Dust Emissions from Cattle Feeding Operations Part 1 of 2: Sources, Factors, and Characteristics

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This publication discusses the sources, factors, and characteristics of dust emissions from cattle-feeding operations.

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With the trend toward larger and more concentrated animal feeding operations (CAFOs), particulate matter (PM) emissions from open-lot CAFOs are an increasingly prominent environmental issue. This is particularly true for CAFOs located in arid and semi-arid climates, where dry conditions favor dust emissions.

Particulate matter, or solid-phase aerosols, may be classified by aerodynamic diameter, which refers to the diameter of a spherical droplet of water that would have the same settling velocity in air as the aerosol particle in question. Fine particles with a mean aerodynamic diameter of about 2.5 micrometers ($PM_{2.5}$) or less may be respired deeply into the lungs. $PM_{2.5}$ is considered a threat to human health because it is associated with respiratory impairment and premature death. The so-called "inhalable" fraction of PM generally consists of particles having a mean aerodynamic diameter less than 10 micrometers (PM_{10}) and includes the $PM_{2.5}$ fraction plus a range of coarser particles, sometimes known as PMcoarse, PMc, or $PM_{10-2.5}$. The coarse fraction of inhalable PM generally is associated with reversible human health effects (e.g., allergic reactions) and quality-of-life factors. Fugitive PM from cattle feedyards also may reduce visibility and serve as a carrier for a range of malodorous compounds.

The provenance of aerosols may be classified as *primary* or *secondary. Primary* aerosols are generated directly by mechanical (e.g., grinding, scouring) or chemical (e.g., combustion) processes. On a cattle feedyard, the main sources of primary PM are hoof action on uncompacted manure, vehicle traffic on unpaved roads, feed pro-

Figure 1. Dust events generated by open-lot concentrated animal feeding operations may reduce ground-level visibility on nearby roadways. (Photo: S. Sakirkin)

cessing (e.g., hay grinding, grain delivery), and combustion of natural gas, gasoline, and diesel fuel. The coarser, mechanically-derived particles are generally implicated in near-field to local environmental air pollution. The finer, chemically-derived particles tend to have environmental significance at the regional to national scale.

Secondary PM forms in the atmosphere as a product of acid/base or sunlight-mediated redox reactions. Secondary aerosols associated with CAFOs derive principally from gas-phase ammonia (a base), which dissolves into atmospheric moisture and there reacts with dissolved sulfate, nitrate, and/or chloride ions (all acids) to form fine particles. Because secondary PM tends to form fine to very fine particles, its environmental implications are regional to transnational.

Fugitive dust emissions from open-lot CAFOs are receiving increased regulatory scrutiny.

Regulatory Matters

Fugitive dust emissions from open-lot CAFOs are receiving increased regulatory scrutiny, especially in the San Joaquin Valley of California and in southern Arizona, where PM concentrations characteristically exceed federal standards. Currently, odors associated with dust are regulated only under nuisance provisions, in which enforcement is driven either by complaints to the state regulatory authority or by nuisance litigation.

The National Ambient Air Quality Standards (NAAQS) establish threshold concentrations for certain *criteria pollutants* above which adverse human health effects may be expected in sensitive individuals. Particulate matter is one of those criteria pollutants. As of November 2011, these standards contain three independent, primary (i.e., directed at protection of public health) standards for PM. For PM_{10}, which was first regulated under the NAAQS in 1987, the only remaining standard is a 24-hour average concentration of 150 micrograms PM_{10} per cubic meter ($\mu g/m^3$). For $PM_{2.5}$, there are currently two standards, a 24-hour average concentration of 35 $\mu g/m^3$ and an annual average concentration of 15 $\mu g/m^3$. Any airshed in which PM concentrations exceed the NAAQS[†] for any criteria pollutant is classified as a nonattainment area (NAA). At present, southern Arizona and south central California are designated as nonattainment areas for PM_{10}, and central and southern California have a number of nonattainment areas for $PM_{2.5}$. In both states, the state implementation plan (SIP) for returning to compliance with the NAAQS prominently involves beneficial management practices (BMPs) for agricultural sources, including CAFOs.[‡]

State air pollution regulatory authorities administer and enforce air pollution regulations. Many states have established their own regulations, which are more stringent than those set by federal agencies. Several states administer programs to monitor ambient air quality, issue operating permits, and conduct compliance inspections and enforcement actions.

Emission Factors and Characteristics

High concentrations of fugitive dust from open-lot CAFOs result from three primary factors. The raw material for dust emissions is uncompacted manure (often mixed with soil) on corral surfaces. The drier that manure is, the more susceptible it is to emission as dust.[§] The mechanical energy required to emit the dust is either animal hoof action or wind scouring (Mielke et al., 1974), so elevated concentrations may occur during periods of increased animal activity or during high-wind events. Finally, and perhaps most important, relatively stable atmospheric conditions known as *inversions* may confine ground-level emissions to a shallow layer of air at the ground level rather than dispersing it to higher elevations through atmospheric turbulence.

Footnotes

[†]"Violation" of the standard does not mean a single instance of a measurement exceeding the numerical standard; rather, "violation" is defined statistically. In the case of the 24-hour PM_{10} standard, three measurements exceeding the standard within a three-year period constitute a violation of that standard. The statistical provisions for the two $PM_{2.5}$ standards are slightly more complicated.

