Mitigation of ammonia emission from agriculture

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Outline

- Nitrogen policies
- Sources of ammonia in agriculture
- Mitigation of ammonia emission
- Emission factors of applied manure and fertilizer

- Mini break

- National Ammonia Model Agriculture
- Trends since 1990 and outlook for 2030
- Challenges
Nitrogen policies

- Ammonia (NH$_3$) and nitrogen oxides (NOx: NO and NO$_2$)
  - Emission ceilings:
    - NEC Directive and UNECE Gothenborg protocol
  - Biodiversity (nature policy)
    - EU birds and habitats directive (Natura 2000)

- Nitrate (NO$_3^-$):
  - EU Nitrates Directive
  - EU Water Framework Directive

- Nitrous oxide (N$_2$O)
  - UNFCCC Kyoto/Paris Convention
Sources of ammonia in agricultural systems

Housing and manure storage
- Housing systems
- Manure storage

Soils
- Applied manure
- Grazing
- Applied fertilizer (mineral and organic)
- Crop residues
Mitigation of ammonia emission

\[ \text{ammonium} \quad \text{NH}_4^+ \quad \rightleftharpoons \quad \text{ammonia} \quad \text{NH}_3 \quad + \quad \text{Proton} \quad \text{H}^+ \]

Main mechanisms of measures to decrease \( \text{NH}_3 \) emission

- Decrease ammonium content in manure and/or soil
- Decrease pH
- Decrease contact of ammonium with air
- Trap volatilized ammonia
Mitigation of ammonia

$\text{ammonium} \quad \text{NH}_4^+ \quad \leftrightarrow \quad \text{ammonia} \quad \text{NH}_3 \quad + \quad \text{Proton} \quad \text{H}^+$

Decrease ammonium content in manure and/or soil

- Less manure production/application
- Less fertilizer application
- Low protein feed
- Urease inhibitors
- Adsorption in soil (CEC)
- Immobilization (straw, additives, bedding materials in housings)
- Manure separation in liquid and solid fraction
Mitigation of ammonia

\[ \text{ammonium} \quad \text{NH}_4^+ \quad \leftrightarrow \quad \text{ammonia} \quad \text{NH}_3 \quad + \quad \text{Proton} \quad \text{H}^+ \]

Decrease pH

- Acidification
- Soil processes: nitrification and NH$_4$ uptake plants
- Ammonia emission itself
Mitigation of ammonia

Decrease contact of ammonium with air

- Cover stored slurry
- Rapid manure removal from floor housing
- Injection or incorporation of manure in soils
- Manure application during/before rain/add water
Mitigation of ammonia

\[
\begin{align*}
\text{ammonium} & \quad \rightarrow \quad \text{ammonia} \\
\text{NH}_4^+ & \quad \rightarrow \quad \text{NH}_3 + \quad \text{Proton} \\
\text{NH}_3 & \quad \leftarrow \quad \text{H}^+ 
\end{align*}
\]

Trap volatilized ammonia

- Air purification in livestock housing
  - Acid traps
  - Biological traps (nitrification)

\[2 \text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4\]
Manure application and grazing

Emission factor, % of TAN (ammoniacal N)

- Grassland
- Arable land

Sources: NEMA; Huijsmans et al.; Bussink et al.
Manure application and grazing

Emission factor, % of TAN (ammoniacal N)

Grassland

- Surface spreading
- Trailing shoe
- Sod injection
- Shallow injection
- Grazing

Arable land

- Surface spreading
- Trailing shoe
- Shallow injection
- In-corporation in 1 track
- Deep injection

Sources: NEMA; Huijsmans et al.; Bussink et al.
Mineral fertilizers

- Emission factors derived from Bouwman et al. (2002):
  - fertilizer type, soil pH, CEC soils, crop: average for NL

### Fertilizer use 2017:
- 53% Calcium ammonium nitrate
- 15% NP, NK and NPK fertilizers
- 8% liquid urea
- 26% other

Source: NEMA
Mini break
National Emission Model Agriculture NEMA

- Used for calculation emission at national scale

- Calculations based on: activity x emission factor
  - Activity data: number of animals, type of feed, housing types, fertilizer use, manure application types etc.
  - Different sources, e.g. agricultural census

- Emission factors (% of N or ammoniacal N (TAN)):
  - Housing, manure and fertilizer application, etc.
  - Measurements, literature
National Emission Model Agriculture NEMA

Total N and TAN excretion livestock

Housing

Storage outside

Export, treatment

Compost and Sewage sludge
Crop residue and ripening
Fertiliser
Slurry and solid manure
Grazing
Fertiliser
Crop residue and ripening

Arable land
Grassland

Van Bruggen et al., 2019
Lagerwerf et al., 2019
Trend in emission

Ammonia emission, million kg NH₃

Source: NEMA; Van Bruggen et al., 2020
Recent trends in ammonia emission

**Factors that increased emission:**

- Increase of number of dairy cattle
- Higher milk production per cow
- Higher protein content of grass roughage
- Less silage maize/more grass in diet cows

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**Factors that decreased emission:**

- Higher implementation rate of low emission housing
- Higher implementation rate of low emission application
- Lower protein content concentrates

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*Source: Van Bruggen et al. 2020 CDM, 2020*
Recent trend and estimate 2020-2030

Ammonia emission, million kg NH$_3$

- Van Bruggen et al., 2020; Velthof et al., 2019
Emission reduction targets 2030

Ammonia emission, million kg NH₃

- Target 2030
- Other
- Mineral fertilizer
- Manure application
- Grazing
- Manure storage
- Housing
Further reduction of ammonia emission?

Possible measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Million kg NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>More grazing</td>
<td>0.5</td>
</tr>
<tr>
<td>Water dilution slurry applied with shallow injection</td>
<td>1-2</td>
</tr>
<tr>
<td>Low emission housings</td>
<td>4-6</td>
</tr>
<tr>
<td>Decrease N content feed</td>
<td>5-11</td>
</tr>
<tr>
<td>Less livestock near Natura 2000</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: PBL; Groenestein et al., 2019

- Effects uncertain: low emission housing and application, reduction protein content in roughage
- High costs
- Sufficient to reach target for 2030?
Conclusions

- Large number of measures to reduce ammonia emission

- Strong decrease in ammonia emission since early nineties
  - Low-emission application techniques very effective

- Recent years: increase in ammonia emission
  - Increase in number of cattle and milk production per cow, more N in roughage

- Large challenges to reduce emission towards 2030
Thank you!