Overview of Ammonia Mitigation BMPs and BATs

Hongwei Xin, Professor
Iowa State University
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Sources of NH₃ Mitigation

- **Pre-excretion**
  - Dietary manipulation
  - Feed or water additives
  - Genetics

- **Post-excretion**
  - Housing and manure handling schemes
  - Indoor treatment (to reduce generation)
  - Exhaust treatment (to reduce emission)
Pre-excretion Mitigation

Dietary Manipulation
Effect of Reducing CP Content on NH$_3$ Emission of High-Rise Layer Houses

- 1% lower dietary CP → 11% reduction in NH$_3$ emission

<table>
<thead>
<tr>
<th></th>
<th>NH$_3$ ER (g/hen-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Diet</td>
<td>0.90 (0.24-1.58)</td>
</tr>
<tr>
<td>LP Diet</td>
<td>0.80 (0.19-1.37)</td>
</tr>
</tbody>
</table>

Liang et al., (2005)
Effect of Adding Dietary Fiber on NH$_3$ Emission from Layer Manure

Roberts et al. (2007)
### 24-month Data of NH$_3$ & H$_2$S Emissions of H-R Layer Houses Fed Different Diets

<table>
<thead>
<tr>
<th>Gas &amp; change</th>
<th>Control (g/hen-d)</th>
<th>DDGS (g/hen-d)</th>
<th>EcoCal (g/hen-d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_3$, g/hen-d</td>
<td>0.96 (0.05)</td>
<td>0.82 (0.05)</td>
<td>0.58 (0.05)</td>
</tr>
<tr>
<td>% reduction</td>
<td>--</td>
<td>14 (5)</td>
<td>39 (5)</td>
</tr>
<tr>
<td>H$_2$S, mg/hen-d</td>
<td>1.79 (0.16)</td>
<td>1.99 (0.13)</td>
<td>5.39 (0.46)</td>
</tr>
<tr>
<td>% increase</td>
<td>--</td>
<td>12 (10)</td>
<td>202 (45)</td>
</tr>
</tbody>
</table>

Xin et al. (2001, Unpublished data)
Manure pH of Hens Fed Three Diets

Xin et al. (2010, Unpublished data)
Post-excretion Mitigation

Housing and Manure Handling Schemes
High-Rise Hen House
Manure-Belt House + Manure Storage
U.S. Trend in Layer Cage Systems

High-rise vs. Manure-belt Cage System – Total Industry

Hi-rise
Manure-belt

Courtesy of Tom Lippi, CTB
High-rise vs. Manure Belt Layer House NH$_3$ Emission Rate

AU = animal unit = 500 kg live body weight
Factors Contributing to Lower Emissions of MB Systems

- Reduced manure residence time and hence its decomposition in the hen house
- Reduced emission surface area in storage
- Generally cooler environment in storage
- Drying manure
NH₃ Emission (g/hen-d) vs. Hen Manure Accumulation Time

\[ y = 0.0027x^2 + 0.025x \]

\[ R^2 = 0.998 \]
NH₃ Emission (g/bird-d) vs. Manure Accumulation Time at Different Ages

Mendes – ISU (2010)
Effect of Stacking Configuration on NH$_3$ Emissions from Hen Manure Storage

Time of Storage, day

NH$_3$ Emission Rate, g/day-hen

Air change per hour = 20
Air temp = 25°C
Stack base = 5 x 6 ft

Li & Xin (2010)
Effects of Hen Manure Moisture & Air Temperature on NH$_3$ Emission

Li & Xin (2010)
Some Practical Aspects of Manure-Belt Layer Systems

- Higher construction costs (~50% more)
- Potentially higher maintenance needs due to longevity of manure belt and conveying system
- Need of separate manure storage facility
New vs. Built-Up Litter of Broiler Houses on NH$_3$ Emissions

![Graph showing cumulative NH$_3$ emission against bird age.

