Adverse Environmental and Off-Site Human Health Effects from Airborne Emissions Emitted from Concentrated Animal Feeding Operations

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James A. Zahn, *Ph.D*

United States Department of Agriculture-Agricultural Research Service

National Swine Research & Information Center

2150 Pammel Drive, Ames, IA 50011 USA

Zahn@nsric.ars.usda.gov

Air Pollutants Emitted from Concentrated Animal Feeding Operations

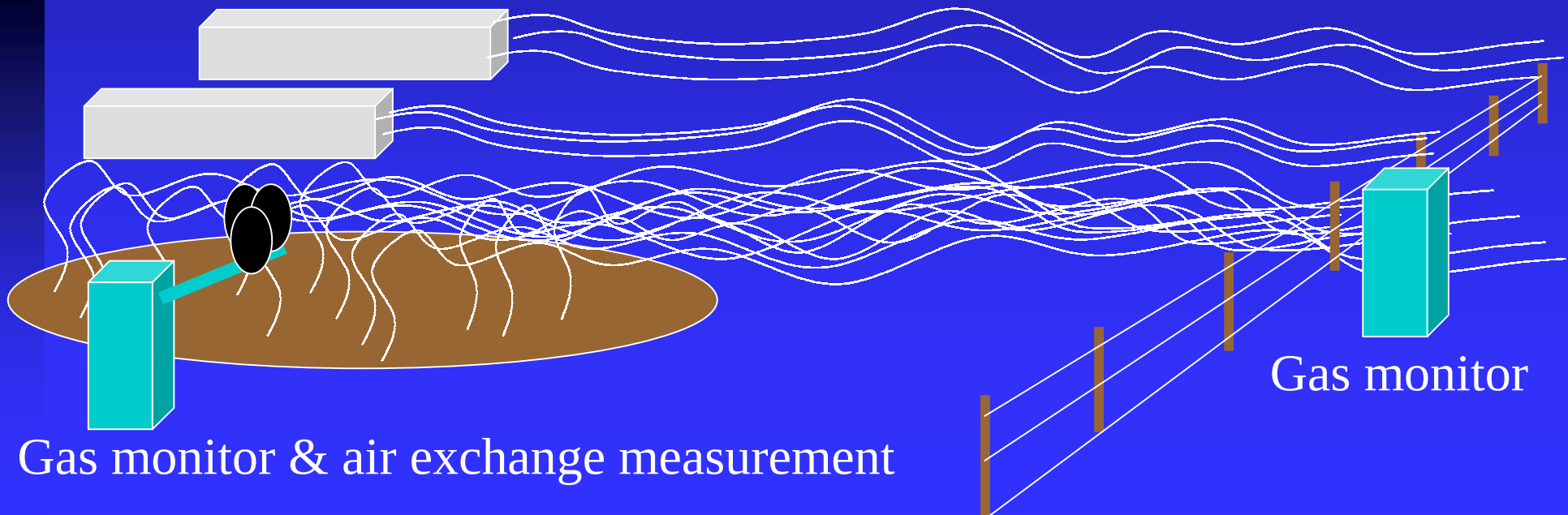
- Non-organic nitrogen-containing compounds:
  - Ammonia (NH_3)*
  - Dinitrogen (N_2)
  - Nitrous oxide (N_2O)
- Hydrogen sulfide (H_2S)*
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Non-methane organic compounds (certain VOC*)
  - Volatile organic compounds (VOC; generally vapor pres. ≥0.1 mm Hg)
  - Non-volatile organic compounds (vapor pres.<0.003mm Hg; >140 amu)
- Particulate matter*
  - Bioaerosols/bioactive compounds (fungi, bacteria, LPS, bioactive secondary metabolites, ect…).

* = regulated air pollutants

Regulation of Emissions from CAFOs:

Measuring Gas Releases from a Point Source

- Concentration of compound in air (μg H_2S per m^3 of air).
  - Advantages: true health-related measure, inexpensive, simple.
  - Disadvantages: concentration is dependent upon wind direction, wind speed, distance, and strength of source (solution to pollution is dilution).
- Emission rate: (μg H_2S per m^2 surface area per second).
  - Advantages: total amount of compound released from point source over time. Independent of environmental conditions and post-source dilution.
  - Requires air flow/air exchange rate and expensive equipment-labor.



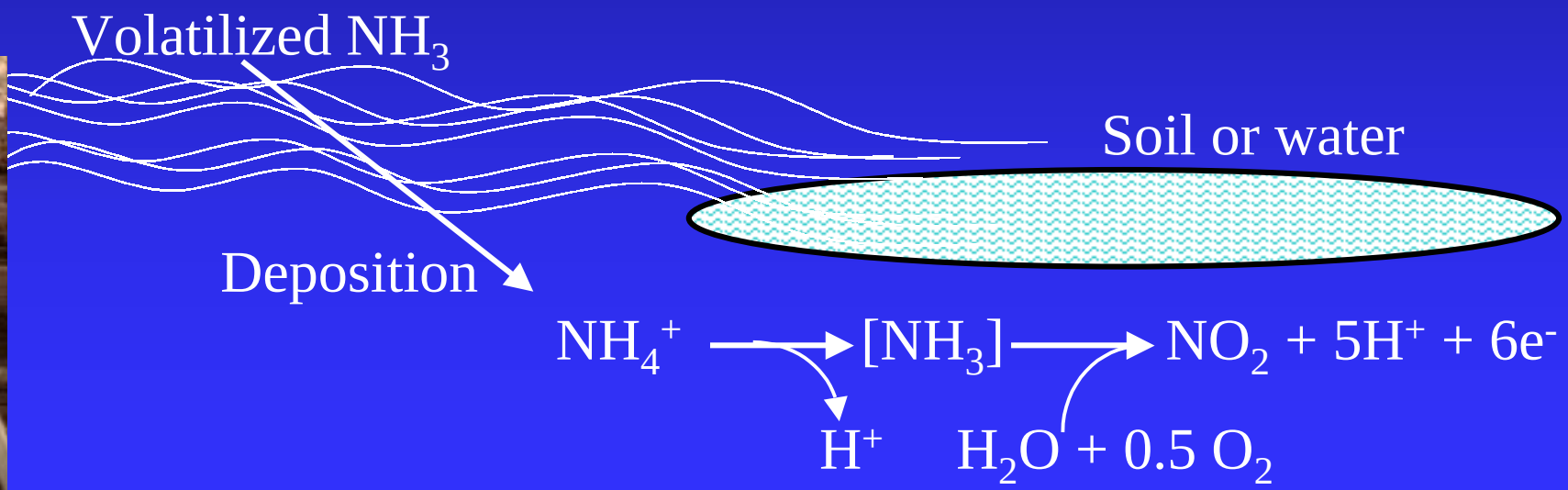
Air Quality Regulations In Agriculture

- Nuisance: (used in 10 States; no measurable standard for calibration)
  - Colorado: Sentometer 7:1 at property boundary
  - Missouri: Sentometer 5.4:1 at property boundary
    - A Dead End? Enforcement problems: a) human olfactory measurement, b) grab sampling.
  - Minnesota & California (mean olfactory perception level = 30 ppb)
    - H_2S 70µg*m^{-3} (70ppb) 0.5 hr ave; ≤ 2 occurrences * $year^{-1}$
    - H_2S 42µg*m^{-3} (30ppb) 0.5 hr ave; ≤ 2 occurrences* 5 day $period^{-1}$
- Human Health / Environmental Quality:
  - At the point source:
    - Occupational exposure standards (i.e. H_2S TWA; 15,000 µg*m^{-3})
    - Superfund; Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 40 CFR Part 302; (NH_3, H_2S, VOC, PM) 100 lbs*day^{-1} from point source.

