Overview of NH_3 Emission from Poultry Facilities and the BMPs and BATs

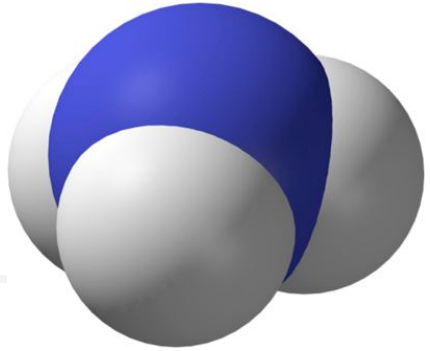
Lingying Zhao

Associate Professor and Extension Specialist
Dept. of Food, Agri. And Biological Engineering
The Ohio State University

Outline

- Ammonia (NH_3) and its generation at animal farms
- NH_3 emissions from poultry facilities
- Its health and environmental impacts
- Overview of the BMPs and BATs
- Summary

What is Ammonia (NH_3)?



- A gas (NH_3), colorless, light than air, highly soluble in water, and has a sharp pungent odor detectable at 5 - 18 ppm.
- Ammonia has two forms, gas phase and liquid or solid ammonium phase.
- one of the important forms of nitrogen (NH_3, NH_4^+, NO_3^-, NO_2^-, N_2O, NO_x and atmospheric N_2) participating in the nitrogen cycle.
- Reacts with gaseous nitrate and sulfate for form fine particles.
- used for the production of fertilizers, nitric acids, fuels, explosives, and refrigerants;

Ammonia Gas and Ammonium

Ammonia easily convert from gaseous phase to liquid and solid phase ammonium (NH_4^+) as pH changes.

$$NH_3 + H_2O \leftrightarrow NH_4OH \leftrightarrow NH_4^+ + OH^-$$

- pH=9.25 (>7)
  - 50% as un-ionized (NH3)
  - 50% as ionized (NH_4^+)
- pH<7
  - 99% as ionized (NH_4^+)

How NH_3 is Generated?

- NH_3 is generated because inefficient conversion of feed N to animal products resulted in N excretion in urine of pigs and cattle and in the uric acid of poultry.
- The fecal enzyme urease catalyzes the hydrolysis of urine urea to form ammonia gas.
- Aerobic decomposition of uric acid of poultry also form ammonia gas.
- Mineralization of undigested protein also result in ammonia gas emission

How NH_3 is Generated (cont)?

- Urine (swine and cattle)
  - Urea hydrolysis

  $CO(NH_2)_2+H_2O \rightarrow CO_2+2NH_3$

- Uric acid (poultry)
  - Aerobic decomposition of uric acid

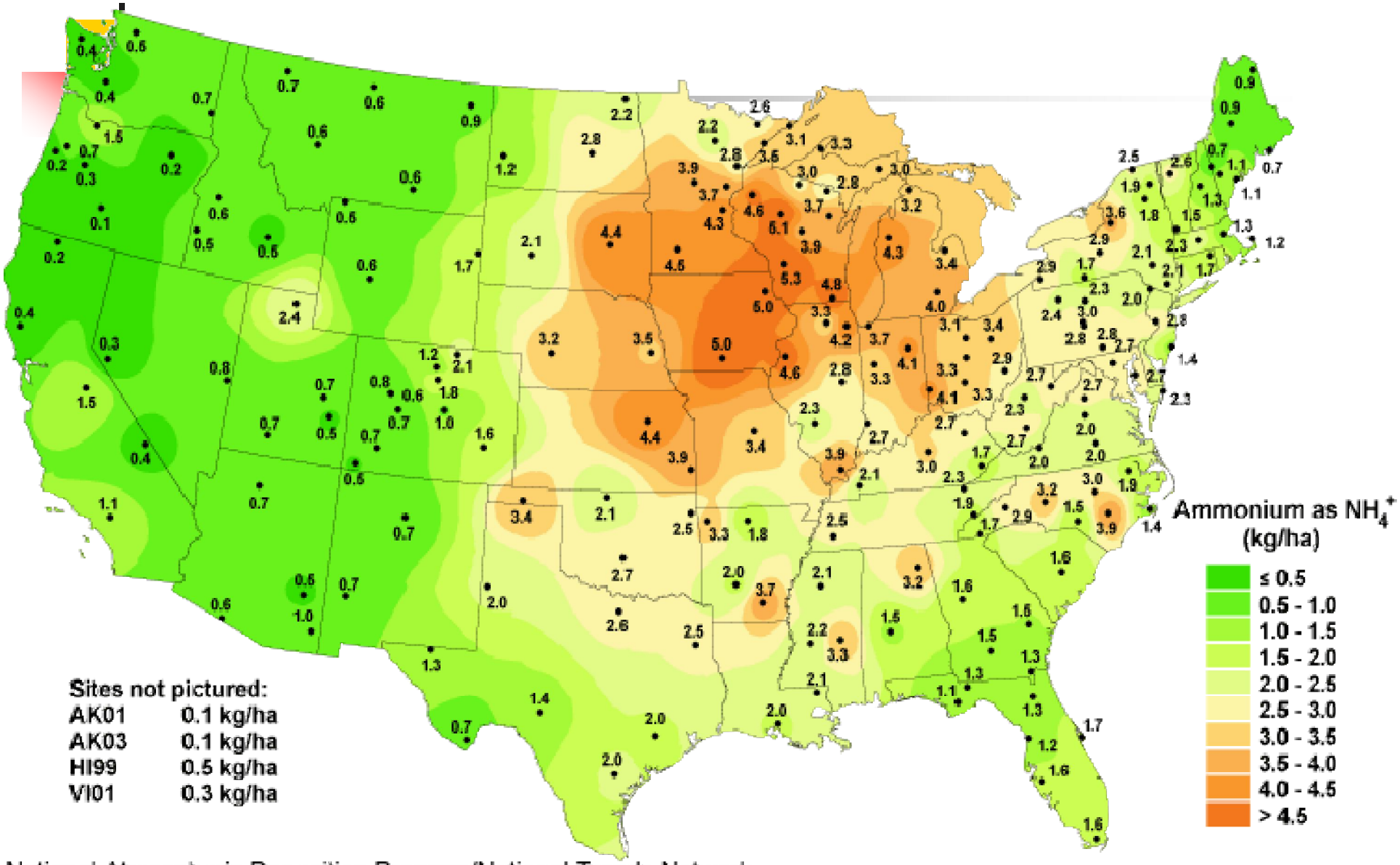
  $C_5H_4O_3N_4 + 1.5O_2+4H_2O \rightarrow 5CO_2+4NH_3$

- Undigested protein
  - Mineralization → NH_3

Fate and Transport of NH_3 Cont...

- After released from the sources, ammonia will disperse vertically and horizontally in the atmosphere.
- Dry and wet deposition will happen near the sources.
- It has a lifetime of 1-5 days in the atmosphere.
- Chemical reactions with other chemicals in the atmosphere form fine particles.
- When is converted to NH_4^+ aerosols, the lifetime increases up to 15 days.

