Background 1

- Critical levels of acidification and nutrient-N are still exceeded in many parts of Europe
- reductions in SO$_2$ and NO$_x$ emissions have been achieved
- by 2010 NH$_3$ is likely to be the largest contributor to acidifying and gaseous N emissions
Map showing the accumulated exceedance of total nitrogen over critical loads for all ecosystems, 1998.

Legend:
- 0 - 25
- 25 - 200
- 200 - 500
- 500 - 1000
- 1000 - 6000

Source: DES 1991 boundary data.
Map showing the accumulated exceedance of total nitrogen over critical loads for all ecosystems, after removal of all NOx.
Map showing the accumulated exceedance of total nitrogen over critical loads for all ecosystems, after removal of all NH3.
Map showing the accumulated exceedance of total nitrogen (NH3+NOx) over critical loads for all ecosystems, after reduction of NH3 by 20%. 

Legend
kg/yr

- 0 - 25
- 25 - 200
- 200 - 500
- 500 - 1000
- 1000 - 6000

Source: OS 1:50k boundary data
Background 2

- The UNECE resolved to apply a multi-effect multi-pollutant approach to prevent or minimise exceedance of critical loads or levels
- Measures to reduce NH$_3$ emissions are required under the 1999 protocol to the Convention on Long-Range Transboundary Air Pollution to abate Acidification, Eutrophication and ground-level O$_3$
Background 3

- Conscious of the need for a cost-effective **regional** approach to combatting air pollution that takes account of the variation in effects and abatement costs *between countries*
Background 4

• *Measures taken to reduce emissions of NO$_X$ and NH$_X$ should not, so far as possible, increase other emissions of reactive-N, including N$_2$O*
Protocol requirements 1

• Countries have been given an emissions ceiling
  – from 4% reduction (France)
  – to 43% (Netherlands)
• with a 15% overall reduction for Europe
• and are required to apply, as a minimum the following control measures
Protocol requirements 2

- To provide information to the general public
- make widely available information on NH$_3$ abatement, including information on Good Agricultural Practice (GAP)
- encourage research into improvements to NH$_3$ databases
- improve NH$_3$ monitoring techniques
- quantify efficacy of NH$_3$ control techniques for farms and their impacts on deposition
Where does it come from?

UK

kg x 10^6

Cattle | Pigs | Poultry | Sheep | Fertilizer | Non-Ag
140   | 20   | 40     | 10    | 30         | 60
Agricultural sources

kg x 10^6

UK

DK

- Cattle
- Pigs
- Poultry
- Fur
- Sheep
- Fertilizers
Emissions at stages of manure management

%
TAN flow

TAN AT EXCRETION

TAN INTO STORAGE

TAN AT SPREADING
Implications for abatement

• NH$_3$ lost ‘upstream’, e.g. buildings and stores may be lost ‘downstream’ e.g. spreading, if no further measures taken.
• surface phenomenon
  – greatest emissions when SA/vol ratio large
  – buildings, spreading, less from stores
  – emissions largely cease when absorbed by soil
Strategy 1

• Reduce emissions at final stage of manure management
  – Losses during spreading minimal
    • 1% of total

• specific measures

• immobilize in litter

• rank according to cost-effectiveness
Strategy 2

- Different strategy to nitrate (NO$_3$), nitrous oxide (N$_2$O)
- surface phenomenon
- reducing excess has limited effect
- need specific measures to reduce NH$_3$
Code of good agricultural practice- 6 sections

- N management
- feeding strategies
- spreading
- storage
- housing
- N fertilizers
N management - balanced N application

• NH₃ emissions arise *before* applied N enters pool of plant-available N
• balancing N inputs to crop needs has much less potential to reduce NH₃ emissions than NO₃
• specific abatement measures are needed to give large reductions in NH₃ emissions
• adopting such measures will conserve N for crop uptake
Livestock feeding strategies

• Ensure livestock not fed more protein than required
• reduces N excretion and hence NH$_3$ emissions
• protein surplus largely excreted as urea or uric acid
• hence reducing protein input gives disproportionate decrease in NH$_3$ losses
Spreading Categories

• 1 - Well researched, practical, quantitative data on their abatement efficiency
• 2 - promising, but research inadequate, or difficult to quantify efficiency. They may be used as part of an abatement strategy
• 3 - ineffective or are likely to be excluded on practical grounds
**Shallow injection** - Slurry is placed in shallow (50-60 mm) open slots

**Band spreading** - Slurry applied in narrow bands by trailing hoses

**Trailing Shoe** - Sward is parted by the shoe and slurry applied to the soil

**Shallow injection** - Slurry is placed in shallow (50-60 mm) open slots
Injection

• Deep injection inserts slurry beneath the surface
  – up to 95% reduction in emissions
• problems with
  – stones
  – damage to grass swards
• slot injection, more applicable, less damage
  – less effective, 60 - 70%
Band spreaders

- Reducing surface area reduces emissions
  - % losses less from large application rates
- trailing shoe, mainly grassland
  - 40-70% reduction
- trailing hose, 10-50%
Field-scale studies