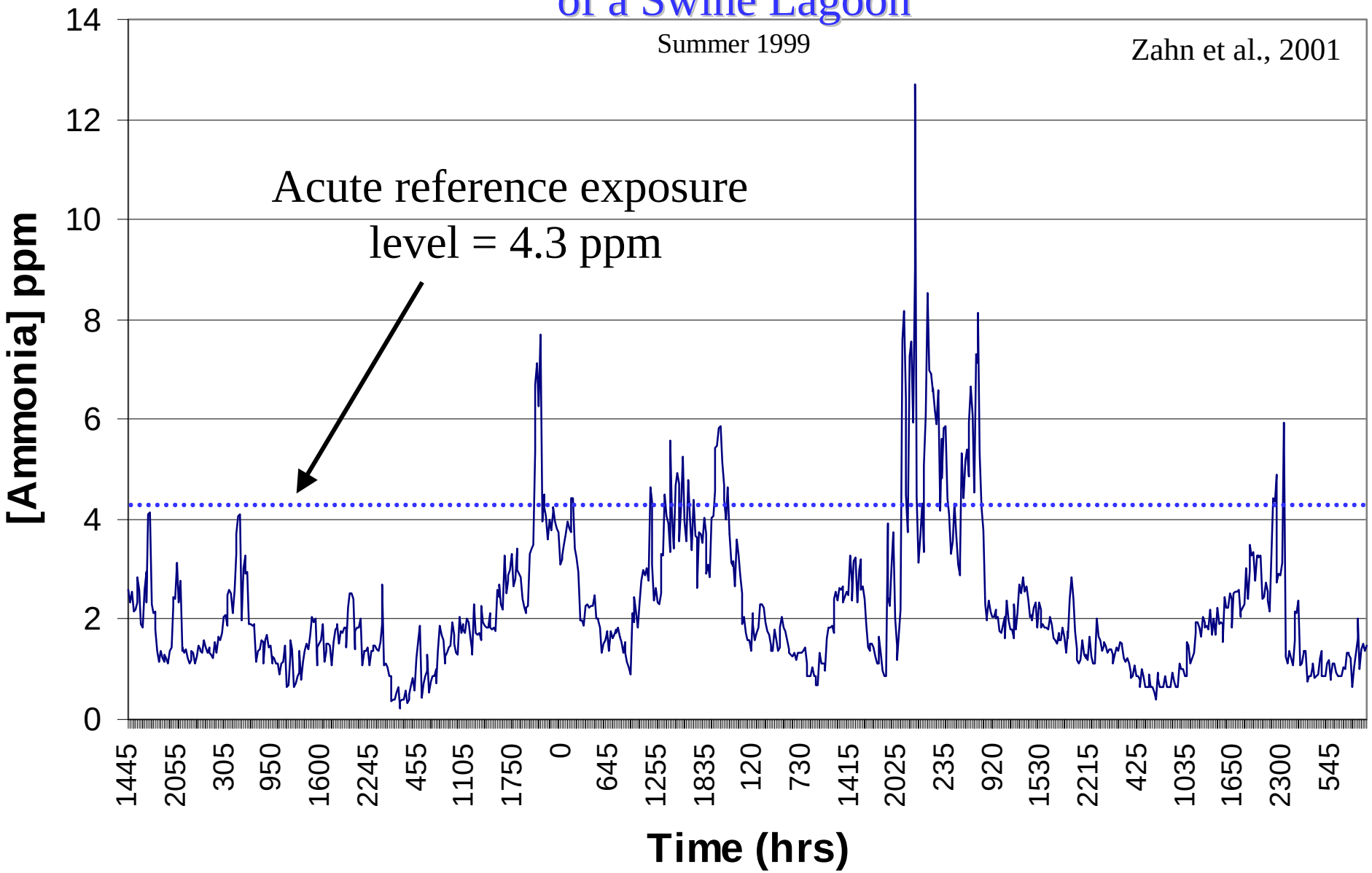
    -- Basis of recent (2000-2002) EPA lawsuits against Premium Standard Farms --
  - Down wind from the point source:
    - Acute health risk values. Below-Lowest Observed Adverse Effect Level (LOAEL) intended to protect sensitive subgroups located near point source.

