Recent Developments in Air Quality From Dairies and Cattle Feedyards

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Where We're Going

1. Quickly: what we care about in air quality, and why
2. A closer look at the biggies, what's been done about them lately, and what it all implies
3. A few closing observations

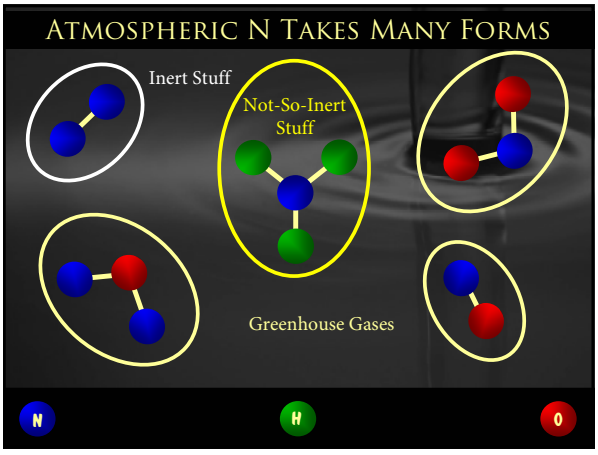
What's All the Fuss?

- Ammonia (NH_3)
- Particulate Matter (PM)
- Odors
- Volatile Organic Compounds (VOCs)
  - VOC
  - RVOC
  - HRVOC
  - OVOC

What's All the Fuss?

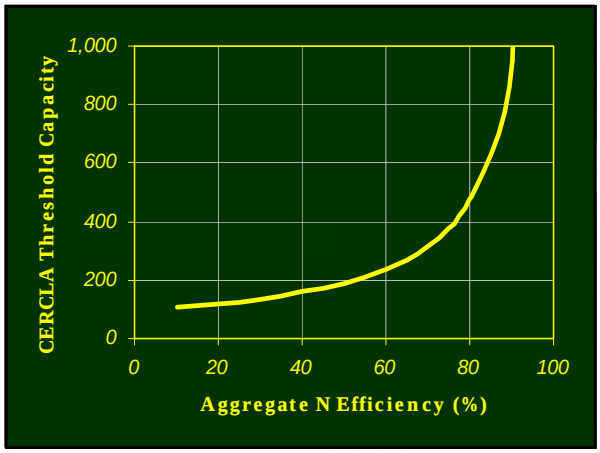
- Hydrogen Sulfide (H_2S)
- Ground-Level Ozone (O_3)
- Greenhouse Gases
  - CO_x
  - N_xO_y
  - C_xH_y
  - others

Atmospheric N Takes Many Forms

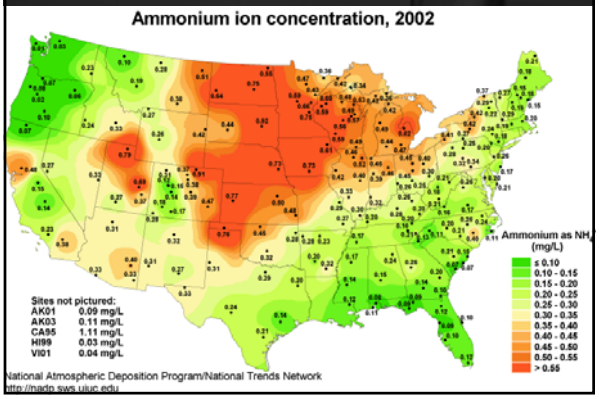


NH_3 Has Some Issues

- Monitoring and reporting requirements under EPCRA?
  - Hazardous substance
  - Reportable quantity = 100 lb
- Neutralizes acid gases (e. g., SO_x, NO_x)
  - Gaseous precursor to fine PM
  - Increases NH_3's atmospheric residence time
  - Helps reduce visibility
- Emissions represent a waste
  - Nutrients
  - Energy!
- Tremendously reactive and "sticky"



