Manure Application Methods to Minimize Ammonia Losses and Maximize Crop N Use

Bill Jokela
Research Soil Scientist, USDA-ARS
Dairy Forage Research Center, Marshfield, WI

Jack Meisinger
Research Soil Scientist, USDA-ARS
Beltville, MD

Midwest Manure Summit
Feb. 15-16, 2011, Green Bay, WI
Overview: Ammonia Loss from Manure

• Issues and Concerns
• Factors in Ammonia Volatilization
• Management Practices to Control Ammonia Emissions
  - Annual Crops
  - Grassland, Perennial Forages
• Economics: N- and P-based application.
Why the concern about ammonia losses?

• Loss of N for crops ($)
• Reduces N:P ratio in manure
  - N-based appl: more P build-up in soil
  - P-based appl: buy more fertilizer N
• Eutrophication of surface waters (esp. marine, estuary) via atmospheric deposition
• Air quality - form fine particulates
NH$_3$ Emissions from Cattle Operations in the UK

- Grazing: 13%
- Land Appl.: 38%
- Housing: 36%
- Storage: 13%

Misselbrook et al., 2000
Goal: Minimize Manure Nutrient Losses, Maximize Crop Utilization
Manure N Pathways

Ammonia (NH$_3$)

NH$_4$-N Urea-N

Manure-N

Organic N

Mineralization

Fast

NH$_4^+$, NO$_3^-$

Denitrification

N$_2$, N$_2$O

Plant-available N

Soil Organic N

Slow

Leaching, Runoff

Organic N

Leaching, Runoff

Manure-N Pathways

NH$_4$-N Urea-N
Pattern of NH$_3$ Loss vs Time

Dairy Slurry on Corn Stubble

NH$_3$-N Emission Rate from Dairy Manure Williston, VT

Cumulative NH$_3$-N Loss from Dairy Manure Williston, VT

- **Dairy and Swine Manure**
  - Rapid NH$_3$ loss initially
  - Low losses after 24-48 hours

- **Poultry Litter**
  - More gradual loss
  - Most lost in first week

Jokela and Meisinger, Unpubl. 2004
More Research Examples: NH$_3$ Emission from Dairy Slurry

- Rapid NH$_3$ loss initially
- Most lost in first 6-8 hours
- Very little lost after 24-48 hours
- Shows importance of early action to control NH$_3$ loss (incorporation, etc.)

Meisinger, 2004
Factors in \( \text{NH}_3 \) Losses from Land Application of Manure

- Manure characteristics: \( \text{NH}_4\text{-N}, \%\text{DM} \)
- Weather: Wind, temperature, rainfall
- Soil properties: pH, CEC
- Surface residue or vegetation

- **Application Methods/Incorporation**
  - Time until incorporation by tillage or rain
  - Tillage method
  - Injection, direct incorporation, etc.
Tillage to Control Ammonia Loss

Timing is critical!

NH₃-N Loss, % of Applied

Hours After Spreading
Tillage Effects on NH$_3$ Loss from Dairy Slurry, 7 days
(Thompson & Meisinger, 2002, Meisinger unpub. 2009)

- Surface: 35% reduction
- Ph'nx or Aer.: 80% reduction
- Turbo Till: 90% reduction
- Chisel Plow: 99% reduction
- Inject or Disc: 90% reduction
- Mold. Plow: 99% reduction
Manure N and Silage Corn Yields
Tillage x Manure x N Fertilizer, VT

- Tillage Methods
  - Moldboard Plow
  - Chisel Plow
  - No-till
- +/- Dairy manure
  - 25 T/A semi-solid
- Fertilizer N
  - 0, 50, 100, 150 lb/A

Jokela, 2004
Manure, Tillage, and Fertilizer N Effects on Corn Silage Yield
No-till vs. Moldboard Plow Incorporation

PSNT:
- 16 ppm
- 12 ppm
- 32 ppm
- 12 ppm

+ M = 25 T/A semi-solid dairy manure
MB Moldboard Plow; NT No-till
Spring manure and tillage

VT, Jokela et al
Direct Incorporation Methods

**Benefits**
- Assure immediate incorporation to conserve NH$_3$
- One operation for manure and tillage
- Options for conservation tillage

**Limitations**
- Slower application
- Higher power requirement

Sweep Injection
Manure Application Method and Timing and N Availability (PSNT)

- **Liquid Dairy Manure** (8000 gal/A)
- **Corn for silage**
- **Application Methods**
  - Surface broadcast (fall)
  - Sweep injection (fall)
  - Shallow s-tine cultivation (fall and spring)

PSNT Results

Corn silage yields followed similar trends

Jokela et al., 1999
Corn yield as affected by method of liquid manure application.

