A Temporal Inventory of Ammonia Emission from Agricultural Sources in Canada

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Policy drivers for NH$_3$ emission inventory in Canada

1. Environmental health
2. Human health
   Air quality: PM$_{2.5}$

Atmospheric modeling of chemistry, movement, and deposition
Environmental Impact

1. Deposition
   (critical loading)
   - Effects in estuarine water
   - Forest ecosystems
   - Biodiversity

2. Direct toxicity - most critical
   proposed UNECE change in critical level from 8 to 2 ug m\(^{-3}\)
   new information on vulnerability of lichens and bryophytes

Gothenburg Protocol: Reduce emission to 1990 levels
Effects of Gothenburg on NH$_3$ Emission
% Change 1992 to 2000
Health Impact
Ammonia is a precursor of secondary particulates PM$_{2.5}$

Ammonium (only basic gas) + Acid gases (sulphate, nitrate, chloride, organic) = Salts forming secondary particulates (PM$_{2.5}$)
Ambient particulate matter accelerates coagulation via an IL-6-dependent pathway
Did You Know?
A single poor visibility day could result in a loss of almost $9 million in future tourist revenues for the Lower Mainland and Fraser Valley. (1)

Why is Visibility Important to You?

1) July 2000 Environment Canada report, The Impact of Visual air Quality on Tourism Revenues in Greater Vancouver and the Lower Fraser Valley
Design Shift for Emission Inventories

Environmental
National inventory of annual emission

Health
Temporal and spatial resolution
NH$_3$ Inventories input to atmospheric models to refine policy

Reason:

Inventory + Atmospheric model (AURAMS)

Predict ambient levels of NH$_4$ and PM$_{2.5}$
Sources of ammonia - Dairy Sector

- NH₃ from Atmosphere
- NH₃ from Soil
- NH₃ from Dairy Sector

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Sensitivity analysis of UK and Canadian NH3 emission models

Indicates the importance of livestock diets to emissions; in particular surplus protein consumption (From Sheppard et al. CJSS 2007, in press)

Sensitivity Chart

Target Forecast: TOTAL of cow, pig and poultry

<table>
<thead>
<tr>
<th>Description</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>D&amp;B % TAN fresh excreta</td>
<td>0.76</td>
</tr>
<tr>
<td>DC&amp;H Tot N excreted</td>
<td>0.34</td>
</tr>
<tr>
<td>Dairy cows &amp; heifers</td>
<td>0.27</td>
</tr>
<tr>
<td>Fatteners 20-130 kg</td>
<td>0.14</td>
</tr>
<tr>
<td>%TAN emmit FYM grass</td>
<td>0.13</td>
</tr>
<tr>
<td>BC&amp;H Tot N excreted</td>
<td>0.11</td>
</tr>
<tr>
<td>Poultry %TAN fresh excreta</td>
<td>0.11</td>
</tr>
<tr>
<td>BC % manure FYM spread direct</td>
<td>0.11</td>
</tr>
<tr>
<td>Calves (&lt;1yr)</td>
<td>0.10</td>
</tr>
<tr>
<td>EF % TAN Hens</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Measured by Rank Correlation
Accounting NH$_3$ Emission from Agricultural Sectors

Livestock
- Cattle
- Pigs
- Poultry
- Sheep
- Horses

N fertiliser
- Type
- Grassland
- Arable

Outdoors
- Pigs
- Grazing
- Poultry
- Yards

Housing
- Type
- Period

Storage
- Manure type
- Store type
- Period

Land
- Land use
- Manure type
- Application method

D. Chadwick, IGER, UK
Calculating NH$_3$ emissions

For each sector/ ecozone/ month

Activity data $\times$ Emission factor $\times$

no. of animals or amt. fertilizer use
## Sources of Activity Data

### Livestock Activities
- **FEED**
- Buildings
- Grazing
- Storage
- Land application

### Crops Activities
- N Fertilizer use

### Table

<table>
<thead>
<tr>
<th>Activity</th>
<th>LFPS Survey</th>
<th>NAPS Survey</th>
<th>Feed Industry</th>
<th>Census</th>
<th>Expert</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEED</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grazing</td>
<td>x</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Storage</td>
<td>x</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Land application</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N Fertilizer use</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

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a Livestock Farm Practices Survey (StatCan, March 2006)
b Nitrogen Application Practices Survey (Ipsos Reid, Dec 2006)
c Feed Industry survey (Environment Canada, Spring 2006)
d Canadian Fertilizer Institute (PPI, Can Fert Inst and others, Fall 2006)
Stratification--Ecoregions
## Livestock Farm Practices Survey 2006