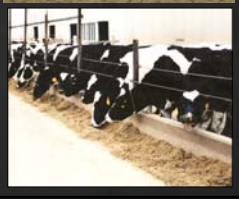
Wet Deposition of NH_4^+



Open-Lot Systems

- Beef feedyards
  - Animal spacing 75-250 ft^2/hd
  - Excreted N 90% of N consumed in feed (Bierman et al., 1996)

- Open-lot dairies
  - Animal spacing 200-400+ ft^2/hd
  - Excreted N 70% of N consumed in feed (Van Horn et al., 1996)



Back-of-the-Envelope Stuff

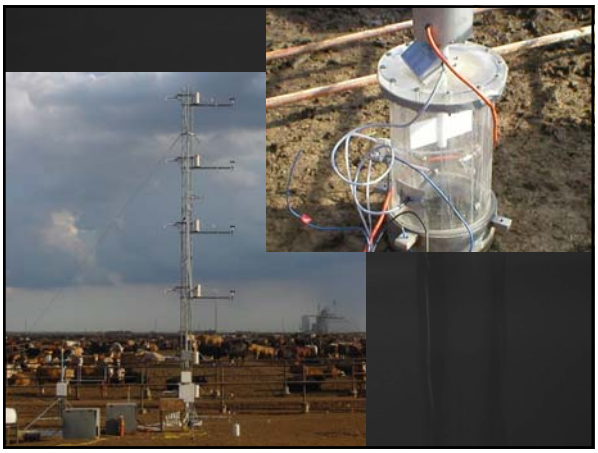
- Assuming an industry-wide (cattle feeding) N-use efficiency of 70%, commercial yards larger than 500 head (!) could be subject to EPCRA
- The N-use efficiency required for a 35,000-hd feedyard to emit less than 100 lb/d? ***>99%***
- The N-use efficiency required for a 2,000-hd dairy to emit less than 100 lb/d? ***>95%***

The Holy Grail

A range of emission factors that expresses the most probable, scientifically justifiable, seasonalized, daily NH_3 emission flux from feedyards and dairies as a function of herd size, stocking density or other appropriate measure of capacity or throughput

Available Methods

- Envelope approaches
  - Mass balance
  - Nutrient ratio (N:P)
- Direct approaches
  - Surface isolation flux chambers
  - Wind tunnels
  - Eddy covariance
- Dispersion/box models
  - Gaussian (ISCST, AERMOD)
  - Lagrangian stochastic – backward, forward
  - Integrated horizontal flux (IHF)
  - Flux-gradient
  - Box



Findings

Method	Beef	Dairy	Comments
	Lb N/1,000 hd-d		
N Balance	195	<650	Uncertainty analysis nearly complete; 30% during winter, 70% during summer: Includes NH_3 and other gaseous N losses
N:P Ratio	213		Includes NH_3 and other gaseous N losses
Flux Chamber	82	26 (OL) 38 (FS)	Dairy #1 (FS): 54 ± 27 (S); 21 ± 22 (W) Dairy #2 (OL): 34 ± 3 (S05); 17 ± 2 (S04) Beef in summer
Flux-Gradient	191		Uncertainty analysis underway
bLS/OPL	182		Uses open-path lasers to measure N
Box Model	191		

Findings

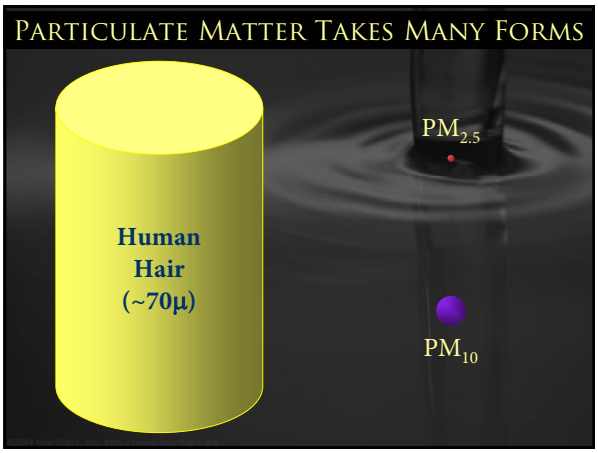
Method	Beef	Dairy	Comments
	% of Fed N		
N Balance	44	<80	Uncertainty analysis nearly complete (beef)
N:P Ratio	48		Varies from 20-51% depending on source material (fresh manure, pen surface, compost)
Flux Chamber	18	3 (OL) – 5 (FS)	Herds are ~15% dry cows, ~85% lactating; excreted N is 79% of fed N
Flux-Gradient	43		Uncertainty analysis underway
bLS/OPL	41		Uses open-path lasers to measure N
Box Model	31-55		

