Part II: Mitigation through Manure Additives & Exhaust Air Treatment

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Sources of Emission 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)

Post-excretion Mitigation

Indoor Treatment to Reduce NH$_3$ Generation

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http://www.extension.org/pages/Controlling_Ammonia_and_Air_Emissions_in_Poultry_Facilities
Manure/Litter Additives

- **Natural zeolite** \(\text{Na}_4\text{K}_4\text{Al}_8\text{Si}_4\text{O}_{12}4\text{H}_2\text{O}\)
  - Adsorption of \(\text{NH}_4^+\)
- **Acidulants (low pH)**
  - Alum (aluminum sulfate)
  - Ferix-3 (ferric sulfate)
  - Poultry Litter Treatment or PLT (sodium bisulfate)

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Reduction of Ammonia Emission from Stored Hen Manure from Topical Application of Additives

<table>
<thead>
<tr>
<th>Additives</th>
<th>Application dosage</th>
</tr>
</thead>
<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

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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

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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

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Vegetative Environmental Buffer

Date reported from a broiler house in DE:

- PM reduction: 49±27% (33 d)
- NH₃ reduction: 46±31% (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 and limited ammonia control.

- Acid scrubbers provide good ammonia control and limited odor control.

- Multi-stage units that include an acid scrubber and a biofilter or bio-scrubber component can provide both odor control and ammonia control.

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Biofilters

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

- Have been researched and demonstrated in the US for a 10+ years (Hoff, Jacobson, Nicolai and others)

Open-faced Biofilter System

Exhaust air ↓ ↓ Odor, ↓ NH₃, ↓ H₂S, ↓ Dust ↓ ↓ Pallets

Biofilter bed

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Acid and Multi-Stage Scrubbers

- Some research currently being conducted in US on acid scrubbers for poultry houses (Moore).
- Commercial units are being rapidly adopted for ammonia control on swine systems in the Netherlands and Germany.
- Some commercial multi-stage scrubbers are in use on Dutch poultry systems. Must include a particulate removal first stage.

Wet scrubber for controlling ammonia and dust developed by ARS (Philip Moore)

Moore is currently evaluating the efficacy of this system for scrubbing ammonia from the air exhausted from broiler houses. Moore reports the construction cost of this system to be ~ $1000.

100 L alum + 220 L water

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Acid Scrubbers
- A weak sulfuric acid solution (pH 2 – 4) is re-circulated over the surface area of the scrubber as exhaust air is passed over it.
- Gaseous ammonia reacts with the acid to form an ammonium salt and is retained in the solution. When the solution pH exceeds 4, it is replaced and the spent solution is stored until re-processing or use as a nitrogen fertilizer.

Acid & Multi-Stage Scrubber use in Europe
- Exhaust air scrubbers are currently being used on a commercial scale on swine production housing in Germany and for swine and poultry in the Netherlands.
- 10% of Dutch swine systems used an exhaust air scrubber for NH3 removal as of January 1, 2008.

Animal Housing Ammonia Scrubber Installations in the Netherlands

<table>
<thead>
<tr>
<th>Systems Installed as of Jan. 1, 2008</th>
<th>Treatment Capacity (CFM)</th>
<th># of farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid scrubbers</td>
<td>39 million</td>
<td>790</td>
</tr>
<tr>
<td>Biotrickling filters</td>
<td>8 million</td>
<td>90</td>
</tr>
<tr>
<td>Total:</td>
<td>47 million</td>
<td>880</td>
</tr>
<tr>
<td>Pig</td>
<td>45 million (10%)</td>
<td>850</td>
</tr>
<tr>
<td>Poultry</td>
<td>2 million (0.4%)</td>
<td>30</td>
</tr>
<tr>
<td>Total:</td>
<td>47 million</td>
<td>880</td>
</tr>
</tbody>
</table>


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Scrubber Design

2-stage scrubber

3-stage scrubber

Acid / Odor Scrubber

Stage 1 NH₃

Stage 2 Odor

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On-farm storage is required for both fresh and spent acid solutions

2 Stage Dust / NH₃ Unit

Layout of 3-Stage Air Scrubber

Exhaust air is treated in steps
- Dust removal
- NH₃ removal
- Odor removal
2- and 3-stage scrubbers tested

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Air Quality Education in Animal Agriculture Webcast Series
Presented by the Livestock and Poultry Environmental Learning Center

Dust Removal

Ammonia Removal
Sulfuric acid solution
pH 2
Recirculation
Discharge on pH > 4

Odor Removal
A G-F pig barn in Germany
Bacterial digestion with biofilter
- Volatile fatty acids
- Sulfuric compounds

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Farm Installation of Air Scrubber
(G-F Pig House in NL)

Farm Installation of Air Scrubber
(Broiler House in NL)

Measured removal efficiencies for ammonia, odor, and particulate matter (PM) by farm-scale multi-pollutant scrubbers in the Netherlands

<table>
<thead>
<tr>
<th>Ammonia</th>
<th>Odor</th>
<th>PM10</th>
<th>PM2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>63 - 98%</td>
<td>0 - 83% [a]</td>
<td>41 - 46%</td>
<td>23 - 61%</td>
</tr>
<tr>
<td>avg: 83%</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>


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Investment and operational cost of scrubbers for newly built production facilities in $ / pig space

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Acid scrubber</th>
<th>Multi-Stage scrubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>$47</td>
<td>$72</td>
</tr>
<tr>
<td>Total operational costs (year⁻¹)</td>
<td>$15</td>
<td>$19</td>
</tr>
</tbody>
</table>


Summary

- Litter additives are commonly used in broiler and turkey productions systems to reduce in-house ammonia levels.
- Exhaust air scrubbers for NH₃ and odor are being used on swine and some poultry systems in Europe, but have not been adopted on a commercial scale in the US.