particulate matter:
measurement techniques

brent w. auvermann
associate professor and extension agricultural engineer
amarillo, tx
outline

- the role of PM measurement in dairy production
  - regulation
  - research
  - self-assessment
- what is PM, and how is it classified?
- what techniques are available to measure PM?
  - direct
  - indirect
the role of PM measurement in dairy production

- regulation
  - mass concentrations \([M \text{ L}^{-3}]\)
    - federal (National Ambient Air Quality Standards)
    - state and local ambient standards
  - emission rates \([M \text{ T}^{-1} \text{ or } M \text{ L}^{-2} \text{ T}^{-1}]\)
    - federal CAA permitting
      - Title V “major sources”
      - New Source Review (NSR)
      - Prevention of Significant Deterioration (PSD)
  - legal proceedings
    - nuisance odor
    - visibility impairment and liability
the role of PM measurement in dairy production

- research
  - baseline monitoring
    - what are the typical concentrations?
    - how do they vary over time?
      - diurnally
      - seasonally
      - with capacity changes
  - determining “emission factors”
    - rate of emissions per unit throughput or production
    - lbs PM$_{10}$ per day per 1,000 day capacity
    - lbs PM$_{2.5}$ per cwt of milk produced
the role of PM measurement in dairy production

- research (cont’d)
  - evaluating abatement measures
    - am i achieving my goals?
    - am i creating new problems by solving old ones?
    - am i spending my money wisely?
    - how could i achieve my goals more efficiently?
    - energy
    - currency
    - labor intensiveness
  - projecting downwind concentrations
    - what are my neighbors’ likely exposures?
    - is there a need to reduce their exposures?
the role of PM measurement in dairy production

- self-assessment
  - determining baseline performance
  - evaluating management changes
    - environmental management systems (EMS)
    - documenting improvements
  - planning future steps
  - engaging neighbors and communities
  - going beyond *what is required to what is possible*
what is PM, and how is it classified?

- no such thing as a “10-micron particle” *per se*
- livestock PM tends to be a mixture of many particle types of variable shape and composition
  - fibers (livestock hair, fibrous feedstuffs)
  - slivers and flakes (dander, clay particles)
  - conglomerates
  - sand and silt
“aerodynamic diameter”
The graph shows the cumulative mass fraction of particles with an aerodynamic diameter less than a certain size for two different aerosols: Aerosol #1 and Aerosol #2.

The median mass median diameter (MMD) is indicated as 17 μm for both aerosols, suggesting they have similar dispersion characteristics in terms of mass distribution.
Particle Size Distributions of Two Aerosol Types

- Aerosol #1
- Aerosol #2
Why Classify Particles by Aerodynamic Diameter?

- Main focus is *human respiratory health*
- The smaller the particle, the easier it is to carry along sharp turns without colliding with the passage walls
- In respiratory systems, the smaller particles penetrate deeper into the lungs where $O_2/CO_2$ exchange occurs
- PM$_{2.5}$ is more of a health threat than PM$_{10}$ or PM$_{50}$

Adapted from Schlesinger et al. (1977)
fine particles are important for other reasons, too
fine particles are important for other reasons, too
what techniques are available to measure PM?

- physical basis
  - direct
    - mass concentration (µg/m³)
    - number concentration (particles/m³)
    - total vs. size-selective aerosols (TSP vs. PMₓ)
  - indirect
    - active (transmissometry, nephelometry, aethalometry)
    - passive (target imaging)
what techniques are available to measure PM?

- time basis
  - time-averaged
    - ambient standards (24-hr, annual)
    - occupational standards (8-hr, 30-min)
    - federal or state “reference methods”
    - obscures short-term phenomena
    - relatively inexpensive to buy, but may be expensive to run
  - continuous/instantaneous
    - more information; can be used to compute time averages
    - “equivalent methods”
    - relatively high capital expense, but lower labor requirements
a virtual tour of some methods
Federal Reference Method (TSP)

- No longer used for federal compliance monitoring
- Measures total suspended particulate (\(\sim \text{PM}_{50}\))
- Operates at 40 cfm
- Captures TSP on an 8”x10” fiberglass filter
- Filter processing required
  - Pre-exposure conditioning to RH, temp specs
  - Pre-exposure weighing
  - Post-exposure conditioning
  - Post-exposure weighing
Federal Reference Method (PM\textsubscript{10})

- Currently used for compliance monitoring
- Size-selective inlet collects larger particles on oily impactor surface
- Operates at 40 cfm
- Captures PM\textsubscript{10} on an 8”x10” fiberglass filter
- Filter processing required
- FRMs also exist for PM\textsubscript{2.5} compliance monitoring
Tapered-Element Oscillating Microbalance (TEOM)

- Continuous monitor
- May be equipped with size-selective inlets for PM$_x$