Ammonium ion wet deposition, 2001



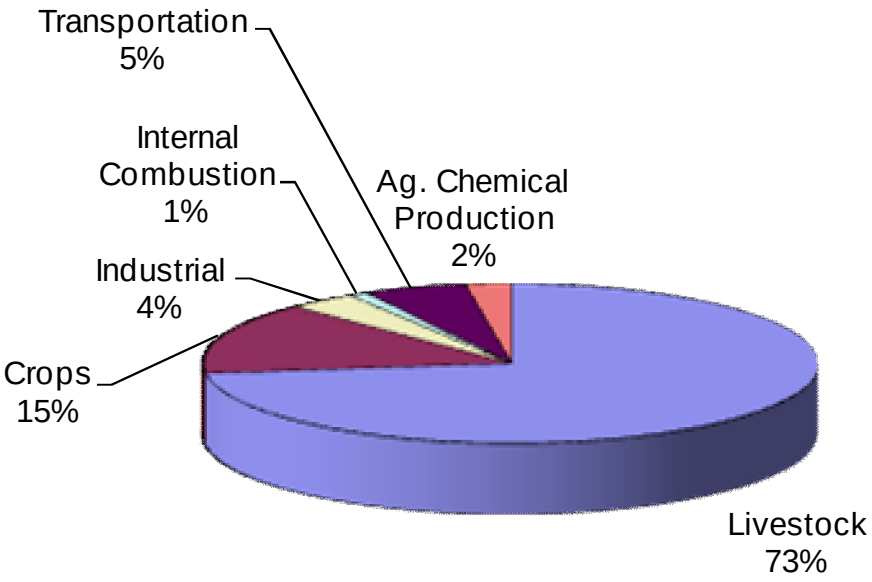
National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

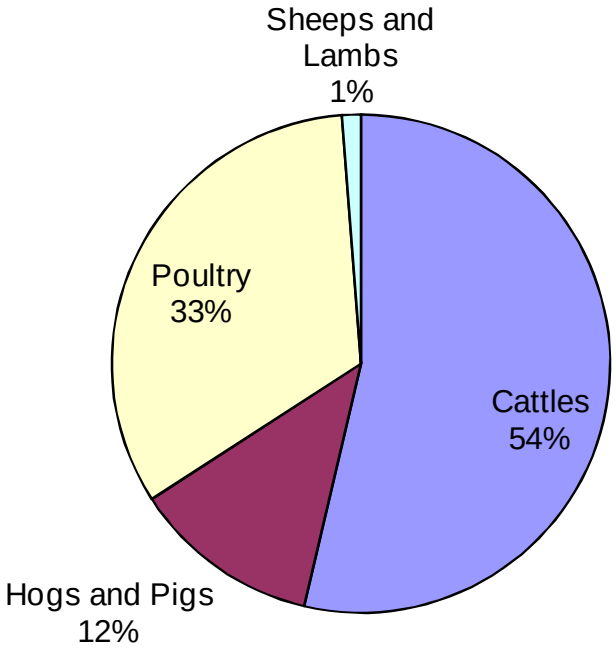
Factors Affecting NH_3 Emission and Transport

- Dietary Factors
  - Excess crude protein in diet
  - Low conversion of dietary N to animal products
  - Total nitrogen content
- Environmental Factors
  - pH
  - Temperature
  - Moisture content
  - Chemical and microbiological activities--additives
  - Ammonia concentration of air
  - Ventilation air / wind speed
- Manure Handling
  - Manure storage time
  - Diffusive and convective transport in the manure

Ammonia Emissions from Poultry Facilities

How Much NH_3 is Emitted?



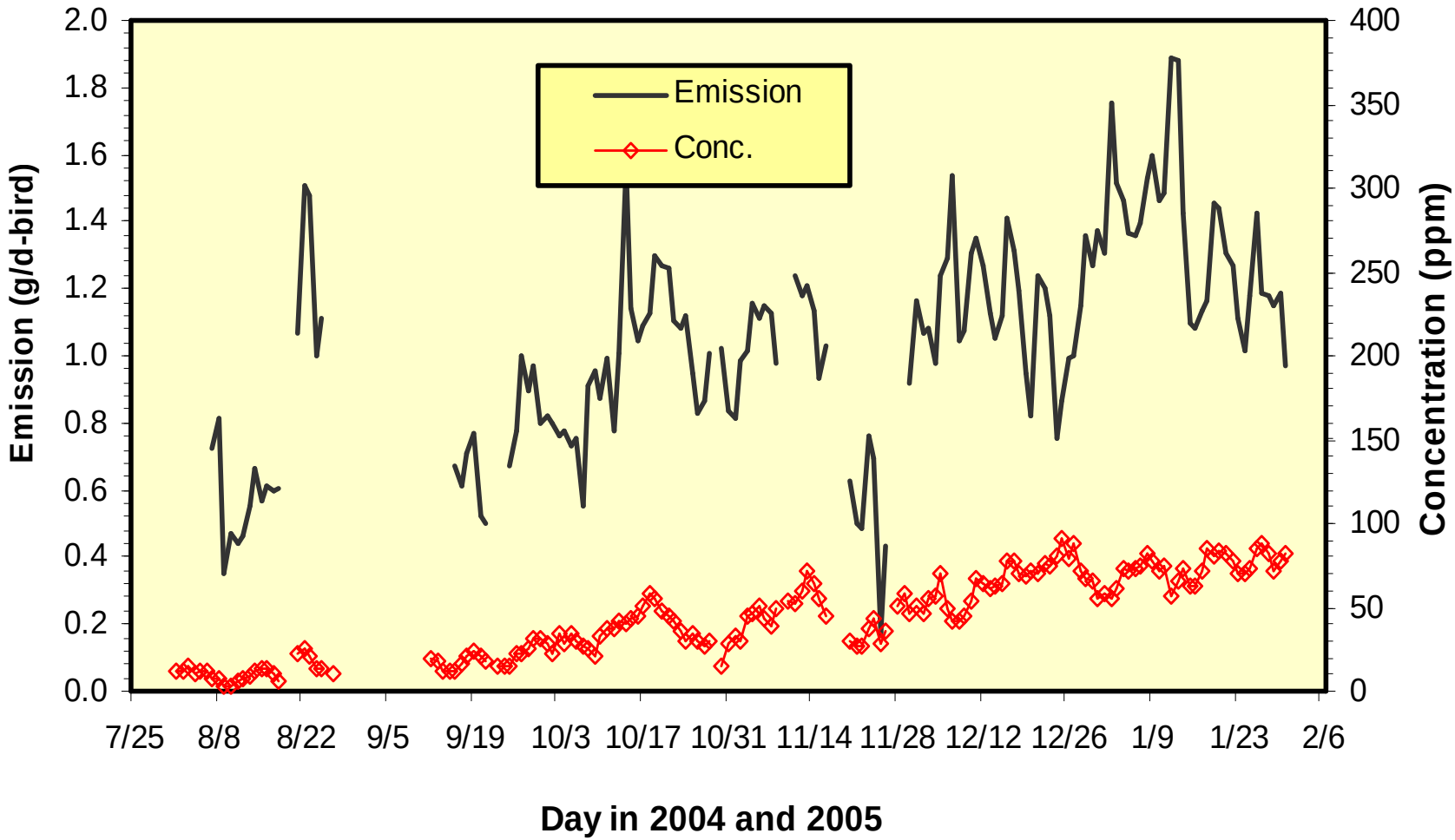


[1] http://pubwiki.extension.org/mediawiki/files/7/70/08junPPmartin.pdf
[2] USEPA, 2002. http://www.epa.gov/ttn/chief/ap42/ch09/related/nh3inventorydraft_jan2004.pdf

