Nitrous oxide emissions from urine and dung

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Content

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• UK GHGPlatform
  • Urine & Dung experiments
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• Summary
Urine and dung - sources of $\text{N}_2\text{O}$

- Grazing livestock convert pasture biomass N into $N_r$
- Urine and dung deposition represent hotspots of N (300-1000 kg/ha N in a patch)
- IPCC default $\text{N}_2\text{O}$ EF (2006 GL): 2% (cattle), 1% (sheep)
- ‘Pasture, Range and Paddock’ represents significant proportion of total $\text{N}_2\text{O}$ from national agricultural emission inventories

![Pie chart showing N$_2$O emissions from various sources in UK agriculture (2013). Total 71.5 kt.](image)
• % of total agricultural N₂O emitted from grazing varies between nations – depends on livestock systems (housing vs grazing period)
Trends in UK GHG emissions from agriculture (IPCC 2006 Guidelines)

- $\text{N}_2\text{O}$ – Tier 1 with CS activity data (N excretion, livestock numbers, fertiliser use)
- $\text{CH}_4$ – Tier 2 for enteric emissions for dairy cattle, other Tier 1 with CS data on livestock numbers, distribution of MMS
Why change to a Tier 2 approach?

- UK set challenging targets
- Industry GHG roadmaps
- Tier 1 is a blunt reporting tool

- Need a reporting tool that better reflects:
  - Soil types & Rainfall zones
  - Management of nitrogen sources
  - Management of grassland and livestock (diet, breed, upland/lowland)
  - Specific mitigation strategies

- Apportion uncertainty to specific parts of the inventory
UK GHG Platform

Nitrous oxide

Data synthesis

Methane

New inventory structure
Nitrous oxide ($InveN_2Ory$) project - N sources

N sources

Nitrogen fertilisers (ammonium nitrate and urea)
Livestock manures (slurry, FYM, poultry manure)
Urine & dung (grazing)

N management

Rate of application (fertiliser N)
Timing of application (manures, urine)
Method of application (slurry)

Mitigation

Nitrification inhibitor
More frequent, smaller doses of N fertiliser

Cardenas et al. (2010)
*InveN$_2$Ory* network of experimental sites

- Represent the principle geoclimatic zones that support agricultural production in the UK

- Address the gaps identified in the initial analysis of current/recent research which has generated IPCC compliant emission factors

- 9 sites: 5 grass and 4 arable
**InveN\textsubscript{2}Ory** – urine & dung treatments

- 5 treatments:
  - Dung
  - Urine
  - Synthetic urine
  - Urine + DCD
  - Control
- 3 blocks
- 5 static chambers/plot

- Dung and ‘real’ urine:
  - Collected from dairy cattle < 7 days prior to experiment
- Synthetic urine:
  - Recipe (Kool et al., 2006)

**Mean application rates (for all sites):**
- **Urine:** 455 kg N ha\textsuperscript{-1}
- **Dung:** 855 kg N ha\textsuperscript{-1}
*Chadwick et al. (2014)*
### Results – site characteristics

<table>
<thead>
<tr>
<th>Site</th>
<th>Clay content (%)</th>
<th>Soil pH</th>
<th>Average annual rainfall (mm)*</th>
<th>Average annual air temp. (°C)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crichton</td>
<td>15</td>
<td>5.6</td>
<td>1244</td>
<td>8.8</td>
</tr>
<tr>
<td>Hillsborough</td>
<td>23</td>
<td>5.9</td>
<td>1140</td>
<td>8.2</td>
</tr>
<tr>
<td>Pwllperian</td>
<td>30</td>
<td>5.6</td>
<td>1869</td>
<td>10.4</td>
</tr>
<tr>
<td>Drayton</td>
<td>59</td>
<td>7.6</td>
<td>756</td>
<td>11.2</td>
</tr>
<tr>
<td>North Wyke</td>
<td>37</td>
<td>5.7</td>
<td>1253</td>
<td>9.7</td>
</tr>
</tbody>
</table>

*Annual rainfall and air temperature of the experimental periods*
Results – urine composition

- **Total N and Urea-N (g/l)**
  - **Total N**
  - **Urea-N**

- **Hippuric acid (mg/l)**

- **Creatinine/Allantoin concentration (mg/l)**
  - **Creatinine**
  - **Allantoin**

- **DM (%) and pH**

- **Crichton - SP**
- **Crichton - SU**
- **Crichton - AU**
- **Drayton - SP**
- **Drayton - SU**
- **Drayton - AU**
- **Hillsborough - SP**
- **Hillsborough - SU**
- **Hillsborough - AU**
- **North wyke - SP**
- **North wyke - SU**
- **North wyke - AU**
- **Pwllpeiran - SP**
- **Pwllpeiran - SU**
- **Pwllpeiran - AU**