Impact of CAFO Emissions on the Environment and Human Health

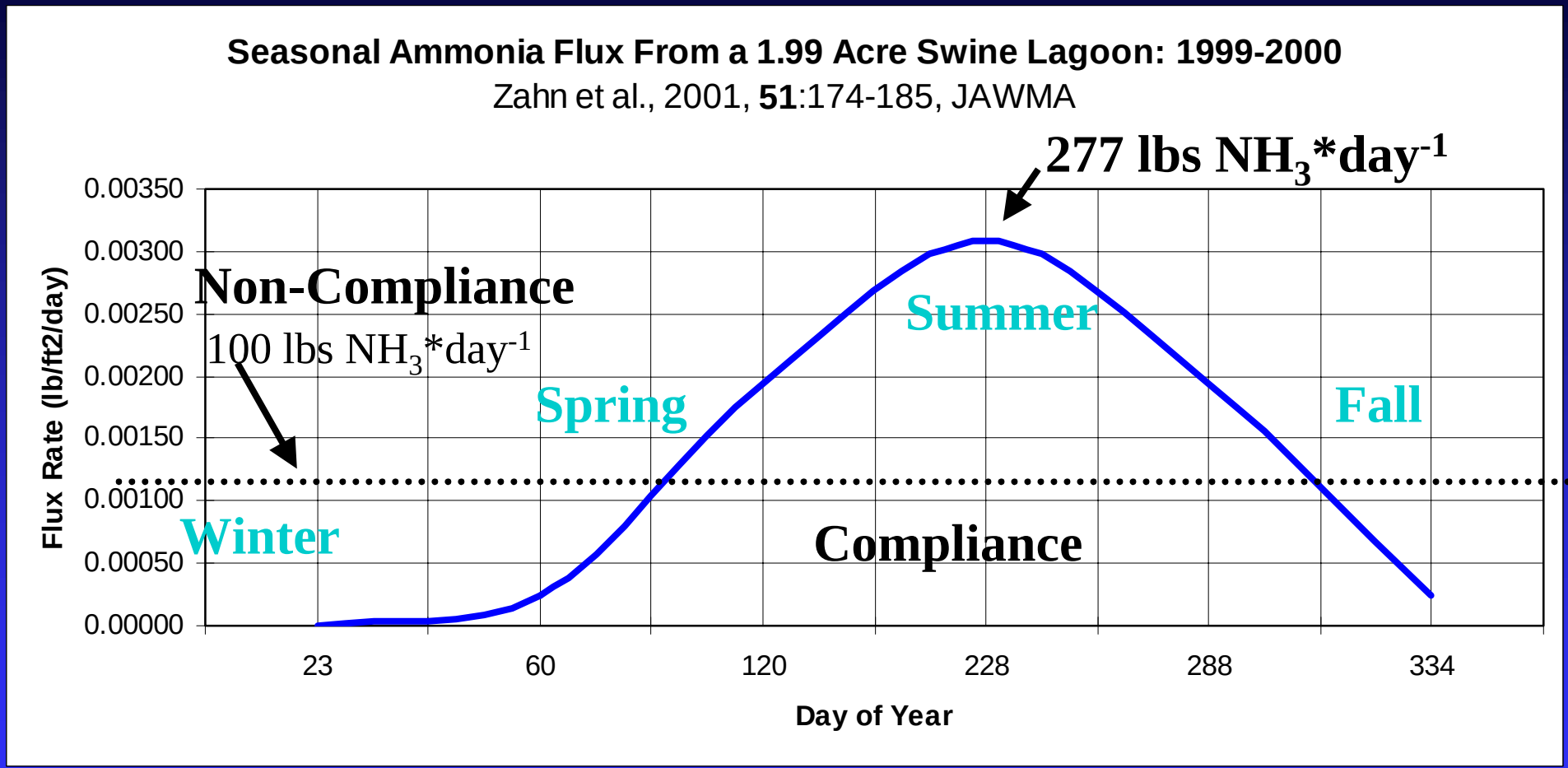
- Ammonia (NH_3):
  - U.S. EPA hazardous substance (recent CERCLA waiver).
  - Acute reference exposure level (1 hr) 3.2 $mg*m^{-3}$ or 4.3 ppm.
  - Deposition associated with decreased water quality and acidification.
  - European "target" air pollutant: <157 kton yr^{-1} (70% reduction standard) by the year 2005. Agriculture considered to produce >80% of total atmospheric NH^3.



Concentration of Ammonia in Air Sampled on the Berm of a Swine Lagoon



Evidence for CERCLA Non-Compliant Swine Lagoon

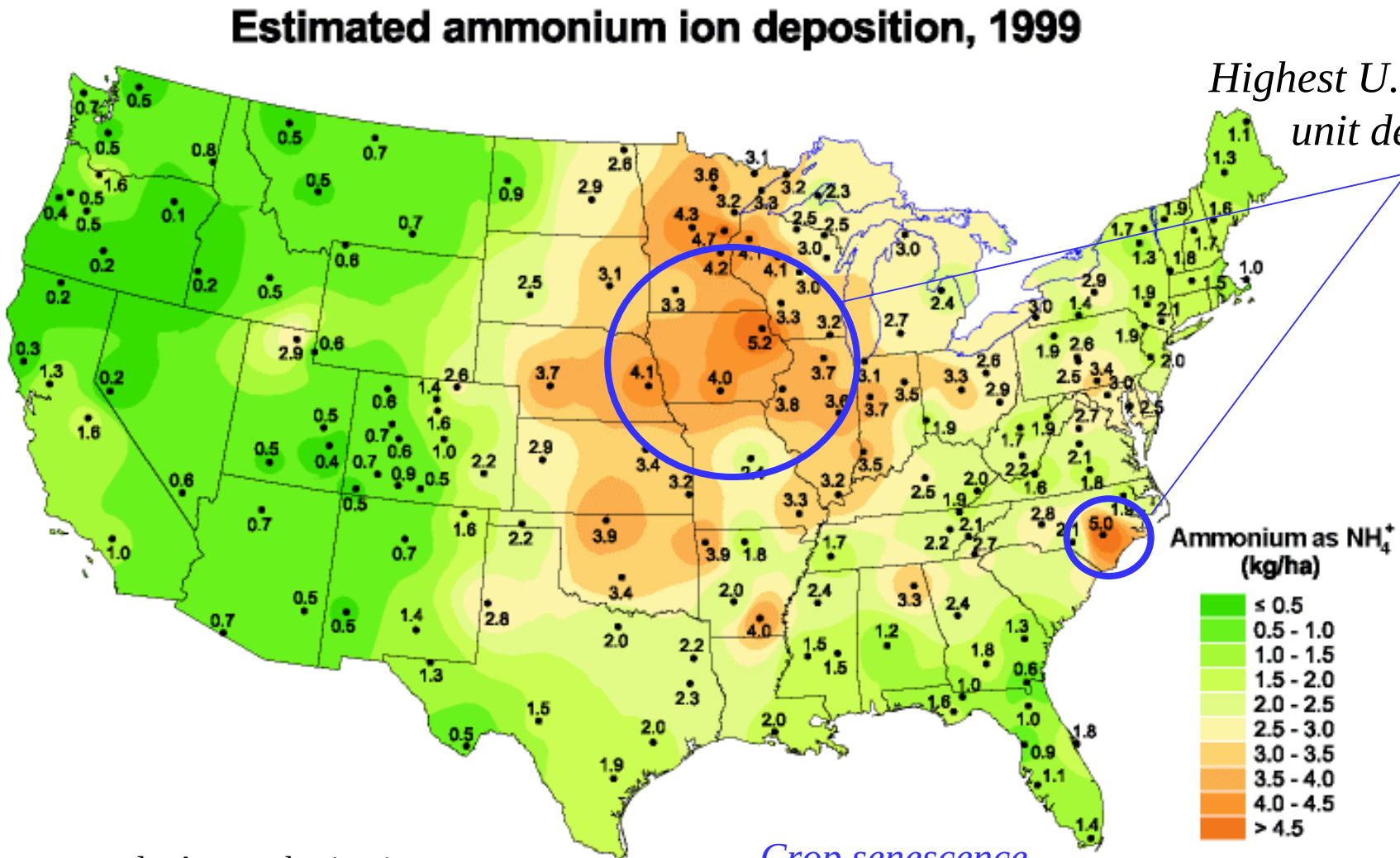


In perspective: 157,000 U.S. swine production facilities produce 103,000,000 hogs yr^{-1}

157,000 facilities x 277 lbs*day^{-1} = 43,489,000 lbs NH_3*day^{-1} from U.S. swine production