• Few studies using more than 1 technique
  – Malgeryd 1998, BS, TS, ShI
  – Mattila 1998, BS, I
  – Mulder and Huijsmans 1994, BS, TS, SII/I
  – Misselbrook and Smith 2000, BS, TS, SII
Field-scale 2

- Some single comparisons have also been made
  - Pain and Misselbrook 1997, I
  - Sommer et al 1997, TH
  - Ferm et al 1999, TH
  - Bless et al 1991, TH
## Overall averages

<table>
<thead>
<tr>
<th>Machine</th>
<th>Arable</th>
<th>Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH</td>
<td>31 (34)</td>
<td>32 (30)</td>
</tr>
<tr>
<td>TS</td>
<td>67 (70)</td>
<td>62 (62)</td>
</tr>
<tr>
<td>Sh/S1 I</td>
<td></td>
<td>72 (72)</td>
</tr>
<tr>
<td>I</td>
<td>70 (52)</td>
<td></td>
</tr>
</tbody>
</table>
## Category 1 - spreading

<table>
<thead>
<tr>
<th>Category</th>
<th>UNECE</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>trailing hose</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>trailing shoe</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>injection – open slot</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>injection – closed slot</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>incorporation of slurry or FYM</td>
<td>80-90</td>
<td>90-95</td>
</tr>
</tbody>
</table>
Category 2 - spreading

• dilution of slurry
  – increased storage capacity
  – increased risk of run-off

• mechanical separation of slurry
  – emissions from solid fraction

• apply water after spreading
Category 3 - spreading

• Acidifying slurry to pH 4-5
  – hazard of handling strong acids
  – Increased \( \text{N}_2 \text{O} \) emissions

• additives e.g. salts of Ca, Mg, Al
  – quantities required too large
## Storage techniques

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Requires</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>solid roof, tent or lid</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>C2</td>
<td>natural crust formation</td>
<td>stirring before spreading</td>
<td>35-50</td>
</tr>
<tr>
<td>C2</td>
<td>floating plastic cover</td>
<td>not well tested</td>
<td>60</td>
</tr>
<tr>
<td>C2</td>
<td>floating oil, leca cover</td>
<td>requires stirring before</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spreading</td>
<td></td>
</tr>
</tbody>
</table>
Ammonia emissions from cattle

- Manure
- Grazing

Graph showing emissions from TAN and NH3.
Extending the grazing season

• In principle large potential benefit
• Practice, not so clear
  – only part of day
  – do emissions continue from house?
• May make a small contribution
Good housekeeping

- Spreading in evening
- Keeping yards clean
- Frequent scraping of cubicles
Encourage FYM storage

• ‘fresh’ FYM 25% TAN, stored FYM 10%
• Where does the TAN go during storage?
  – Not much NH$_3$
  – N$_2$O
  – N$_2$
  – Leaching
  – immobilization
  – ???
## Cost-curve output

<table>
<thead>
<tr>
<th>Measure</th>
<th>cost (£ x 10^6)</th>
<th>NH₃ red (kg x 10^6)</th>
<th>cost (£ per kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>immediate incorp FYM to arable land by disc</td>
<td>0.31</td>
<td>1.009</td>
<td>0.31</td>
</tr>
<tr>
<td>crust formation on lagoons</td>
<td>0.05</td>
<td>0.127</td>
<td>0.39</td>
</tr>
<tr>
<td>immediate incorp slurry to arable land by disc</td>
<td>1.63</td>
<td>3.388</td>
<td>0.48</td>
</tr>
<tr>
<td>crust formation on slurry tanks</td>
<td>0.198</td>
<td>0.119</td>
<td>1.66</td>
</tr>
<tr>
<td>application of slurry to grass by trailing shoe</td>
<td>37.893</td>
<td>9.487</td>
<td>3.99</td>
</tr>
<tr>
<td>increased frequency of scraping slurry from cubicle buildings</td>
<td>10.251</td>
<td>2.187</td>
<td>4.69</td>
</tr>
<tr>
<td>store all FYM</td>
<td>20.639</td>
<td>3.375</td>
<td>6.12</td>
</tr>
</tbody>
</table>
Cost-curve dairy

£ x 10^6

% NH₃ reduction
Feeding strategies

- Very effective for pigs (synthetic amino acids)
  - but expensive
- Less effective for poultry
  - and costs exceed profit margin
- Complex for ruminants
  - all grass
  - mixed forages
Effect of fertilizer-N on autumn SMN (from Sylvester-Bradley & Chambers)
Background 1

• Critical levels of acidification and nutrient-N are still exceeded in many parts of Europe

• measures to reduce NH$_3$ emissions are required under the protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to abate Acidification, Eutrophication and ground-level O$_3$
Background 2

• The UNECE resolved to apply a multi-effect multi-pollutant approach to prevent or minimise exceedance of critical loads or levels

• conscious of the need for a cost-effective regional approach to combatting air pollution that takes account of the variation in effects and abatement costs between countries