Particulate Matter

Nucleation

- In aqueous solution, two or more species react to form a low-solubility product known as a precipitate
- Because the precipitate has relatively low solubility, it immediately forms a solid particle in aqueous suspension
- The particle provides a surface on which more of these reactions can occur

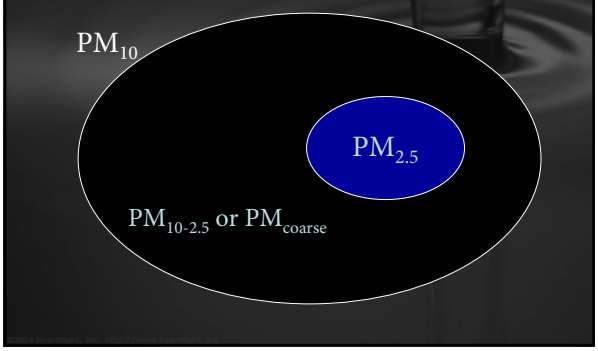
Particulate Matter Takes Many Forms



A Primer on PM

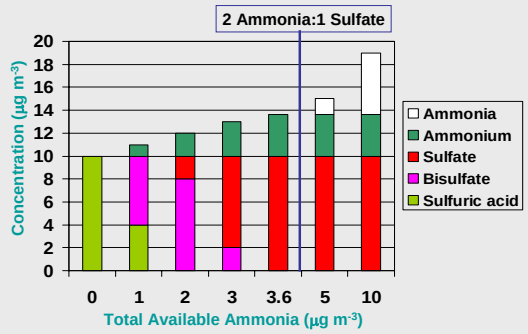
- Particle "diameter" is kind of a misnomer
  - Shape, density and volume
  - Aerodynamic equivalent diameter?
  - Equivalent spherical diameter?
- Not all PM is created equal
  - Mechanically vs. chemically derived
  - Inert vs. reactive
  - Chemical vs. biological vs. physical activity
- Physiological significance
  - Composition x size x dose
  - Inhalable vs. respirable

Fractions of Interest



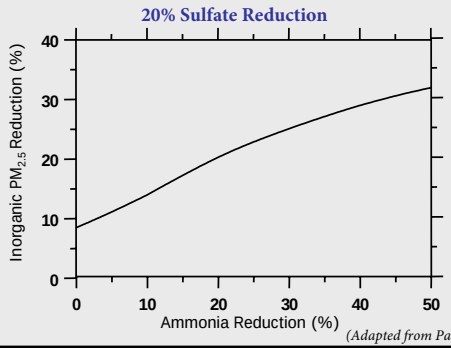
Secondary $PM_{2.5}$

The Sulfuric Acid/Ammonia System



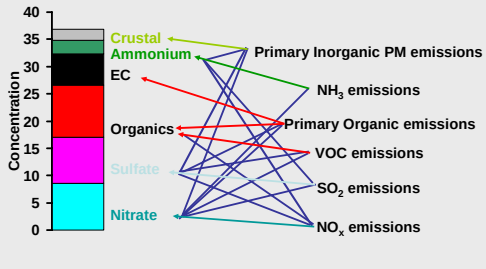
(Adapted from Pandis, 2003)

Reductions in Ammonia (July 2001)



(Adapted from Pandis, 2003)

Interactions between Fine PM and Their Precursors



$PM_{2.5}$ Composition during the Winter

(Adapted from Pandis, 2003)

Air Pollution in Pittsburgh

(Adapted from Pandis, 2003)