- Solid blue line: Built-up litter
- Dotted blue line with markers: Built-up litter Downtime
- Red line with markers: New bedding
- Red dashed line with markers: New bedding Downtime

Source: Burns et al. (2007)
Factors to Consider in Using New vs. Built-Up Litters

- Availability and price of bedding materials
- Higher energy cost helps offset high price of bedding, hence may justify its use every flock.
- Improved bird health and performance
- Built-up litter requires more ventilation to control NH₃ level – likely increase emissions.
- Break-even LP gas price in 1992 was $0.75/gal. Analysis based on current pricing is needed.
Post-excretion Mitigation

Indoor Treatment to Reduce NH$_3$ Generation
Manure/Litter Additives

- **Natural zeolite** $[(Na_4K_4)(Al_8Si_{40})O_{96} \cdot 24H_2O]$
  - Adsorption of $NH_4^+$

- **Acidulants (low pH)**
  - Alum (aluminum sulfate)
  - Ferix-3 (ferric sulfate)
  - Poultry Litter Treatment or PLT (sodium bisulfate)
Reduction of NH₃ Emission from Stored Hen Manure by Topically Applied Additives

<table>
<thead>
<tr>
<th>Additives</th>
<th>Application dosage</th>
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<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Zeolite</td>
<td>68%</td>
</tr>
<tr>
<td>Liquid Alum</td>
<td>63%</td>
</tr>
<tr>
<td>Alum Powder</td>
<td>81%</td>
</tr>
<tr>
<td>Ferix-3</td>
<td>82%</td>
</tr>
<tr>
<td>PLT</td>
<td>74%</td>
</tr>
</tbody>
</table>

Reduction based on single application over a 7 day period  
Li et al. (2008)
Topical Application of Chemical Additives in Broiler Systems

e.g., 100 – 200 lbs alum per 1000 ft$^2$ floor area recommended; with lower dosage lasting ~ 2 wk and hi dosage ~ 3 wk

Moore et al. (2000)

In-house Ammonia Level

- Untreated litter
- Alum treated litter

25ppm, Critical Ammonia Level
Some Practical Issues with Chemical Applications

- Corrosive nature of the low pH chemicals necessitates caution in applicator health/safety and housing equipment protection (e.g., fans).
- Must be re-applied to between flocks to maintain effectiveness.
Post-excretion Mitigation

Treatment of Animal Housing Exhaust Air
Exhaust Air Treatment Systems

- Dispersive Systems with some treatment
  - Vegetative Buffers
  - Windbreak Walls
  - Biomass Walls & Bio Curtains

- Exhaust Air Treatment Systems
  - Biofilters
  - Single Stage Biological Scrubbers
  - Single Stage Acid Scrubbers
  - Multi-Stage, Multi-pollutant Scrubbers
Vegetative Environmental Buffer

Data reported from a broiler house in DE:

- PM reduction: $49\pm27\%$ (33 d)
- NH$_3$ reduction: $46\pm31\%$ (29 d)
- Odor reduction: negligible

Malone et al. (2006)
Biocurtains or Biomass Wall

Reduce dust emissions by 17-20% from poultry houses.
Cost ~ $5000 per tunnel-ventilated house

Cornstalk or straw wall traps dust, reducing odor 40-90% from swine or poultry facilities (Dong et al., 2002)
Bio-filters and Scrubbers

- Biofilters provide good odor control but limited ammonia control.
- Acid scrubbers provide good ammonia control but limited odor control.
- Multi-stage units that include an acid scrubber and a biofilter component can provide both odor and ammonia control.
Biofilters

- Have been used for odor control of swine houses in Germany for 20+ years (Oldenburg Biofilters)

- Have been researched and demonstrated in the US for more than a decade (Nicolai, Jacobson, Hoff, and others)
Open-faced Biofilter System

Exhaust air

↓Odor, ↓ NH₃, ↓ H₂S, ↓ Dust

Biofilter bed

Pallets
Biofilter on a German Swine Farm
Commercial (single or multi-stage) units are being adopted to control NH$_3$ and odor for animal housing in Germany and Holland.

