From Ammonia to $PM_{2.5}$

Brent Auvermann
Texas Cooperative Extension
Texas Agricultural Experiment Station
Amarillo, TX

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Forms of Atmospheric Nitrogen

N_2

NO_X

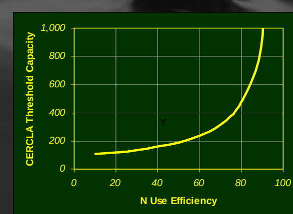
NH_3

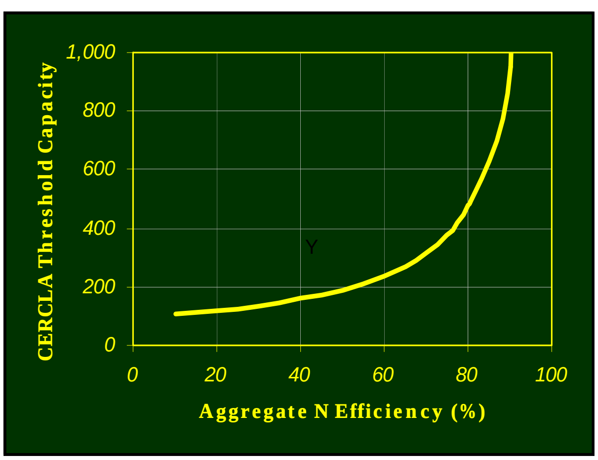
N_2O

NO

NH_3 – What's the Big Deal?

- Superfund/EPCRA – Federal litigation on broad CAFO front
  - Multiple species
  - Multiple states
  - Do the math
- NH_3 + (SO_4, NO_3 or Cl) >> $PM_{2.5}$
- NH_3 + PM >> synergistic effect on animal pulmonary health >> effect on *human* health?





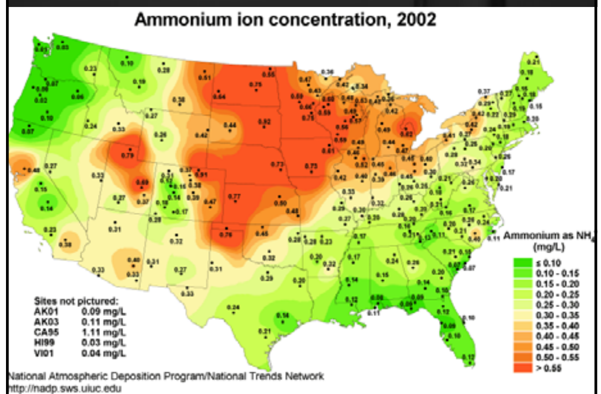
Open-Lot Systems

- 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)

Fate of Excreted N in Open-Lot Systems

- Collected in solid manure
  - Spread
  - Stored (stockpiles, mounds, other)
  - Composted and spread
- Remains on corral surface
  - Stable if it remains dry
  - Runs off into holding pond
- Volatilized as NH_3(g) directly
  - Increases with wet/dry cycling

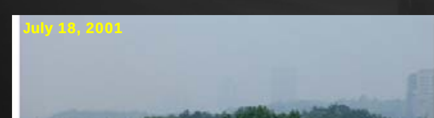


Extinction efficiencies for ubiquitous particle types (Malm, 1999)

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***

Air Pollution in Pittsburgh

$PM_{2.5}$=4 μg m^{-3}



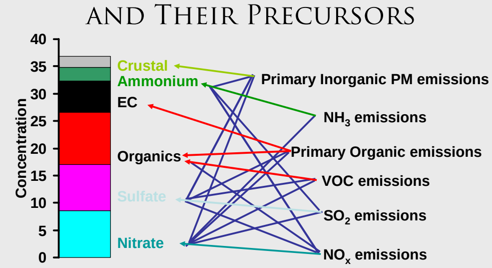
$PM_{2.5}$=45 μg m^{-3}

(Adapted from Pandis, 2003)

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

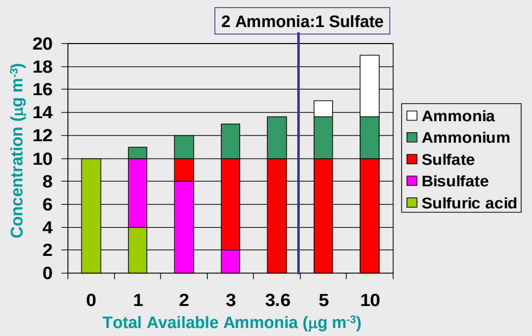
Interactions between Fine PM and Their Precursors



$PM_{2.5}$ Composition during the Winter

(Adapted from Pandis, 2003)

The Sulfuric Acid/Ammonia System (Pandis, CMU)



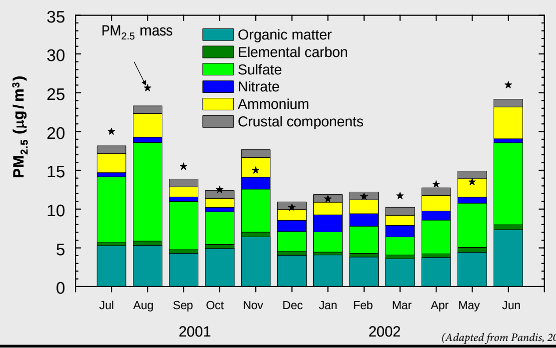
(Adapted from Pandis, 2003)

Ammonium Nitrate Formation

- The formation of ammonium nitrate requires
  - Nitric acid (major sources of NOx in the US are transportation and power plants)
  - Free ammonia (ammonia not taken up by sulfate)
- The formation reaction is favored at:
  - Low temperatures (night, winter, fall, spring)
  - High relative humidity
- Hypothesis: A significant fraction of the sulfate reduced will be replaced by nitrate when SO_2 emissions are reduced.

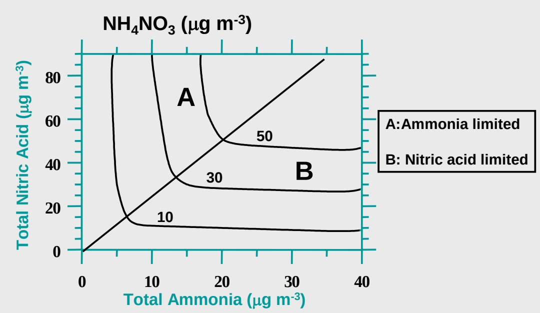
(Adapted from Pandis, 2003)

Fine PM Composition



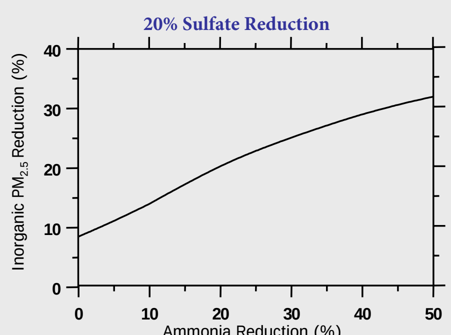
(Adapted from Pandis, 2003)

Which is the Limiting Reactant?



(Adapted from Pandis, 2003)

Reductions in Ammonia (July 2001)



(Adapted from Pandis, 2003)

Reducing Inorganic $PM_{2.5}$

- Controls of SO_2 will reduce sulfate and $PM_{2.5}$ in all seasons.
- A fraction of the now existing sulfate will be replaced by nitrate.
- For Pittsburgh, ammonia controls in all seasons can minimize the replacement of sulfate by nitrate.
- For Pittsburgh, NO_x controls will help reduce the nitrate during the winter but they will have a small effect during the summer.

(Adapted from Pandis, 2003)