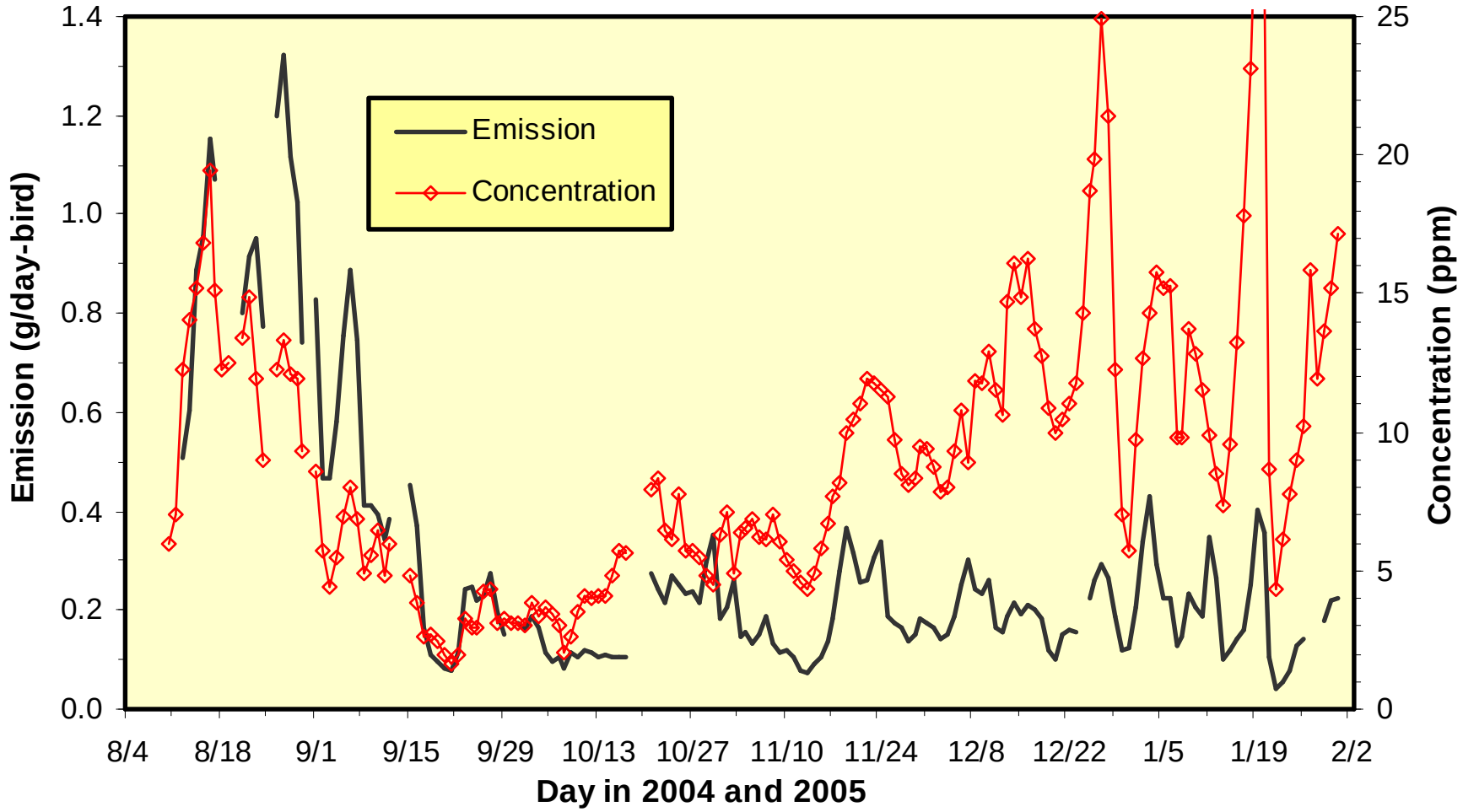
High-rise deep-pit (HR) layer barn

Manure-belt (MB) layer barns

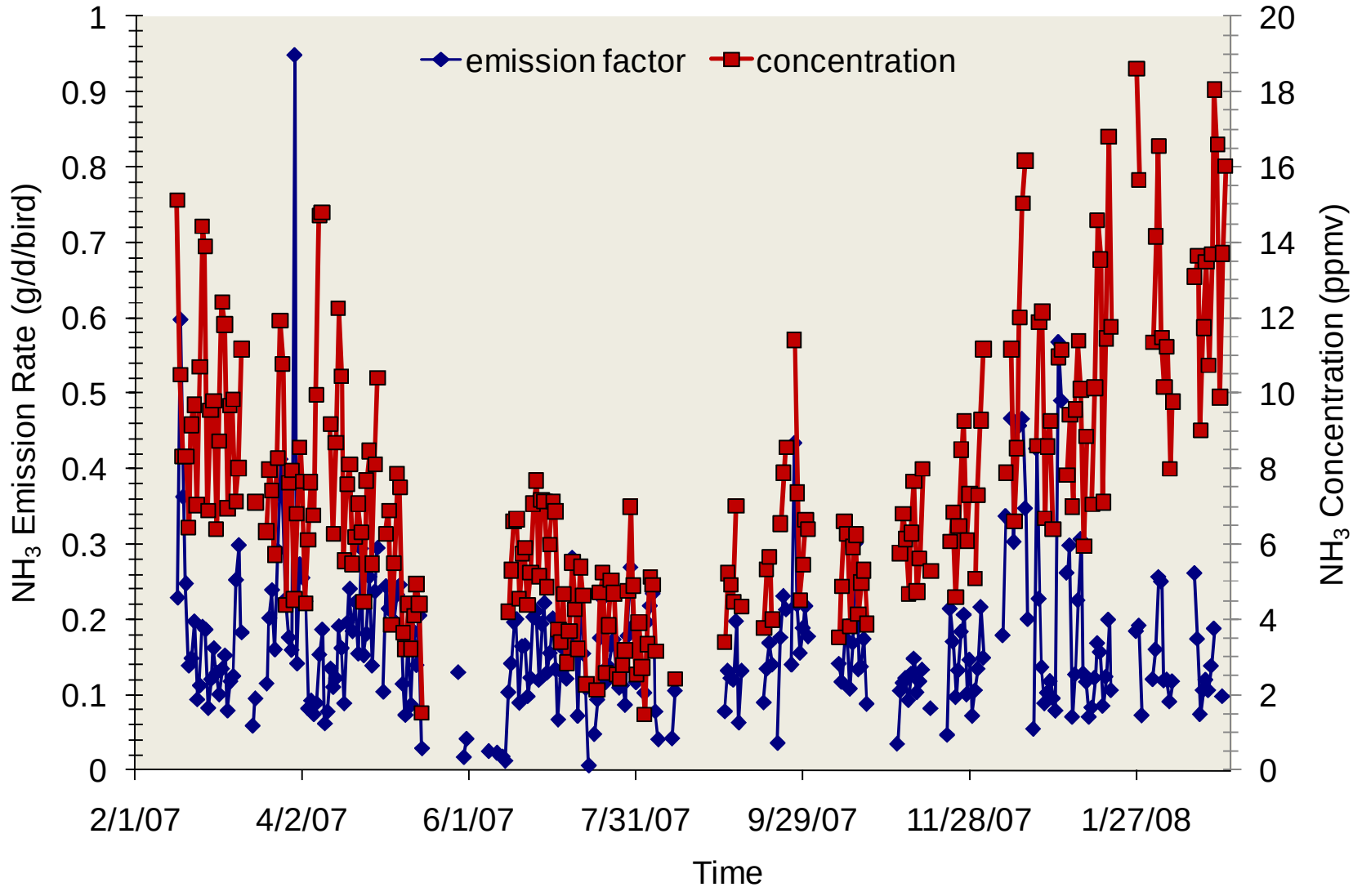
Deep-Pit High-Rise Barn- NH_3 Concentration & Emission