Zahn et al., 2001

CAFO Density as a Major Contributor to Atmospheric Ammonia Deposition



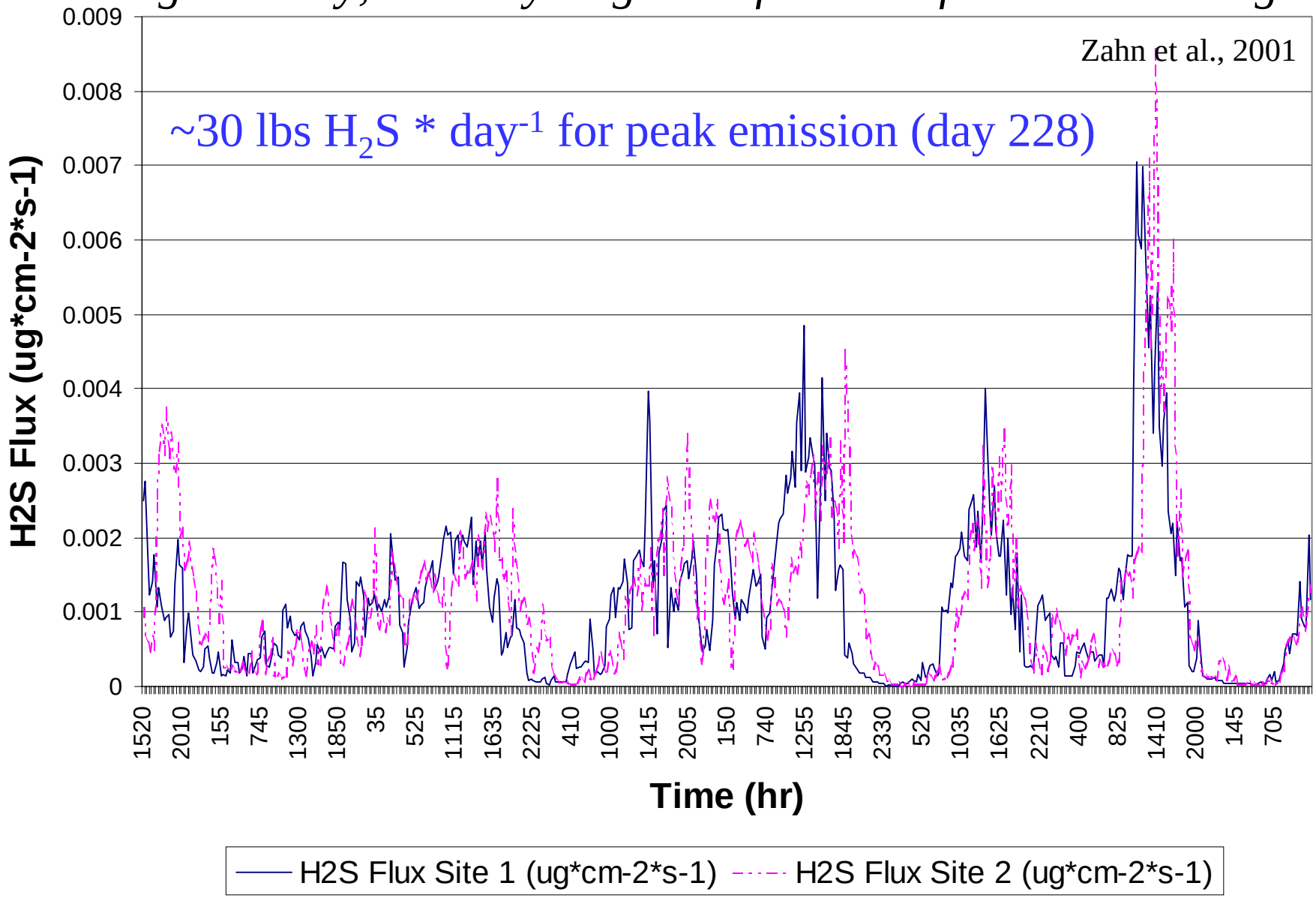
Lawrence, et al., Atmospheric nitrogen In the Mississippi River Basin – Emissions deposition And Transport, Science to the Total Environment, **248**: 87-99

Crop senescence
CAFO emission
Nitrogen fertilization

Impact of CAFO Emissions on the Environment and Human Health

- Hydrogen sulfide (H_2S):
  - Major weakly acidic gas emitted from CAFOs.
  - Ambient air quality standard to limit odor nuisance.
    - Only certain states (MN, CA)
    - Mean olfactory perception 30 ppb (42 $\mu g*m^{-3}$).
    - Easy and relatively inexpensive to measure.
  - Linked to neurobehavioral dysfunction (oil refinery sites).
    - Endogenous neuromodulator in hippocampus (Kilburn & Warshaw, 1995).
  - Acute health risk value (HRV):
    - U.S. EPA not considered criteria or hazardous air pollutant
    - MN 60 ppb or 80 $\mu g*m^{-3}$ acute HRV
    - CA 30 ppb or 42 $\mu g*m^{-3}$ for acute reference exposure level (REL)
    - CA 08 ppb or 10 $\mu g*m^{-3}$ for chronic REL (nasal histological changes).

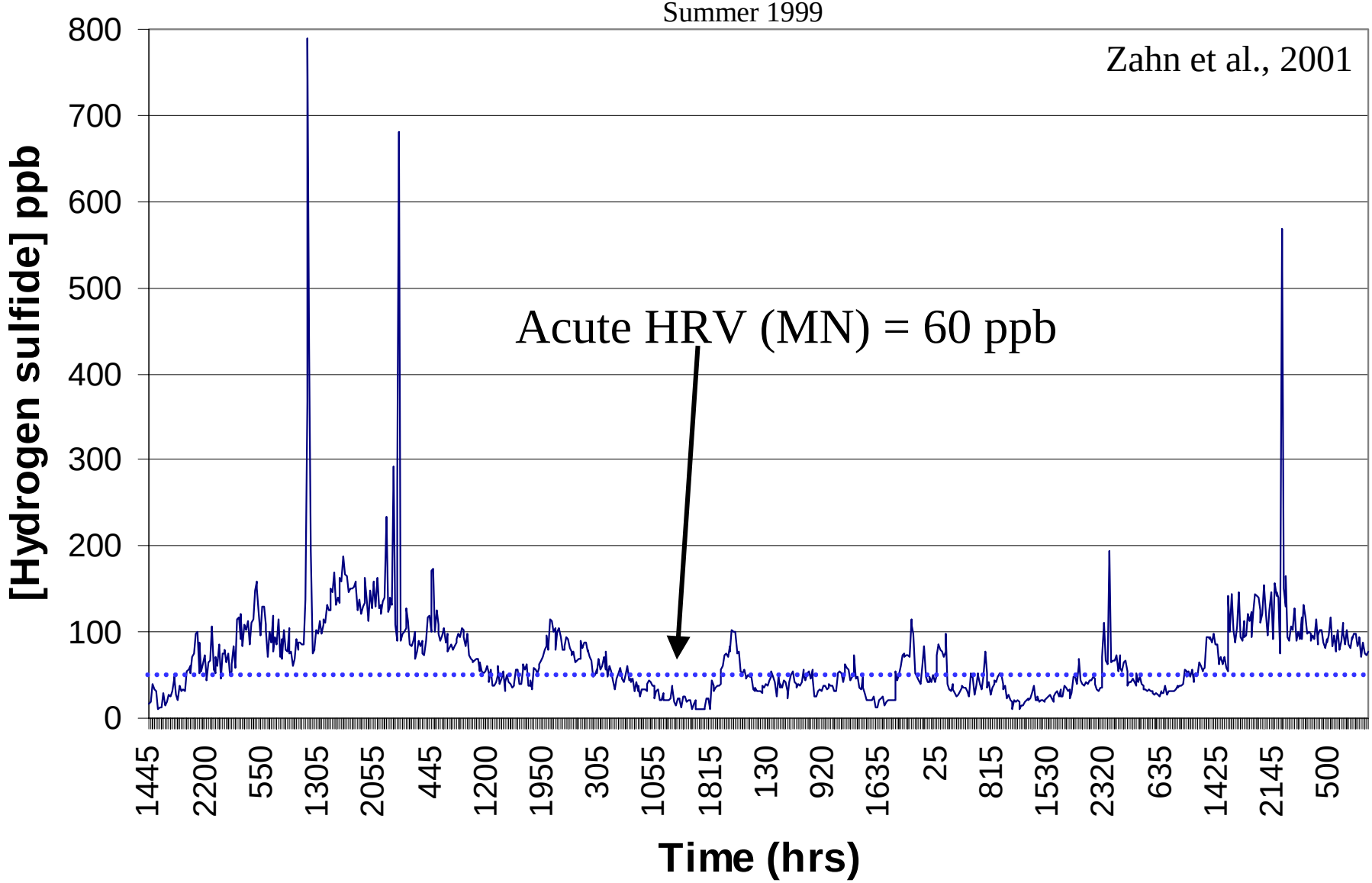
17 through 24 July, 1999 Hydrogen Sulfide Flux from a Swine Lagoon