- **DM (%) and pH**

- **Hippuric acid**
Results – $\text{N}_2\text{O}$ emissions (site level) North Wyke

Spring application

<table>
<thead>
<tr>
<th>N$_2$O lost as % of N applied</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine</td>
<td>2.96</td>
</tr>
<tr>
<td>Urine + DCD</td>
<td>1.00</td>
</tr>
<tr>
<td>Artificial urine</td>
<td>2.23</td>
</tr>
<tr>
<td>Dung</td>
<td>0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N$_2$O flux (g N$_2$O-N ha$^{-1}$ d$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
</tr>
<tr>
<td>8,000</td>
</tr>
</tbody>
</table>
Results – summary data

Effect of ‘application’ timing (across all sites) on N₂O EFs

Means with different letters within each treatment are significantly different (P<0.05)
Results – summary data

Site differences in N$_2$O EFs (across all timings)

Means with different letters within each treatment are significantly different (P<0.05)
### Results - synthesis

<table>
<thead>
<tr>
<th>N₂O EF (%)</th>
<th>average</th>
<th>standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine (15)</td>
<td>0.69</td>
<td>0.12</td>
</tr>
<tr>
<td>Urine + DCD (15)</td>
<td>0.37</td>
<td>0.06</td>
</tr>
<tr>
<td>Dung (15)</td>
<td>0.19</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### Recent NZ data

<table>
<thead>
<tr>
<th>Recent NZ data</th>
<th>Topography</th>
<th>Urine N₂O EF</th>
<th>Dung N₂O EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelliher et al (2014)</td>
<td>Lowland</td>
<td>1.16 (55)</td>
<td>0.23 (20)</td>
</tr>
<tr>
<td>Dairy</td>
<td>Hill (low slope)</td>
<td>0.84 (16)</td>
<td>0.20 (4)</td>
</tr>
<tr>
<td>Beef</td>
<td>Hill (low slope)</td>
<td>0.99 (4)</td>
<td>0.21 (12)</td>
</tr>
<tr>
<td>Beef</td>
<td>Hill (medium slope)</td>
<td>0.32 (4)</td>
<td>0.06 (4)</td>
</tr>
<tr>
<td>Sheep</td>
<td>Lowland</td>
<td>0.55 (4)</td>
<td>0.08 (12)</td>
</tr>
<tr>
<td>Sheep</td>
<td>Hill (low slope)</td>
<td>0.40 (12)</td>
<td>0.11 (8)</td>
</tr>
<tr>
<td>Sheep</td>
<td>Hill (medium slope)</td>
<td>0.16 (8)</td>
<td>-</td>
</tr>
</tbody>
</table>

**InveN₂Ory** combined excretal (urine + dung) EF = 0.57-0.59*

*depends on proportion of N excreted in urine vs dung (75:25 or 80:20)
Relationships – statistical models

**Urine** $\text{N}_2\text{O EF} = f\ \text{Ammonium-N, Creatinine, Urea-N}$

$r^2=0.724$

$r^2=0.864$ if air temperature and rainfall included

**Dung** $\text{N}_2\text{O EF} = f\ \text{Rainfall, %Clay, %DM, %WFPS, SOC, BD, soil pH, pH}$

$r^2=0.688$

- Urine $\text{N}_2\text{O EF}$ predominantly controlled by urine composition
- Dung $\text{N}_2\text{O EF}$ predominantly controlled by physical environment
Wider synthesis - additional data sets

- UK $\textit{InveN}_2\textit{Ory}$ 15 experiments
- UK – additional 2 experiments
- Irish - 12 new experiments - Agricultural Greenhouse Gas Research Initiative (AGRI-I)
- e.g. New Zealand (Kelliher et al., 2104)
Summary

• Urine and dung N$_2$O emissions vary across sites and seasons

• Urine N$_2$O EF of 0.69% significantly greater than that for dung (0.19%)

• Produce a combined excretal EF for cattle of 0.57-0.59%, which is much lower than IPCC default (2% cattle and 1% sheep)......implications......

• DCD efficacy variable – but with average reduction of 38% from urine (range 0-75%)
Future research

• Sheep urine/dung (assume the same $N_2O$ EF as for cattle)?

• Effect of stocking density – urine patch overlap?

• Upland soils / extensive systems – e.g. acid soils, cooler/wetter soils, reduced palatability of vegetation

• Mitigation strategies (manipulate urine composition and/or livestock movement, targeted use of inhibitors)

• Understanding what controls efficacy of inhibitors
Thanks!!

• Organisers of the GGAA2016 Conference

• *InveN₂Ory* project field and lab teams

• Dr Dan Dhanoa (statistics)

• Funders
Literature cited