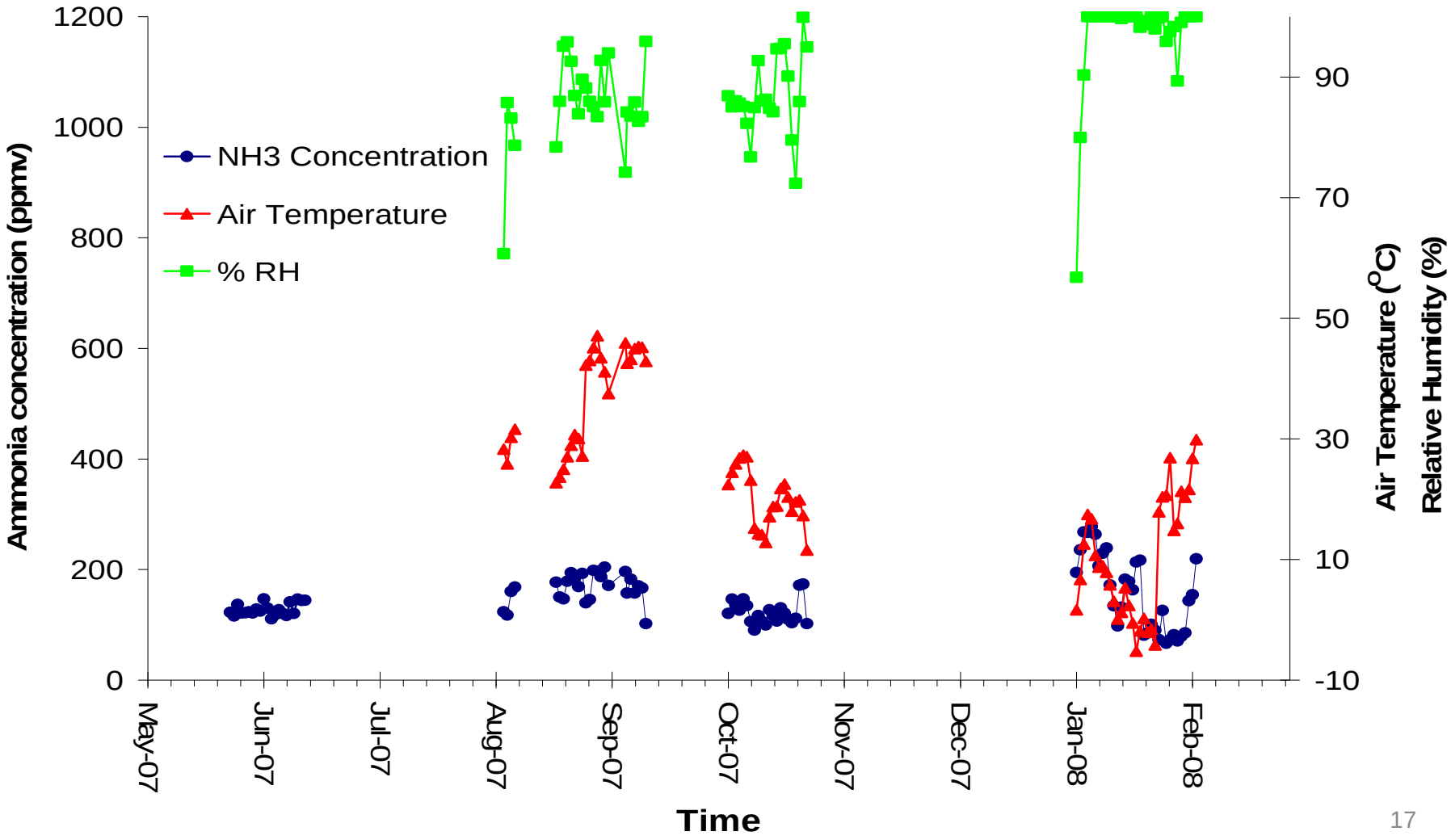
Manure-Belt Barn—
NH_3 Concentration & Emission



Ammonia Concentrations & Emissions from Manure-Belt Layer Facilities



Seasonal Variations in Ammonia Concentrations and Emissions



A Summary of NH_3 Concentrations and Emissions of Layer Facilities

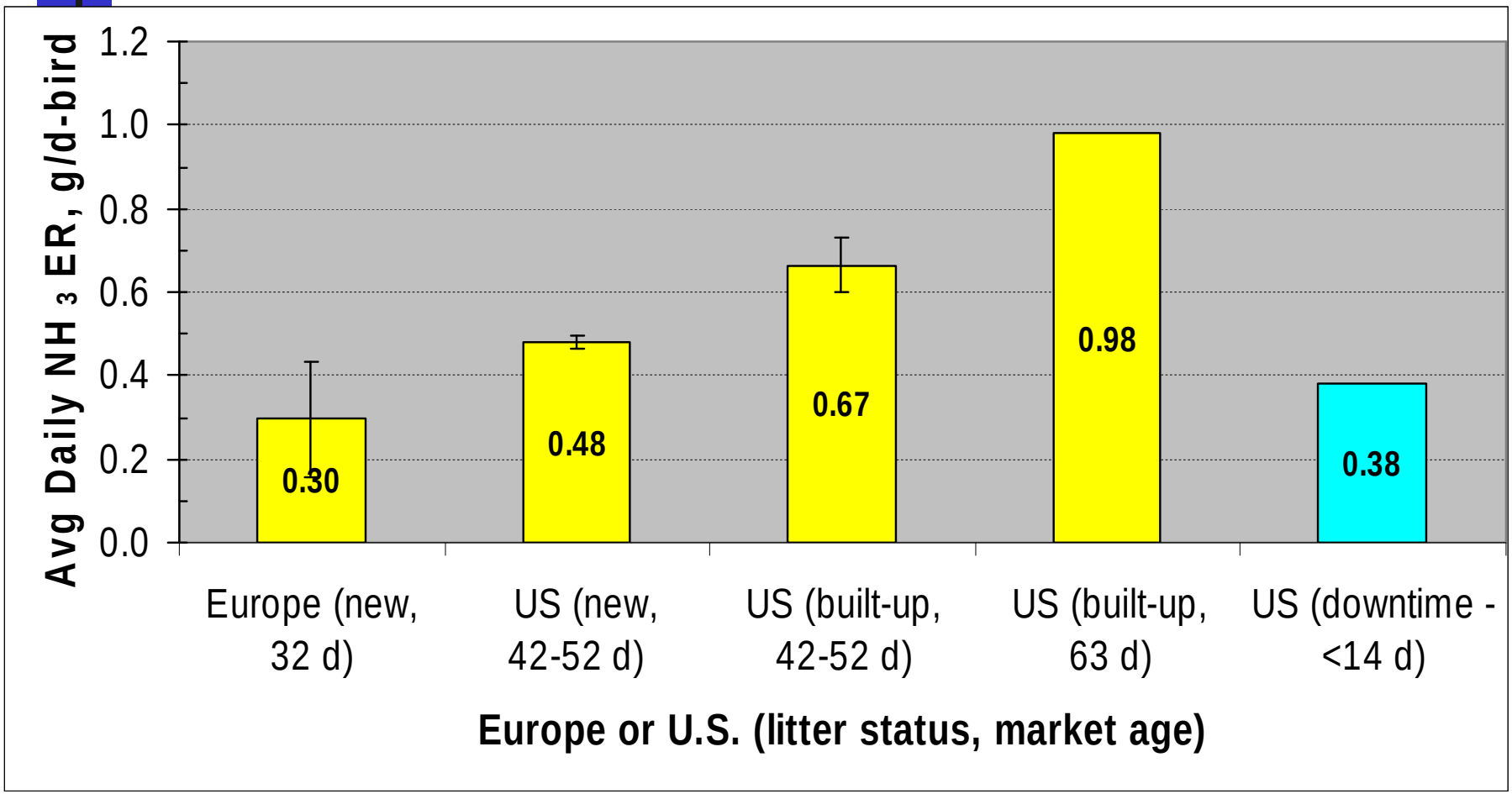
Poultry Layer Facilities	Daily Average NH_3 Concentration (ppmv) Mean (Min-Max)	Daily Average NH_3 Emissions (g/d/bird) Mean ± Std
High-Rise Deep-Pit Barns	40 (0-90)	1.03 ±0.39
Manure-Belt Barns 1—daily 1/7 manure removal	9.1 (0-25)	0.29 ± o.27
Manure-Belt Barn 2—manure removal every 3 day	6.7 (0-19)	0.16 ± 0.13
Manure Composting Facilities	130 (66-278)	0.32 ± 0.14