Iowa: 40,000 facilities x 30 lbs per day = 1,200,000 lbs H_2S released per day

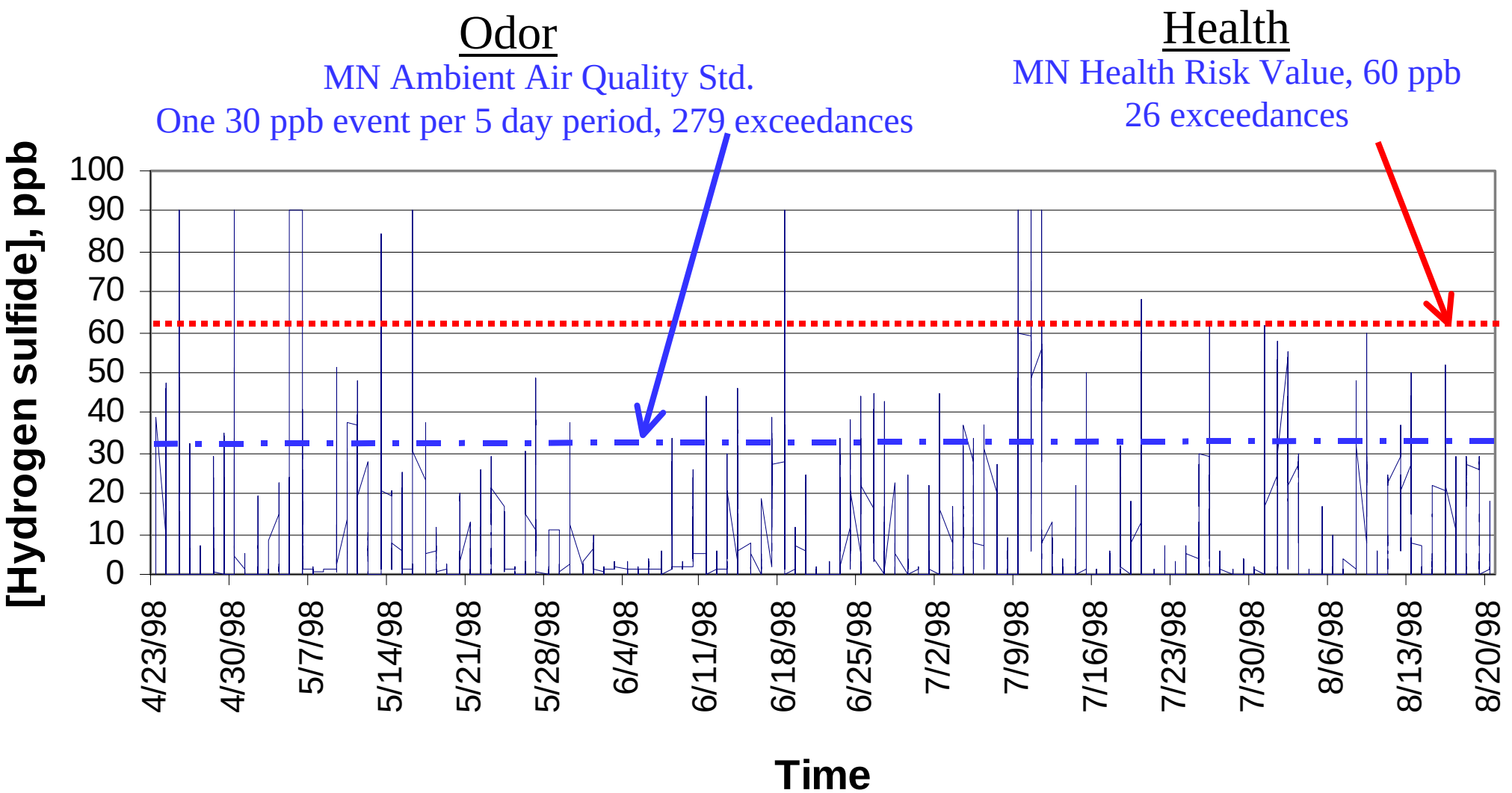
Concentration of Hydrogen Sulfide in Air Sampled on the Berm of a Swine Lagoon