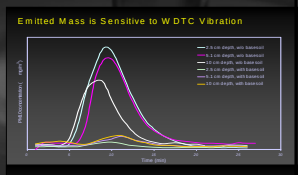
Open-Path Transmissometry

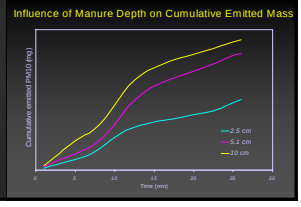
Extinction efficiencies for ubiquitous particle types (Malm, 1999)

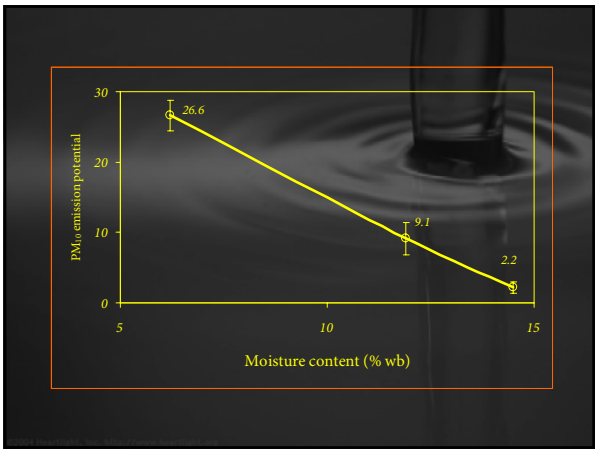
Particle Type	*Dry Extinction Efficiency (m^2/g)*
Sulfates	3.0
Organics	3.0
Elemental Carbon	10.0
Nitrates	3.0
Soil Dust	1.25
Coarse Particles	0.6
Feedyard PM_{10}/TSP	***0.5-0.6/0.3-0.4***

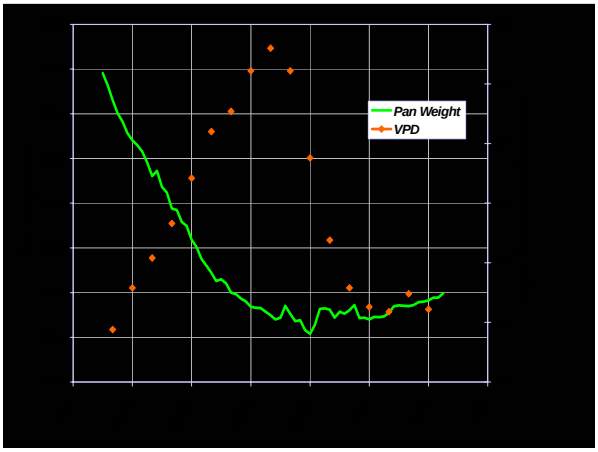
Primary PM

Weight Drop Test Chambers (TAES & KSU)