U.S. Broiler & Turkey Facilities

- Mostly built-up litter, some with litter treatment
- Tunnel ventilation or hybrid system
- Cooling pads or misters
- Pancake brooders & space heaters
- Broilers marketed at 6-9 wk
- Hen & tom turkeys at 12 & 20 wk

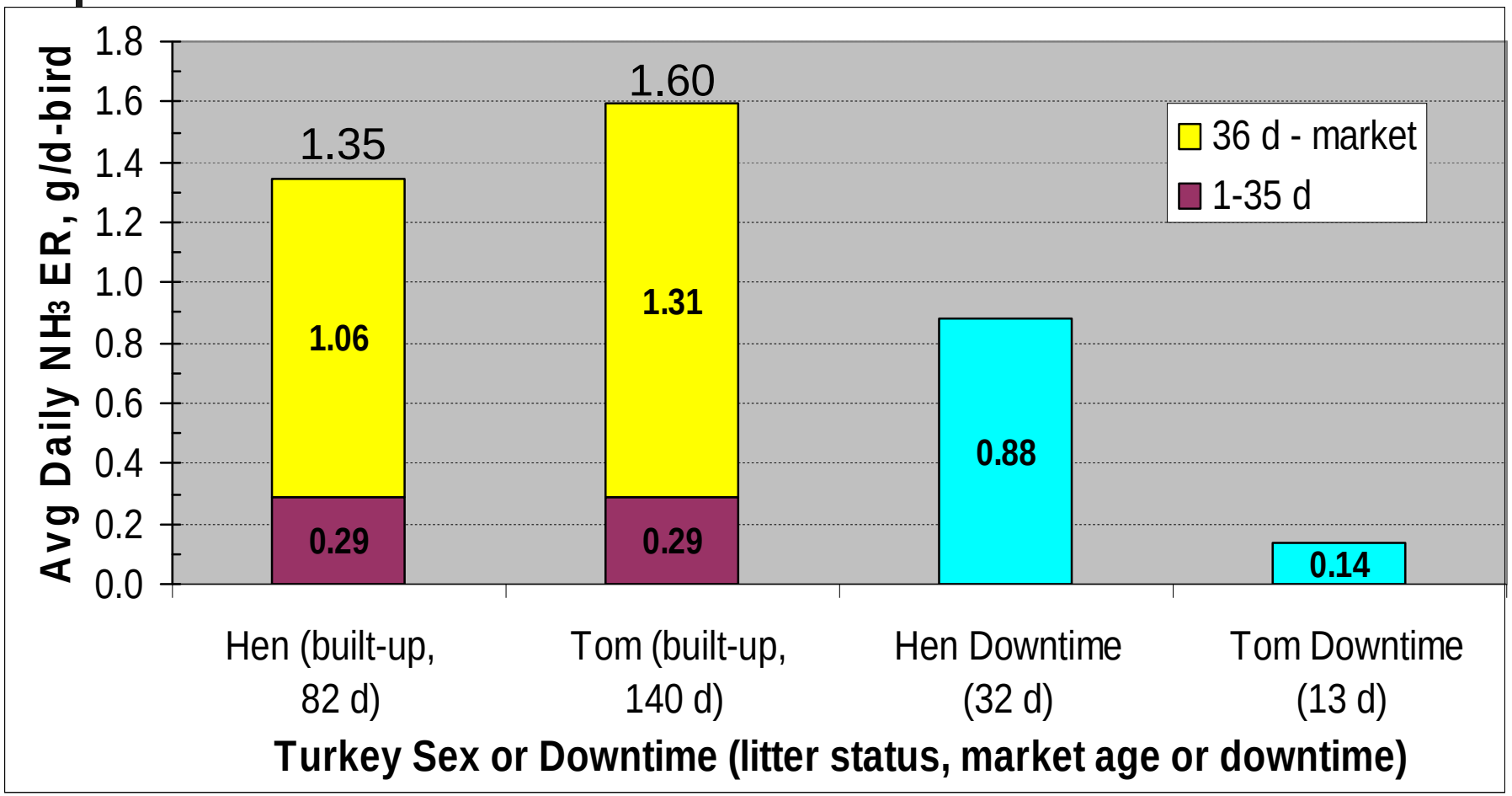
Source: Hongwei Xin, 2011

NH_3 Emission Rate (ER) of Broiler Houses – European & US Data



Source: Hongwei Xin, 2011

NH_3 Emission Rate (ER) of Turkey Houses in Iowa & Minnesota



Source: Hongwei Xin, 2011

Health and environmental impacts of Ammonia Emission

Its impact on Human health

The heath effects of ammonia have been recognized through extensive literature.

Concentration (ppm)	Length of exposure	Health effects
50	< 24 hours	Slight, temporary eye and throat irritations and urge to cough
100	6 weeks	Irritation of eyes, nose, and throat
500	30 mins	Increased air intake into lungs, sor nose and throat
5000	< 30 mins	Kills quickly

Impacts on Poultry Animal Health

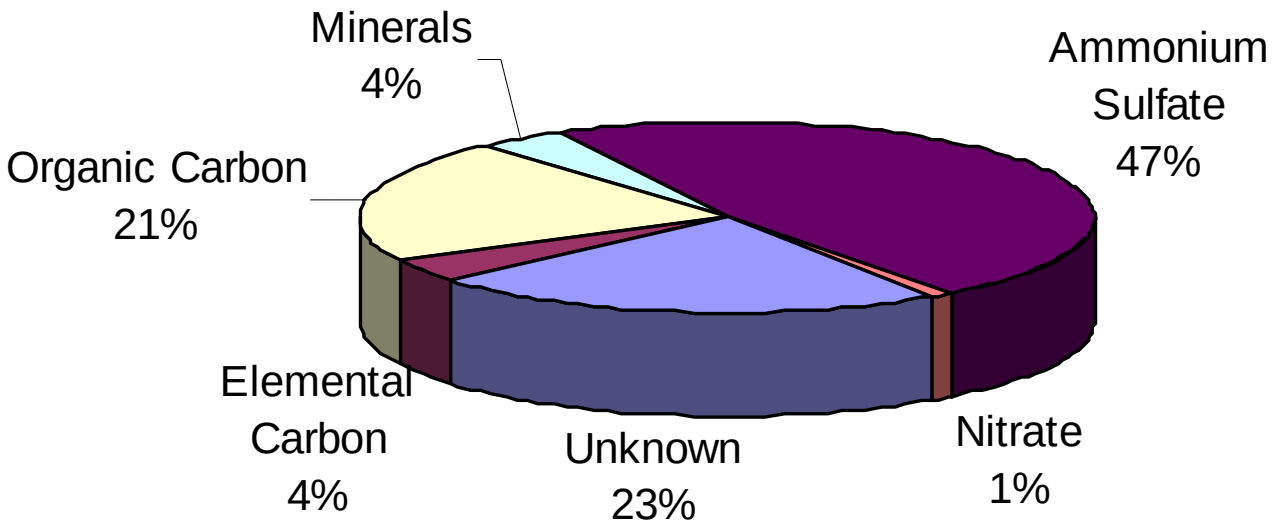
- At level of 10 ppm, trachea irritation was shown in turkeys.
- At above 25 ppm, growth rate and feed conversion was impaired and the final body weight was reduced.
- At levels of above 50 ppm, the birds are more susceptible to bacterial infections such as E. coli.
- At above 100 ppm, the chick mortality was increased significantly.