Summer 1999



Property Boundary [H_2S] Adjacent to a Swine Production Facility

MDA Scientific single point monitor; 0.5 hr ave.; detection range 0-90 ppb



MPCA, 1999

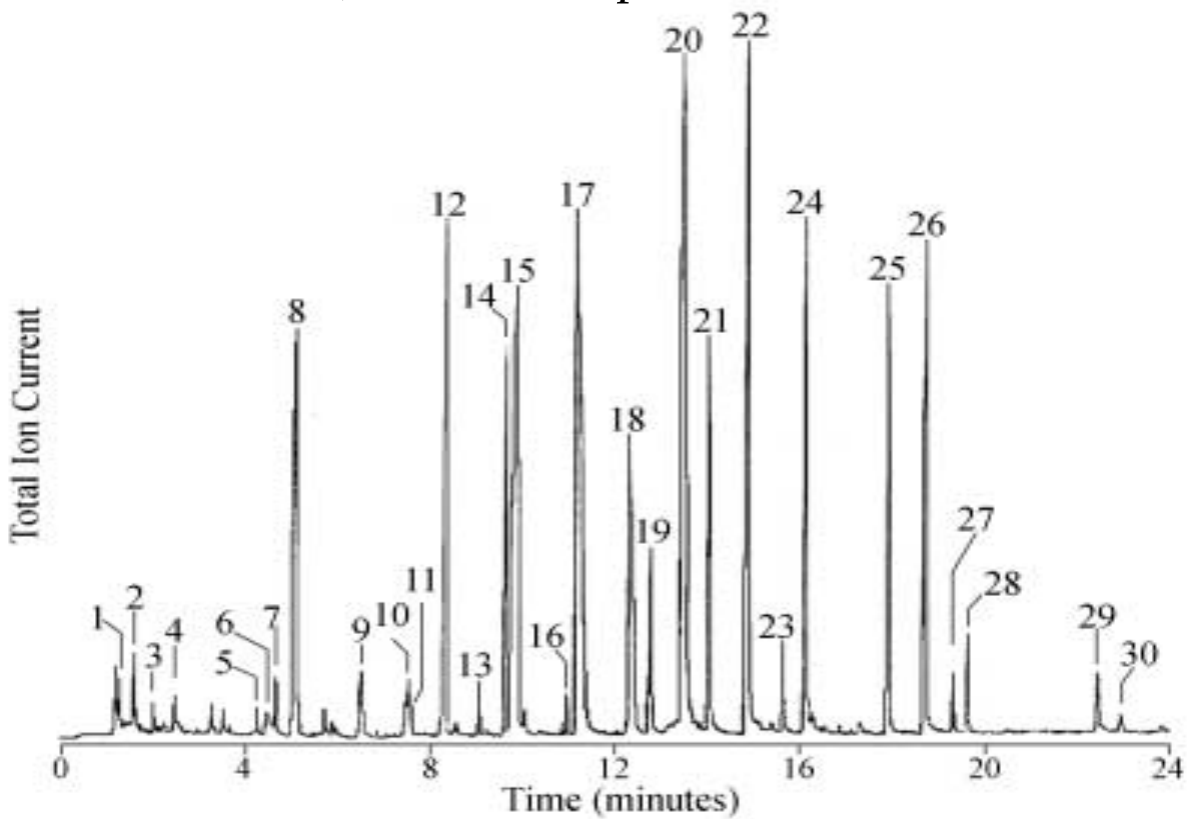
Impact of CAFO Emissions on the Environment and Human Health

- Volatile Organic Compounds (VOC):
  - Generally vapor pres. ≥0.1 mm Hg, and mass ≤140 amu.
  - Best indicator of agricultural odor intensity.
  - Relatively low concentrations present in air (≤ 250µg*m^{-3}).
  - Exceptional diversity (between 100 to 300 different cpds).
  - Priority pollutants: adverse impact on human health.
    - Benzene, chronic REL 60 µg*m^{-3} or 18 ppb; toluene, cresol, phenol, n-hexane, carbon disulfide, methanol (toxic substance list).
  - Reactive Organic Gas (U.S. EPA).
    - Participates in atmospheric photochemical reactions and formation of ozone in the lower atmosphere.

Volatile Organic Compounds Emitted from a Swine Lagoon

GC-MS

TIC, Electron Impact Ionization

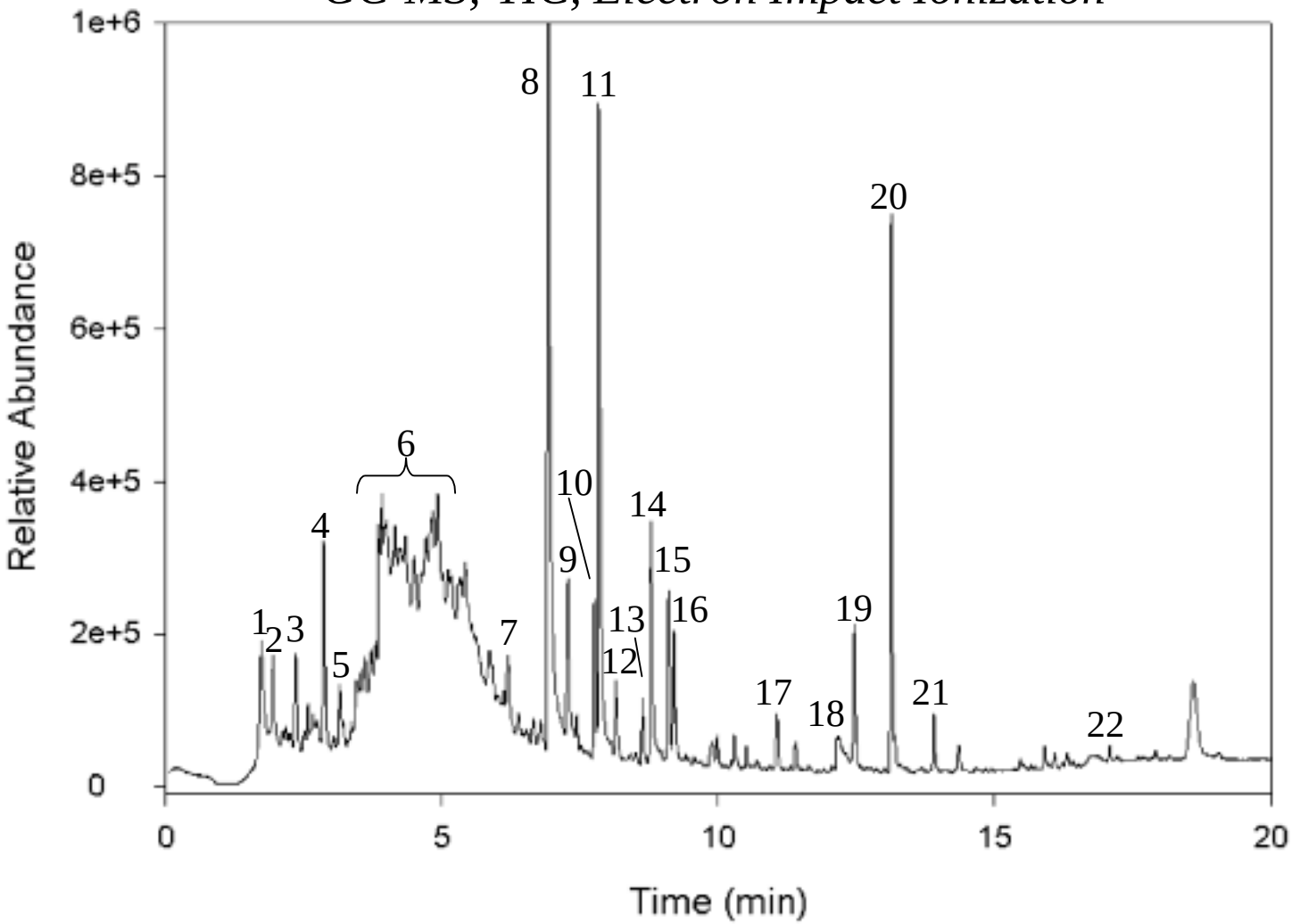


1. n-Hexane
2. Methane, thiobis
3. 1-Octene
4. Acetic acid, ethyl ester
5. 2-Butanol
6. Butanoic acid, ethyl ester
7. Ethanethioic acid, S-methyl ester
8. Dimethyl disulfide
9. 1-Butanol
10. 3-Methyl-1-butanol
11. 4-Methyl-2-pentanol
12. 1-Pentanol
13. 4-Methyl-1-pentanol
14. 1-Hexanol
15. Dimethyl trisulfide
16. 1-Heptanol
17. Acetic acid
18. Propanoic acid
19. 2-Methyl propanoic acid
20. Butanoic acid
21. 3-Methyl butanoic acid
22. Pentanoic acid
23. 4-Methyl Pentanoic acid
24. Hexanoic acid
25. Phenol
26. 4-Methyl phenol
27. 2-Peperidinone
28. 4-Ethyl phenol
29. Indole
30. 3-Methyl indole