<table>
<thead>
<tr>
<th>Region</th>
<th>Responses</th>
<th>Rate of response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic, Ontario, Manitoba</td>
<td>1,179</td>
<td>78.1</td>
</tr>
<tr>
<td>Quebec</td>
<td>433</td>
<td>66.2</td>
</tr>
<tr>
<td>Sask, Albert and B.C.</td>
<td>1,418</td>
<td>74.3</td>
</tr>
<tr>
<td>Canada-wide</td>
<td>3,030</td>
<td>74.4</td>
</tr>
<tr>
<td>Large farms</td>
<td>81</td>
<td>50.6</td>
</tr>
</tbody>
</table>
NH$_3$ Emissions by sector in Canada
Total = 511,000 t/yr

- Industrial
- Non-Industrial
- Transportation
- Incineration
- Miscellaneous
- Open sources
- Agriculture

439,000 t/yr (86%)
>$200,000,000 lost fertilizer value
NH3 Emissions by agricultural sector
Total = 439,000 t/yr
Annual NH3 Emissions from livestock sectors in Canadian Provinces

Poultry

Broilers
Layers
Turkeys

Pigs

Dairy

Beef
Monthly emissions from the dairy sector in three regions of Eastern Canada
BEEF in Alberta

Zone 7 includes feedlots (finishing steers) and rangeland (cows)

Zone 8 includes cows and young steers

- Sharp increase in April-May is due to temperature increase and land spread

- Gradual decrease over growing season for cows reflects decline in grass quality on pastures.
POULTRY in Quebec (2) and Ontario (4)

Peaks reflect contrasting land application practices. In two zones
Dairy and Pigs in Ontario Zone 3

Dairy cows show double peak reflecting spring and fall manure application.

The pattern is less clear for pigs but reasons are not clear.
Monthly NH3 Emissions from fertilizers

QC St Lawrence

ON Eastern

MB Black Soil

SK Black Soil

NH3 Emission t/month

Month
Annual NH₃ emissions all sources
40x40 km grid
Monthly NH₃ emissions from all agricultural sources
Monthly NH$_3$ emissions (all agricultural sources)
Effect of Frequency of Field Trafficability on Emission Intensity
Field trafficability based on ‘Versatile Soil Moisture Model’

- Based on rainfall, evapotranspiration and soil texture
- No spreading if:
  - snow-covered
  - rains on the day
  - soil moisture too high to support equipment
Manure spreading single days, forage, Ontario
More working time on forage than arable (cereal) land

Manure spreading 50th pct'tile single days, Ontario

- Days: 0, 5, 10, 15, 20, 25, 30
- Months: M, A, M, J
- Cereal: Brown bars
- Forage: Light blue bars
Manure spreading workdays on forages for April (days) (50% probability)
Manure spreading workdays on forages for June (days) (50% probability)
Daily ammonia emissions from dairy cattle using different models

Annual Model

NH₃ Emission (kg NH₃/animal-day)

Jan  Mar  May  Jul  Sep  Nov
Daily ammonia emissions from dairy cattle using different models

New Inventory

[Bar graph showing daily ammonia emissions from January to November with the highest emissions in May and the lowest in March.]
Daily ammonia emissions from dairy cattle using different models
Daily ammonia emissions from dairy cattle using different models
Summary

- In ‘shoulder’ months (~April, ~October) there is a greater likelihood that landspreading will be focused into a few days of the month
- Flux on the non-spreading days would be comparable to winter values
Conclusions- General

- Emissions are very sensitive to rates of excretion of urea, difficult to estimate for cattle

- TAN-flow emission inventories show central tendency because conserving in early phase will lead to more emissions later

- More work is needed on seasonal emission models and factors

- Local (dry) deposition may be significant factor but is ignored by inventories
Conclusions - Canada

- Largest emissions from beef, fertilizer, swine
- Hot spots - spatial: south AB; south MB; Fraser Valley, BC; south ON; south QC
- Hotspot - temporal: May (on manure and fertilizer spreading days)
- Ammonia loss ~ 1/3 N fertilizer input; implications for N balances?
- Results on impact of emissions and reduction scenarios are now being completed
- Abatement opportunities include protein ration for cattle, increasing manure injection/ incorporation, deeper manure storages and covers.
Thank you

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