<table>
<thead>
<tr>
<th>Application Method</th>
<th>Grain Yield 5-site avg.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (no manure)</td>
<td>89</td>
</tr>
<tr>
<td>Broadcast (7 day incorp.)</td>
<td>107</td>
</tr>
<tr>
<td>Vertical knife injection</td>
<td>115</td>
</tr>
<tr>
<td>Horizontal sweep injection</td>
<td>123</td>
</tr>
</tbody>
</table>

* Sites = Dairy = 2, Hog = 3. Minnesota, 1992-93

Schmitt et al 1995

Credit: G. Randall
N Budget for Slurry Placement
(Thompson et al, 1987; UK)

Surf. Broadcast

Injected

- NH3
- Denitrification
- Crop N
- Soil Org. N
Application Method and Incorporation Effects on NH₃ and Denitrification Losses
Liquid Dairy Manure on Corn, Marshfield, WI.

Manure Application (6500 gal/a)
- Broadcast vs injection
- Time of incorporation
- Pre-plant and sidedress

Prelim. 2010 results
Pre-Plant Manure

NH₃ Emission Rates
- Surface >> Disk > Inject

N₂O Flux
- Inject > Disk > Surface
- N₂O-N << NH₃-N but environmentally important

Jokela and Laboski, Unpubl. 2010
Application Method Effects on NH$_3$ and Nitrate Leaching Losses

Liquid Dairy Manure, No-till Silage Corn, Prairie du Sac, WI.

Application Methods
• Injection
• Partial incorporation (aerator)
• Surface application

(Powell, Jokela, and Misselbrook, 2011)
NH₃ and Other N Losses from Liquid Dairy Manure

- Greatest NH₃ emission rate first 6 to 24 h after application
- Injection or incorporation reduced NH₃ loss, but...
  - Possible trade-off with N₂O emission (Marshfield)
  - Possible trade-off with NO₃⁻ leaching (PduSac)
- Need to adjust manure rate to account for reduced NH₃-N losses
- Consider alternative injection/incorporation methods
Another Alternative: Sidedress Manure?

Potential Benefits
- Another window to apply manure
- May be drier conditions
- Good N availability and yields
- Can use PSNT to determine rate

Injected liquid swine manure in Ontario

Ontario: Ball-Coelho et al. 2005
Is manure incorporation compatible with conservation tillage?

Tillage: manure and residue incorporation

Low-disturbance options
Another option: “Zone-jection”

- Combines zone- or strip-tillage and manure injection

Ball-Coelho 2005, 2006 Ontario
What about manure on grass/perennial forages?
Surface Broadcast Application

- Fast and relatively inexpensive, but...
- Large ammonia-N losses
  - Economic loss for crop
  - Inconsistent crop response
- Can damage sward and contaminate forage
- Poor uniformity
- Runoff losses of nutrients and pathogens
Injection on Grassland

Sweden
Alternatives to Surface Broadcast

Drop-hose/Surface-band

Sliding Shoe/Trailing Foot/ Drag-shoe/Sleigh-foot

Sweden

Quebec

BC
### Application Methods Effects on NH$_3$ Losses on Grassland in Europe

<table>
<thead>
<tr>
<th>Application Method</th>
<th>NH$_3$ Loss Reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Band</td>
<td>20-60%</td>
</tr>
<tr>
<td>Sliding-shoe/trailing-foot</td>
<td>40-75%</td>
</tr>
<tr>
<td>Shallow Injection</td>
<td>60-95%</td>
</tr>
</tbody>
</table>

* Compared to surface broadcast application, typically 40-75% of applied NH$_4$-N

Stevens and Laughlin 1997; Huijsmans et al 2001; Sommer and Hutchins 2001

### Ammonia Losses
- High variability across experiments

### Yields (vs surface broadcast)
- Typically higher with surface band or sliding-shoe (vs surface bdcs)
- Decrease or increase with injection
Trailing-Foot/Band Application

- **Trailing-foot/Band vs Bdcst**
  - Reduced NH$_3$ emission average of 46% (high rate) and 27% (low rate). (6-trial average)
  - Increased grass yields in 2 of 4 site-years (6-14%)

Pfluke, Jokela, and Bosworth, 2011; Carter, Jokela, and Bosworth, 2010
Tine-Aeration with Banded Manure Assisted Infiltration, or Sub-surface deposition (SSD)
Tine-Aeration with Banded Manure

• Ammonia Loss: 50% reduction vs broadcast
• Runoff: 50-90% lower runoff N and P
• Odor: reduced by 1/3,
• N₂O Emission: Tine-Aeration > Bdcst > Control
• Yields: Tine-Aeration > Surface Band > Broadcast

Bittman et al 2005
Van Vliet 2006
Nutrient Balance
Corn/Dairy Manure
Nitrogen Basis

Quick (< 12 hrs) Manure Incorporation

> 4-Day Manure Incorporation
Nutrient Balance
Corn/Dairy Manure
Phosphorus Basis

Quick (< 12 hrs) Manure Incorporation

> 4-Day Manure Incorporation
Summary: Manure Management to Control N Loss and Improve Crop Nutrient Utilization

- Poor manure management = NH₃ and other N loss, environmental problems, odor, economic loss.
- Improved management
  - Quick manure incorporation
  - Optimum rate
  - Good timing
- Several application options available for annual crops, conservation tillage, and grassland
- Improved management:
  - Better match with crop need
  - More efficient use of manure nutrients
  - Less impact on environment