Zahn et al., 2001

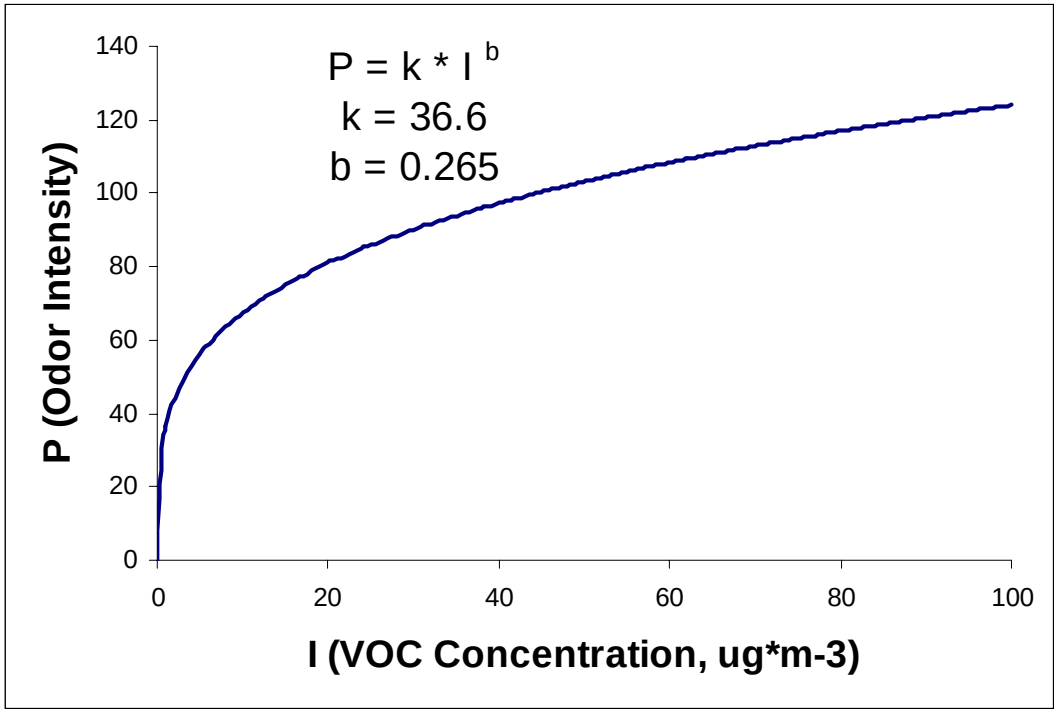
Volatile Organic Compounds Emitted from a Swine Confinement

GC-MS; TIC, Electron Impact Ionization



1. Piperazine
2. 2-Octanamine
3. Benzene
4. Toluene
5. Hexanal
6. Alkanaes
7. Nonanal
8. Acetic acid
9. 2-Ethyl-1-hexanol
10. Benzaldehyde
11. Propionic acid
12. Isobutyric acid
13. Benzonitrile
14. Butyric acid
15. 1-Phenyl ethanone
16. Isovaleric acid
17. 1-Methyl napthalene
18. Hexamine
19. Phenol
20. p-Cresol
21. 4-Ethyl phenol
22. 3-Methyl indole

Zahn et al., 2001



[VOC] as a Indicator of Swine Odor Intensity

Zahn et al., 2001, J. Environ. Qual., 30:624-634

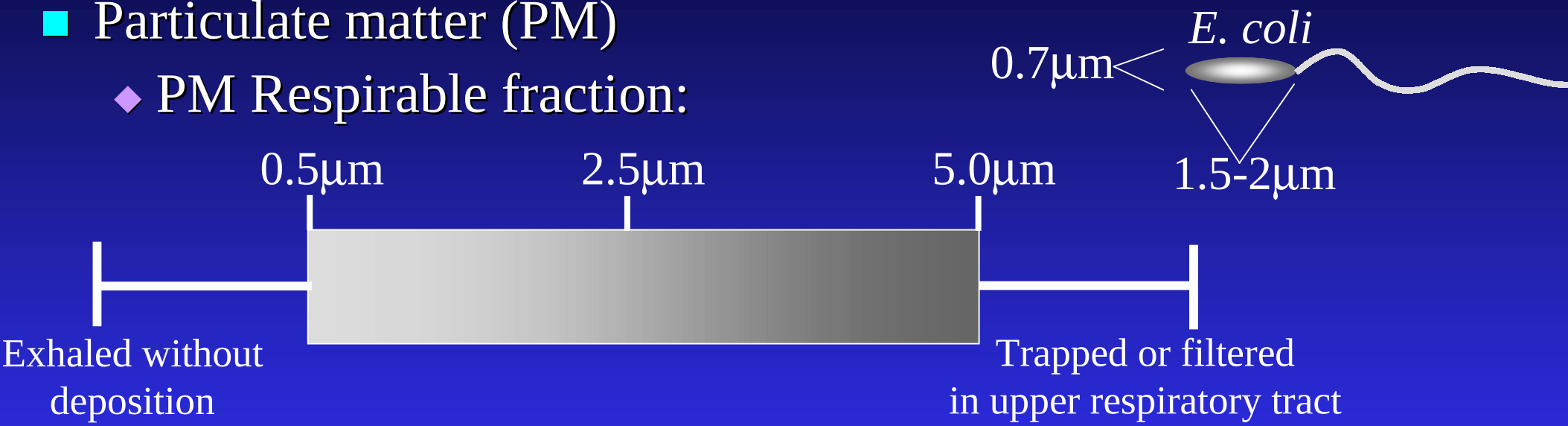
Mathematical model for swine odor intensity using measured concentration of nine VOC from ag site air samples