NH_3 and Particulate Matter[6]

Ammonia gas can react with sulfuric and nitric acids in the atmosphere to form fine particles

- $NH_{3\ (g)} + H_2SO_{4(g)} \rightarrow (NH_4)_2SO4_{(g,l)}$ (ammonium sulfate)
- $NH_{3\ (g)} + HNO_{3(g)} \rightarrow NH_4NO_{3(g,l)}$ (ammonium nitrate)

NH_3 and $PM_{2.5}$



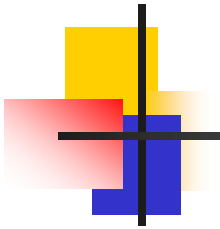
Source: Anderson N., R. Strader, and C. Davidson. 2003. Airborne reduced nitrogen: ammonia emissions from agriculture and other sources. Environment International. 29(2003): 277-286.

Its Environmental Impacts Cont...

- Ammonia deposition or wet deposition to the ecosystem leads to over-fertilization or eutrophication.
- The nutrient imbalance in the soil can be harmful to some crops while excessive nutrients in aquatic systems lead to decreased biological diversity;
- Ammonium sulfates deposited into soil and water systems can also get oxidized to form a mixture of nitric and sulfuric acids to cause ecosystem acidification.
- ⋆ Conversion to ammonium ion, and subsequently $PM_{2.5}$, its aerosol form, and eventual smog formation.

Overview of Effective BMPs and BATs for Ammonia Emissions from Poultry Facilities

Principles for Mitigating NH_3 Emissions in Animal Buildings



- Minimize air emission generation at the sources
- Reduce ammonia emission in the building
- Reduce ammonia emission at manure storages
- Capture ammonia emission at the exhausts of poultry facilities

Factors Affecting NH_3 Emission and Transport

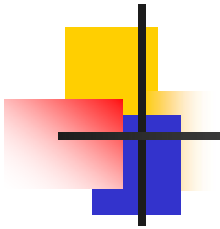
- Dietary Factors
  - Excess crude protein in diet
  - Low conversion of dietary N to animal products
  - Total nitrogen content
- Environmental Factors
  - pH
  - Temperature
  - Moisture content
  - Chemical and microbiological activities--additives
  - Ammonia concentration of air
  - Ventilation air / wind speed
- Manure Handling
  - Manure storage time
  - Diffusive and convective transport in the manure

Diet Manipulation and Feed Additives

One of the most important means of mitigation of air emissions

- Reducing nitrogen intake and using synthetic amino acid to reduce NH_3 emission.
- Adding dietary fiber to reduce ammonia emission (Xin, 2011)
- Balancing feed ingredients and improving the digestibility to reduce odor and ammonia emissions.

Manure Additives for Odor and Gas Control



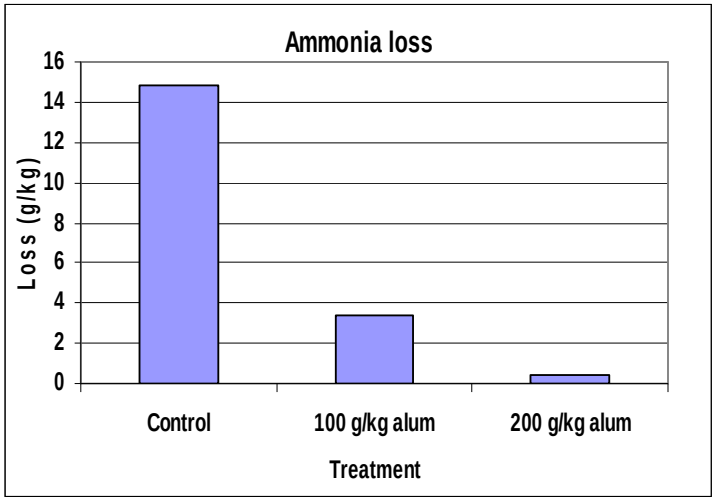
Chemical and biological substances added to manure that

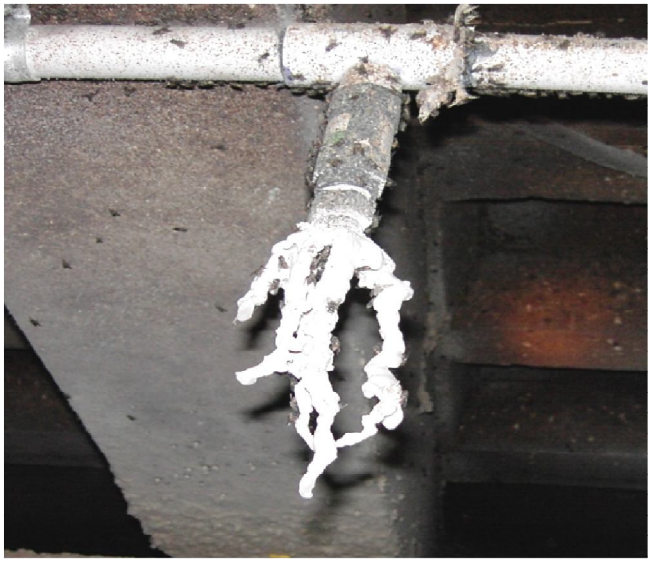
- Change manure pH: Alum (liquid or powder), ferric sulfate, sodium bisulfate
- Adsorb ammonium: Zeolite
- Change manure microbial population: many products on market

Alum has been applied to Layer Manure and Broiler Litter

- Alum has been shown to reduce ammonia volatilization very significantly during a 42-day incubation of poultry litter

- A field test at a Ohio layer facility showed that Aluminum Sulfate (Liquid Alum) and Aluminum Chloride (AlCl3) spraying system reduced NH_3 emission by 33%- 40% in short test periods.





Good Manure Handling Practice

- Keep Manure dry
- Remove manure out of the building
- Store manure in cool, covered facilities
- Reduce manure storage surface area

Poultry Facilities and NH_3 Emissions

- High-Rise Deep-Pit Layer Facility

Poultry Facilities and NH_3 Emissions

Manure-Belt (MB) layer facility

Manure Composting

- Two times nitrogen conservation rate than the deep-pit high-rise layer facilities (Keener et al. 2002)
- High ammonia concentrations in the composting building