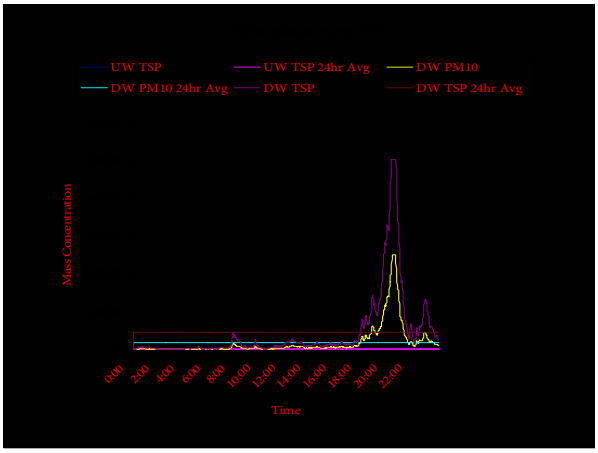


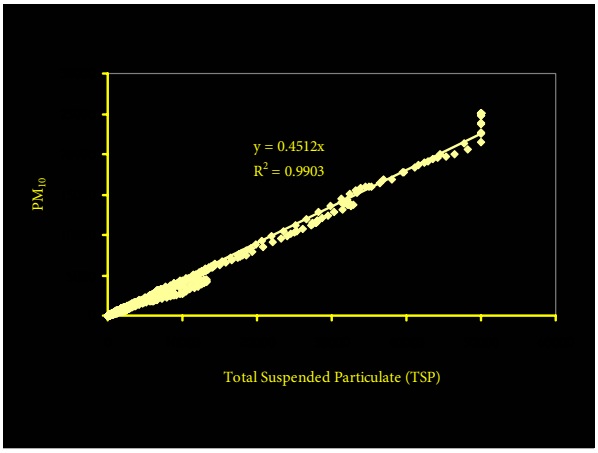


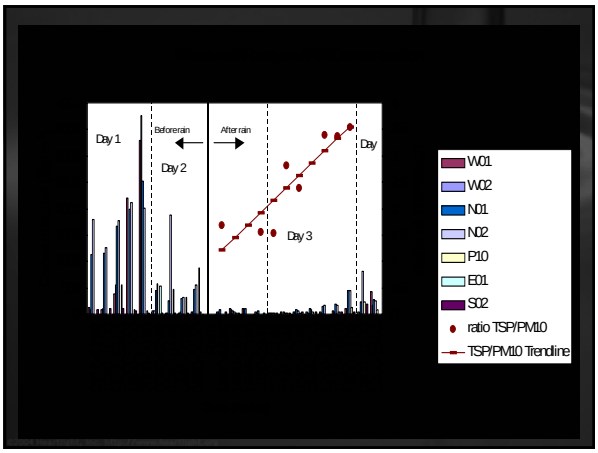


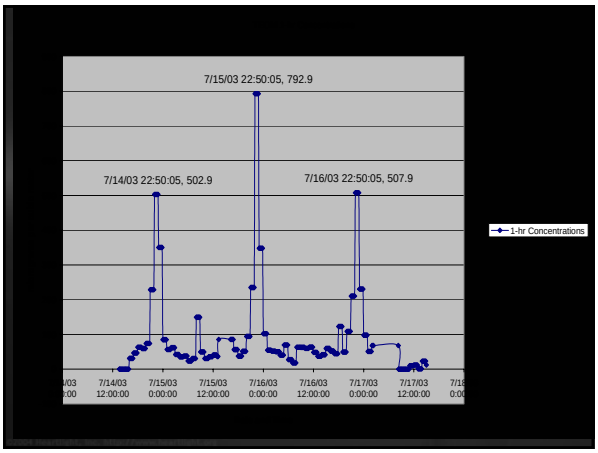
Continuous PM Monitoring, Feedyard "C"

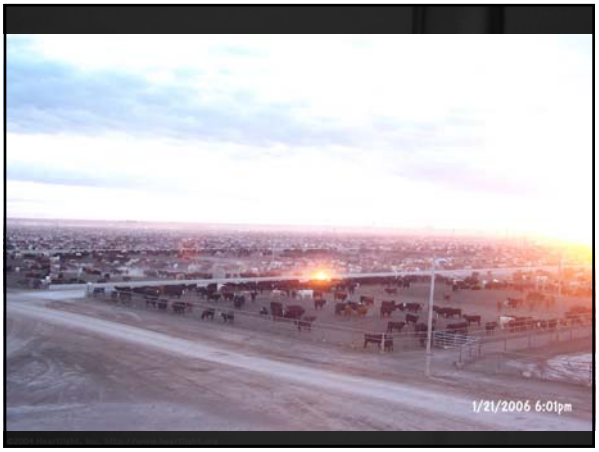
- Diurnal concentration trends
- PM_{10}/TSP ratio
- Dispersion modeling to infer emission rate
- Federal reference methods vs. continuous methods
- Visibility vs. PM concentration & RH











Take These Home With You

- In the West, relying on water alone for open-lot dust control is a no-no
- Manure harvesting
  - reduces dust potential directly AND
  - makes applied water go further
- Ammonia emissions are ~40-50% of fed N
- Abatement measures?
  - We know how to do it
  - Big money, big energy, big hassle