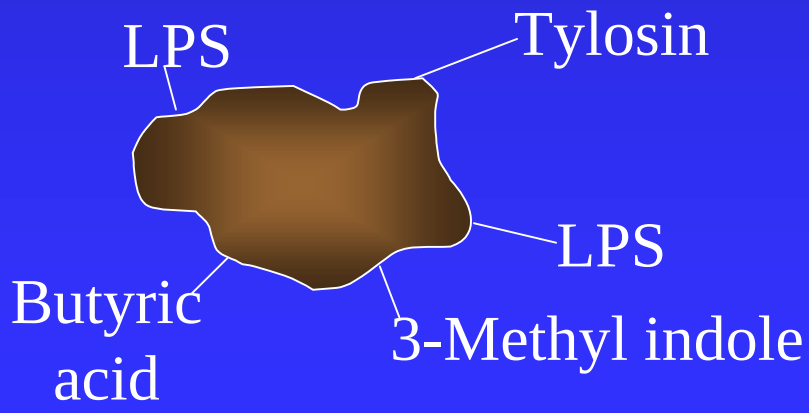
$$\textit{Odor Intensity} = 50.0 + (20.2(a/22.7)) + (5.5(b/34)) + 47.3(c/10.7)) + (7.8(d/21.0)) + (22.8(e/24.5)) + (3.5(f/146.0)) + (3.9(g/14.2)) + (-116.5(h/11.2)) + (89.57(i/18.0))$$

Where: a = valeric acid ($\mu g*m^{-3}$ in air), b = butyric acid ($\mu g*m^{-3}$ in air), c = heptanoic acid ($\mu g*m^{-3}$ in air), d = phenol ($\mu g*m^{-3}$ in air), e = 4-methyl phenol ($\mu g*m^{-3}$ in air), f = acetic acid ($\mu g*m^{-3}$ in air), g = isobutyric acid ($\mu g*m^{-3}$ in air), h = 4-ethyl phenol ($\mu g*m^{-3}$ in air), i = 3-methyl indole ($\mu g*m^{-3}$ in air).

Impact of CAFO Emissions on the Environment and Human Health

- Particulate matter (PM)
  - PM Respirable fraction:





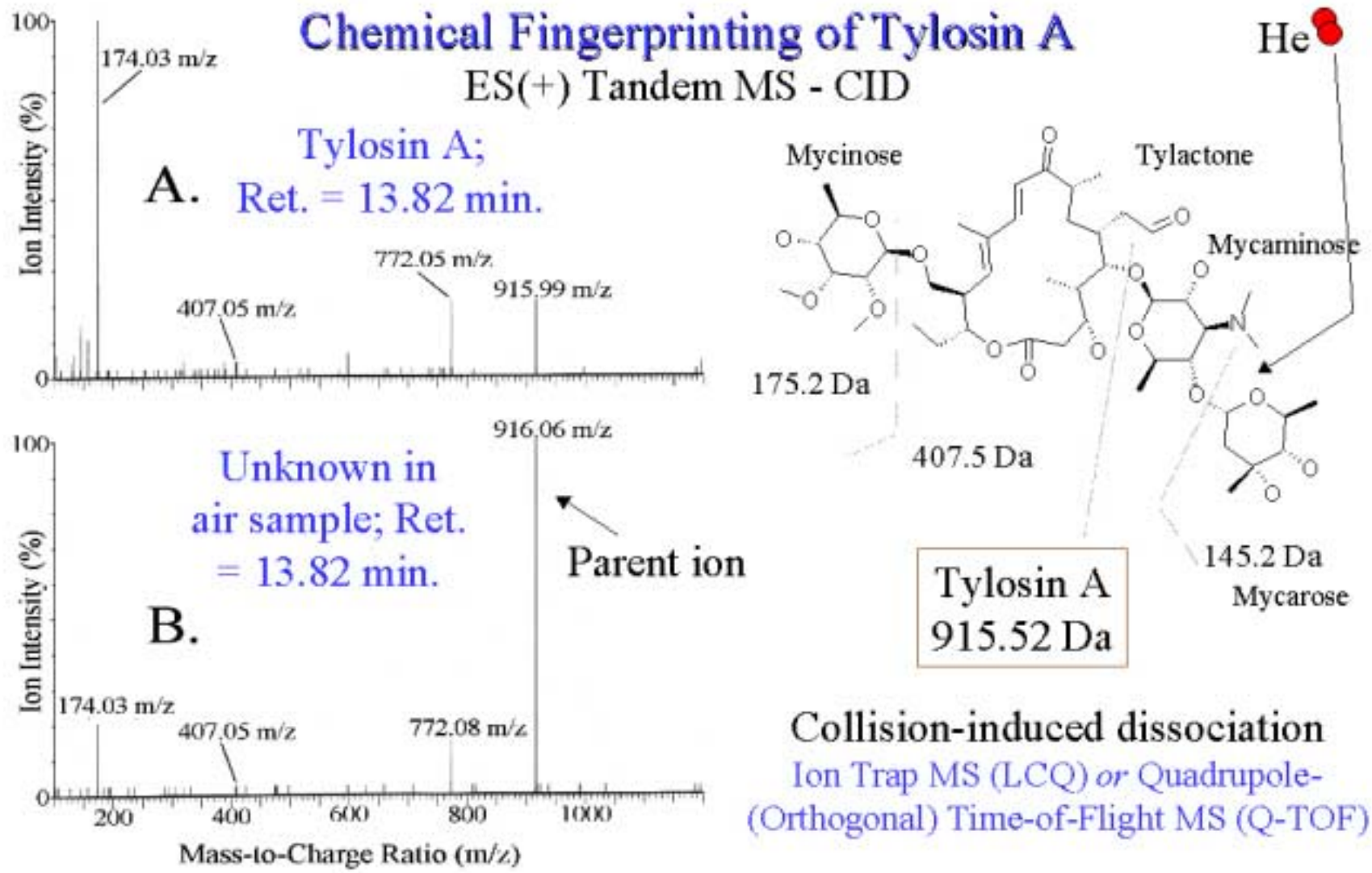
PM as a carrier molecule:

- Bacteria & spores
- Endotoxins
- Antibiotics (from feed)
- Odorants (VOC)

Impact of CAFO Emissions on the Environment and Human Health

- Non-Volatile Organic Compounds (particulate associated):
  - Vapor pres.<0.003mm Hg; and mass >140 amu.
  - Particulate-borne compounds. Bioactive microbial secondary metabolites. Extremely active <0.1 ppb.
  - Many are allergens or toxins, and some have been associated with ill symptoms of damp buildings.
  - Examples: Antibiotics, mycotoxins, G- lypopolysaccharide, β-D-glucans, valinomycin, kalafungin (cAMP kinase inhibitors).

Identification of Tylosin in Air Emitted from Swine Barns using Tylan in Animal Feed as a Growth Promoter



Conclusions

- Air pollutants from CAFO have the potential to adversely impact human health – onsite and offsite.
  - Considerable diversity exists among States in ambient air quality standards and ability to enforce laws.
- Hydrogen sulfide has been determined to cause off-site health risks to CAFO neighbors (MN):
  - low acute HRV (42 to 80 $\mu g*m^{-3}$).
  - H_2S is the major sulfur cpd. from CAFOs (>95% of total S).
- Air pollutants from CAFOs can cause environmental damage/change – E.U. legislation NH_3:
  - Zahn et al., 2001 – CAFO emissions exceed EPA CERCLA regs.
  - Acidificiation (shifts from native diverse plant communities)
  - Eutrophication (freshwater fouling and toxic blooms)
  - Global warming (CH_4, N_2O, and VOC)

Acknowledgements

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