey Z. Multilobar lung infiltrates after exposure to dust storm: the Haboob Lung Syndrome. American Journal of Medicine 2013;126:e5–e7.
7. Buck BJ, Goossens D, Metcalf RV, et al. Naturally occurring asbestos: potential for human exposure, Southern Nevada, USA. Soil Science Society of America Journal 2013;77:2192–2204.
8. Winkler P. The growth of atmospheric aerosol particles as a function of the relative humidity—II. An improved concept of mixed nuclei. Journal of Aerosol Science 1973;4:373–387.
9. Gill TE, Stout JE, Peinado P. Composition and characteristics of aerosols in the Southern High Plains of Texas (USA). American Institute of Physics Conference Proceedings 2009;1099:255–258.
10. Wigner KA, Peterson RE. Synoptic climatology of blowing dust in the Texas South Plains, 1947-84. Journal of Arid Environments 1987;13:199–209.
11. Lee JA, Tchakerian VP. Magnitude and frequency of blowing dust on the Southern High Plains of the United States, 1947–1989. Annals of the Association of American Geographers 1995;85:684–693.
12. Lee JA, Moffett KE, Allen BL, et al. Environmental controls on blowing dust direction at Lubbock, Texas, USA. Earth Surface Processes and Landforms 1994;19:437–449.
13. Lei H, Wang JX, Tong DQ, et al. Merged dust climatology in Phoenix, Arizona based on satellite and station data. Climate Dynamics. 2016;47:2785–2799.
14. Prospero JM, Ginoux P, Torres O, et al. Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product. Reviews of Geophysics 2002;40:1002.
15. Lee JA, Gill TE, Mulligan KR, et al. Land use/land cover and point sources of the 15 December 2003 dust storm in southwestern North America. Geomorphology 2009;105: 18–27.
16. Perry KD, Cahill TA, Eldred RA, et al. Long-range transport of North African dust to the eastern United States. Journal of Geophysical Research: Atmospheres 1997;102D: 11225–11238.
17. Husar RB, Tratt DM, Schichtel BA, et al. Asian dust events of April 1998. Journal of Geophysical Research: Atmospheres 2001;106D:18317–18330.
18. Donarummo J, Ram M, Stoermer EF. Possible deposit of soil dust from the 1930's US dust bowl identified in Greenland ice. Geophysical Research Letters 2003;30:1269.
19. Lee JA, Gill TE. Multiple causes of wind erosion in the Dust Bowl. Aeolian Research 2015;19:15–36.
20. Stout JE, Lee JA. Indirect evidence of wind erosion trends on the Southern High Plains of North America. Journal of Arid Environments 2003;55:43–61.