Biofilter

- Odor reduction

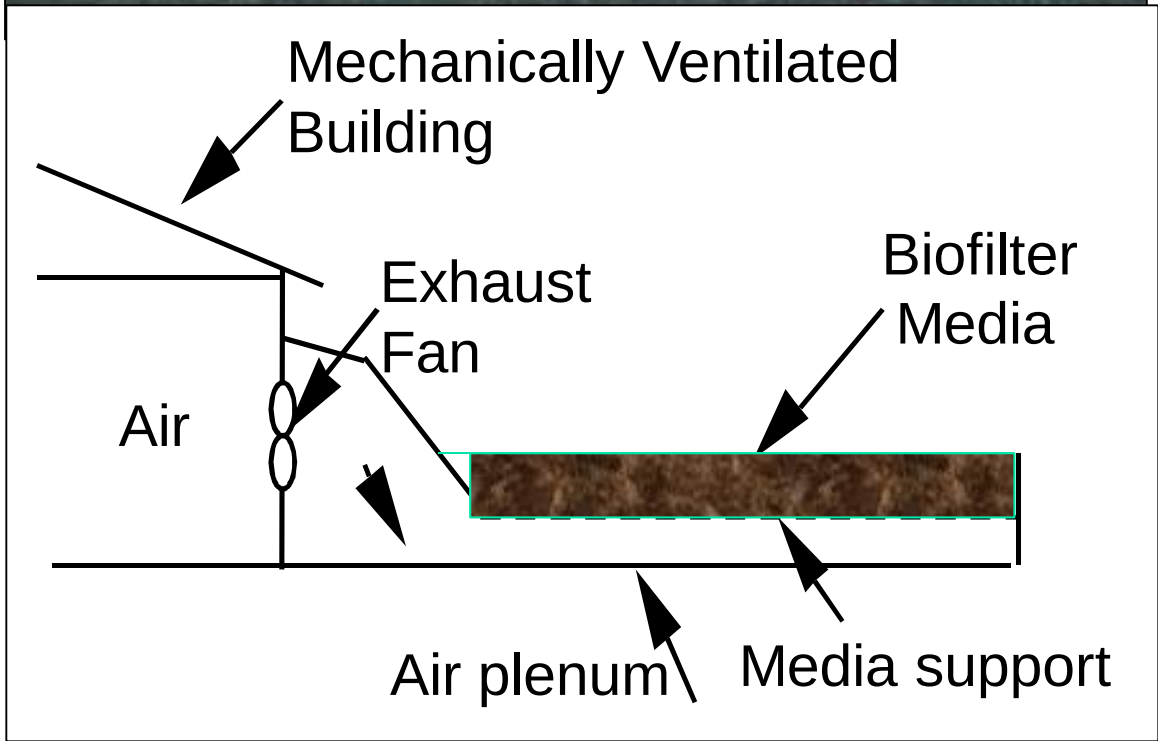
  80% - 90%

- H_2S reduction

  80% - 90%

- NH_3 reduction

  50% - 60%



Washing Walls

Use water to “scrub” air leaving buildings. Water recirculates through evaporative pad scrubber. Used with power ventilation systems

- Total dust reduced
  - 20% - 60% reduction
- Ammonia reduced
  - 33% - 50% reduction
- Odors were slightly reduced

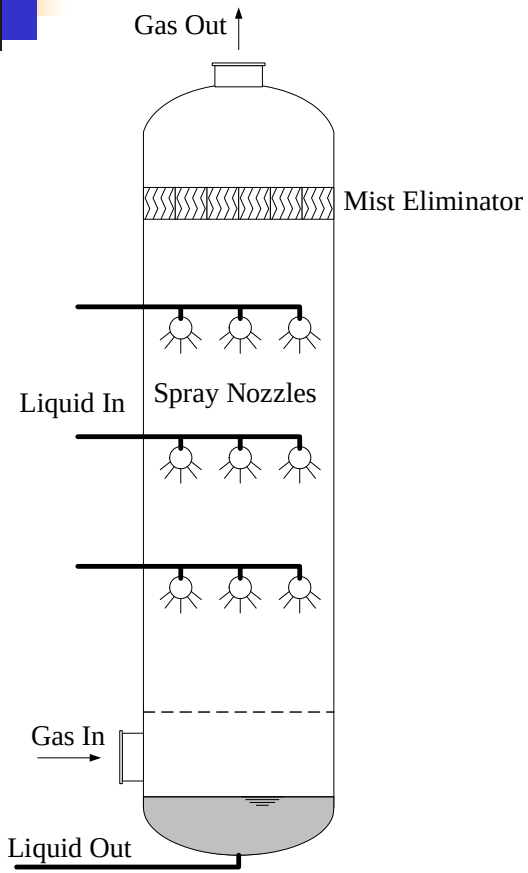
Wet Scrubbers

Use water and chemicals to “scrub” air pollutants laden air steams leaving buildings

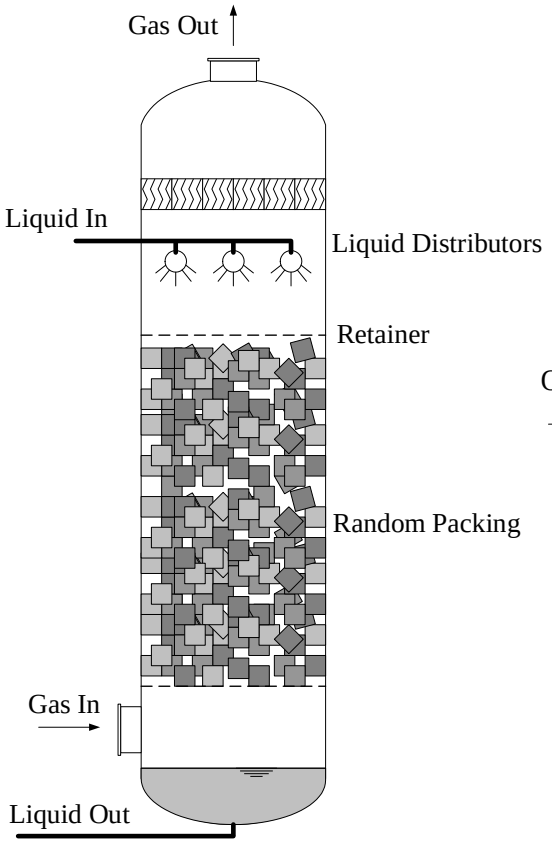
Two types of Wet Scrubbers:

- European Acid packed bed wet scrubber or fiber bed acid scrubber— ammonia removal efficiencies of 63%-98% with an average of 81% (Melse et al., 2005, 2008)
- OSU acid spray wet scrubbers can achieve NH_3 removal efficiencies of 99%-75% at 5-400 ppm inlet NH_3 concentration (Manuzon et al. 2007)