[‡]See e.g., *http://www.azda.gov/ACT/CMPCostEff.pdf* (accessed 13 November 2011).

[§]See Razote et al. (2006), "Laboratory evaluation of the dust-emission potential of cattle feedlot surfaces," *Transactions of the ASABE* 49(4):1117-1124; and Guo et al. (2011), "Laboratory evaluation of dust-control effectiveness of pen surface treatments for cattle feedlots," *Journal of Environmental Quality* 40(5):1503-1509.

A diurnal pattern of dust emissions peaking shortly after sunset is commonly observed at many CAFOs in the semi-arid West. This phenomenon, commonly known as the evening dust peak (EDP), results from the temporal coincidence of the three primary factors. First, pen surface moisture is at its daily minimum in the late afternoon to early evening so that dry pen-surface conditions predominate (McCullough et al., 2001). Second, as the sun angle and daytime temperatures decrease, cattle become more active, and the increased hoof action suspends more manure particles in the air. Third, atmospheric stability increases, the boundary-layer mixing height decreases, and winds diminish, reducing atmospheric dispersion. When those three conditions coincide, the peak short-term concentration (e.g., 5- to 30-minute averages) may be 10 to 15 times higher than the 24-hour average (*Figure 2*).*

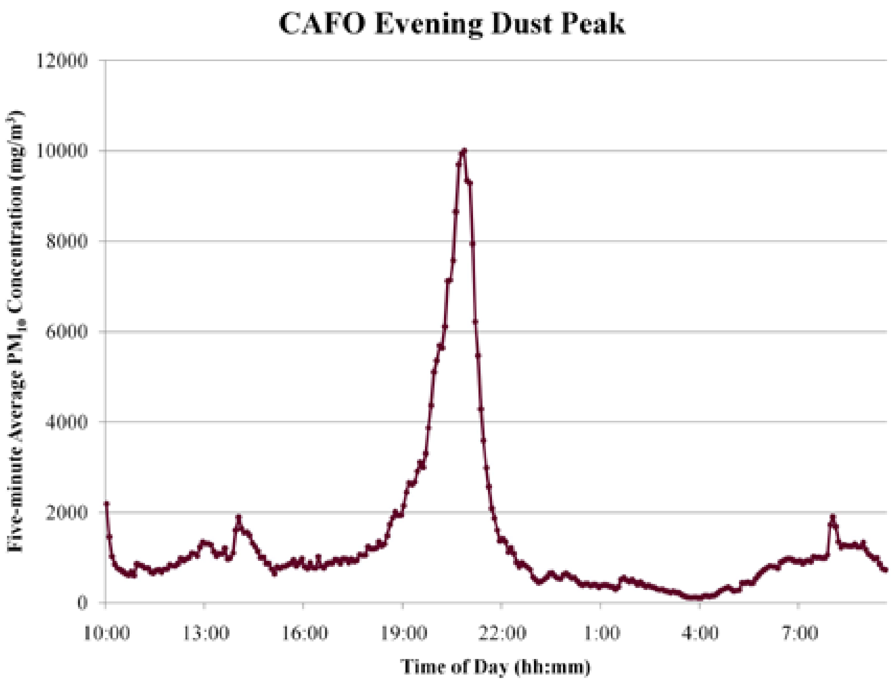

Figure 2. Five-minute average PM_{10} concentrations immediately downwind of the pen area showing the diurnal pattern of the evening dust peak typical of cattle feedyards in the West. Note that these data are not property-line concentrations.

Many states monitor ambient air quality, issue operating permits, and conduct enforcement.

Footnote

*These values of the peak-to-mean ratio are characteristic of open-lot beef feed-yards. For open-lot dairies, which feature significantly different patterns of animal behavior and increased shaded area as compared with feedyards, the peak-to-mean ratio is considerably smaller. See Auvermann (2011), "Texas/New Mexico open-lot research," Proceedings of the Western Dairy Air Quality Symposium, Sacramento, CA, April 20.

References

Auvermann, B. A. 2011. Texas/New Mexico open-lot research. Proc. Western Dairy Air Quality Symposium. Sacramento, Cal.

Guo L., R. G. Maghirang, E. B. Razote, and B. W. Auvermann. 2011. Laboratory evaluation of dust-control effectiveness of pen surface treatments for cattle feedlots. *J. Environ. Quality* 40(5):1503-1509.

McCullough, M. C., D. B. Parker, C. A. Robinson, and B. W. Auvermann. 2001. Hydraulic conductivity, bulk density, moisture content, and electrical conductivity of a new sandy loam feedlot surface. *Appl. Eng. in Agric.* 17(4): 539-544.

Mielke, L. N., N. P. Swanson, and T. M. McCalla. 1974. Soil profile conditions of cattle feedlots. *J. Environ. Quality* 3(1):14-17.

Razote, E. B., R. G. Maghirang, B. Z. Predicala, J. P. Murphy, B. W. Auvermann, J. P. Harner III, and W. L. Hargrove. 2006. Laboratory evaluation of the dust-emission potential of cattle feedlot surfaces. Trans. ASABE 49(4):1117-1124.

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