As of January 1, 2008, 10% of swine barns & 0.4% poultry barns in Holland used exhaust air scrubbers for NH$_3$ removal.

Research are being conducted in US on acid scrubbers for poultry houses (AR, OH).
Acid Scrubbers

- A weak sulfuric acid solution (pH of 2 - 4) is re-circulated over the surface area of the scrubber as exhaust air passes over it.

- Gaseous NH₃ reacts with the acid to form ammonium (NH₄⁺) salt and is retained in the solution. When solution pH >4, it is replaced and the spent solution is stored until re-processing or use as a nitrogen fertilizer.
Scrubber Design

2-stage scrubber

3-stage scrubber
Dust Removal

Air

Diagram showing dust removal process.
Ammonia Removal

- Sulfuric acid solution pH 2
- Recirculation
- Discharge when pH > 4
Odor Removal

- Bacterial digestion with biofilter
  - Volatile fatty acids
  - Sulfuric compounds

A G-F pig barn in Germany
Acid Scrubber
Farm Installation of Air Scrubber (G-F Pig House in NL)
Acid Scrubber

The system requires on-farm storage of both fresh and spent acid solutions.
Farm Installation of Air Scrubber (Broiler House in NL)
Measured removal efficiencies for NH$_3$, odor, and PM by farm-scale multi-pollutant scrubbers in the Netherlands

<table>
<thead>
<tr>
<th>Ammonia</th>
<th>Odor</th>
<th>PM$_{10}$</th>
<th>PM$_{2.5}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>63 – 98%</td>
<td>0 – 83%</td>
<td>41 – 46%</td>
<td>23 – 61%</td>
</tr>
<tr>
<td>Avg: 81%</td>
<td>Avg: 40%</td>
<td>Avg: 43%</td>
<td>Avg: 42%</td>
</tr>
<tr>
<td>(n = 7)</td>
<td>(n = 8)</td>
<td>(n = 2)</td>
<td>(n = 2)</td>
</tr>
</tbody>
</table>

Source: Melse et al. (2008)
### Investment and Operational Costs of Scrubbers for Newly Built Facilities in $ per Pig Space

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Acid Scrubber</th>
<th>Multi-stage Scrubber</th>
</tr>
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<tbody>
<tr>
<td>Capital</td>
<td>$47</td>
<td>$72</td>
</tr>
<tr>
<td>Operational (per year)</td>
<td>$15</td>
<td>$19</td>
</tr>
</tbody>
</table>

Source: Melse et al. (2008)
Challenge of Dust to Scrubbers
Wet scrubber for controlling NH\textsubscript{3} and dust developed by ARS (P.A. Moore)

Slide credit: P.A. Moore – USDA ARS
Moore is evaluating the efficacy of this system for scrubbing NH₃ from the broiler house exhaust air. Moore reports the construction cost of this system to be ~ $1000.

Pump  
100 L alum +  
220 L water  
400 L reservoir

Slide credit: P.A. Moore – USDA ARS
SUMMARY

- Nutritionally balanced hen diets with lower crude protein helps reducing ammonia (NH₃) emissions w/o adverse impact on hen production performance.

- EcoCal (7%) and DDGS (10%) diets have been shown to reduce NH₃ emissions from high-rise layer houses by 39% and 14%, respectively, based on a 2-year field study.
SUMMARY

- Frequent removal of manure from animal houses improve IAQ and significantly reduce house-level ammonia (NH₃) emissions.

- Ammonia emission rate increases with hen manure accumulation time (1 – 7 days).

- Reducing manure storage surface area reduces NH₃ emissions; higher manure MC or temperature lead to higher NH₃ emission.
Summary

- Litter additives are commonly used in broiler and turkey productions systems to reduce in-house NH$_3$ levels.

- Exhaust air scrubbers for NH$_3$ and odor control are being applied to swine and some poultry systems in Europe, but have not been adopted on a commercial scale in the US.