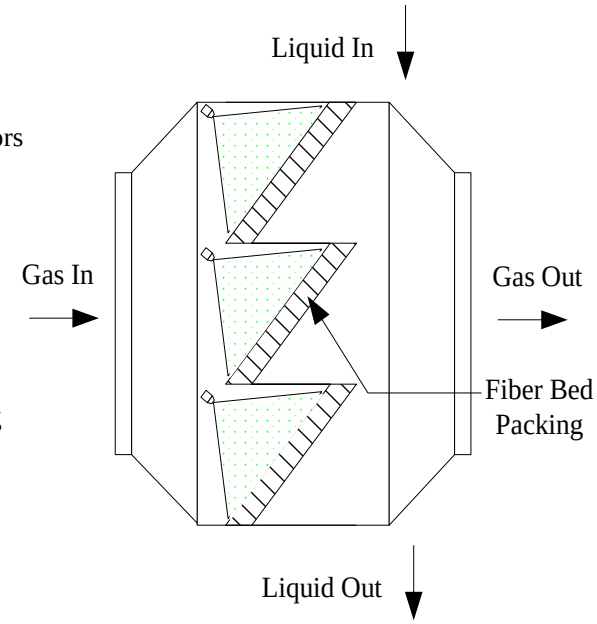
Schematics of Wet Scrubbers



Spray

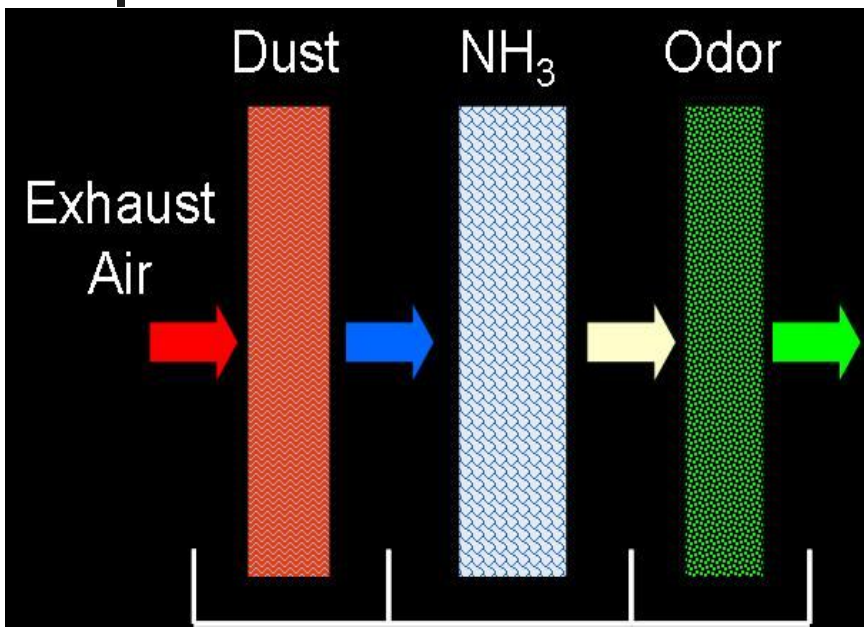


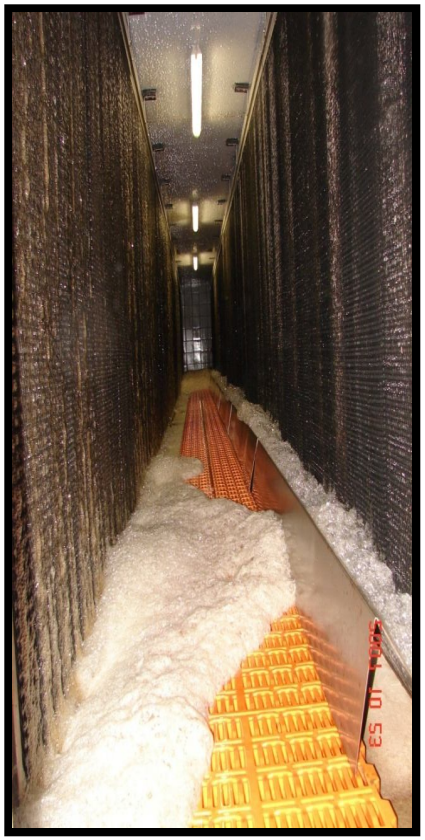
Packed-Bed

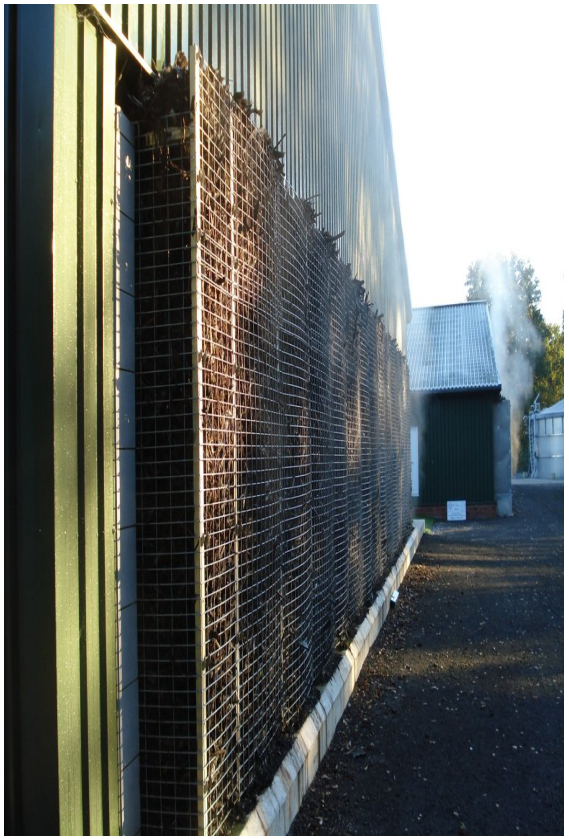


Fiber-Bed

European
Fiber Bed Wet Scrubbers





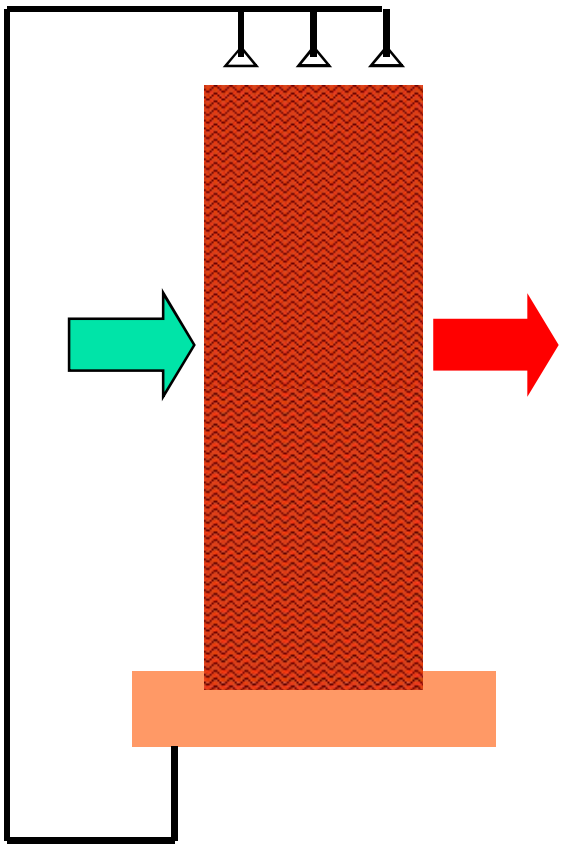


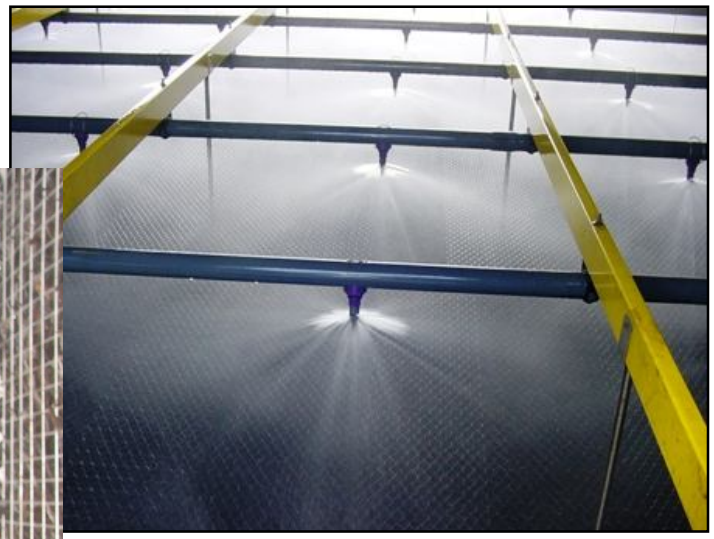
Packed –bed and 3-stage scrubber :

- Capital cost: $47-$72/pig
- Operation cost:$15-$19/year

Source: Hongwei Xin, 2011

Ammonia Removal





- **Sulfuric acid solution pH 2**
- **Recirculation**
- **Efficiency 63-98%**

Source: Hongwei Xin, 2011

OSU Spray Acid Wet Scrubber

Spray scrubbers

- spray system has low back pressure
- scrubbing liquid recycled as fertilizer

Summary Points

- Inefficient conversion of feed N to animal products resulted in N excretion as ammonia.
- Total nitrogen in manure, temperature, pH, manure moisture level, and microbial activities affect ammonia generation. Air speed, ammonia concentration, and weather conditions affect ammonia dispersion and transport
- High level of ammonia has significant health effects on human and poultry animals
- Ammonia emission is a pre-cursor of PM2.5 particle and cause ecosystem eutrophication and acidity.

Summary Points (Cont.)

- Effective BMPs and BATs to reduce NH3 emissions from poultry facilities are:
  - Diet manipulation and feed additives
  - Manure additives
  - Drying manure
  - Storing manure in cool and covered space with small manure surface area
  - Composting manure
  - Adopting manure belt building systems
  - Using wet scrubbers to capture ammonia for fertilizer

Thank You ! Qestions?

Lingying Zhao

Associate Professor and Extension Specialist

Dept. of Food, Agri. and

Biological Engineering

The Ohio State University

Phone: (614) 292-2366

Fax: (614) 292-9448

Email: zhao.119@osu.edu

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