Integrated approaches to nitrogen management

Some German experiences

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Air Pollutant Effects on Terrestrial Ecosystems
Outline

• The UBA strategy for the reduction of Nitrogen emissions

• What does „integrated“ mean?

• What is still missing?
Why a strategy?

• N cascade not established as a concept
• N related environmental protection targets will not be reached
• They will be easier to reach when emitters and effects are treated in an holistic manner

Customers

• Policy (NEC Dir. / Gothenburg Protocol; Nitrate & WF Directive; IPPC Directive; UNFCCC; CAP revision)
• NGOs and interested public
• European (NinE, COST729, TFRN, ...) & global N-etworks
Method and procedure

- UBA in-house working group and knowledge and publicly available / mostly official reported data
- external review via international status seminar (Nov 2008) and follow-up revision
- Report to MinEnv
- to follow: policy implementation by Environment and other Ministries

www.uba.de/luft-e/index.htm
Structure

1. Effects in relation to the N-Cascade
2. Nr related policies and quality targets
3. National Nitrogen budget
4. Evaluation of measures & instruments in relation to quality targets
5. Policy recommendations
German N emissions and targets

**Emissions**
- NO$_3$ / NH$_4$ to waters
- NO$_x$ to atmosphere
- NH$_3$ to atmosphere
- N$_2$O to atmosphere

**NEC Directive targets**
- NEC 2010 for NH$_3$
- NEC 2010 for NO$_x$
N related environmental targets not reached

- Critical Loads for eutrophication and acidification exceeded on 95 % / 85 % of area

- Insufficient reduction of N inputs into coastal waters

- 14 % of measurement sites exceed nitrate concentrations limit values

- PM10, ozone and NO₂ limit values partly exceeded
N-Budget for Germany
N-Budget for Germany

**import:**
- 1808 Gg mineral fertiliser
- 372 Gg feedingstuff import
- 300 Gg biological N fixation
- 514 Gg combustion
- 260 Gg transboundary atmospheric transport

**quantifiable export:**
- 450 Gg river-based transport to sea
- 700 Gg transboundary atmospheric transport
- 830 Gg denitrification estimates:
  - rivers, agriculture, wastewater management

**about 3200 Gg total**

**Uncertain fate of reactive N:**
- about 40 % of the annual import (accumulation? / loss? / export?)

**about 2000 Gg total**
**N-Budget for Germany**

- **15%** transport
- **13%** industry & energy
- **63%** atmospheric pathway
- **57%** agriculture
- **15%** wastewater
- **37%** soil-water pathway

**Emissions [Gg]**

- agriculture: 1062 Gg
- transport: 270 Gg
- energy & industry: 244 Gg
- wastewater: 270 Gg
- waste: 10 Gg
- total: 1856 Gg

*van der Hoek et al., 1998*
Assessment of measures & instruments
• N-reduction potential [Gg a\(^{-1}\)]
• cost-effectiveness [€ / kg N]
• synergies & „pollution swapping“
• mandatory vs. optional

Emission sectors
• agriculture
• transport
• energy & industry
• waste- & wastewater management
Assessment of measures & instruments

- synergies & trade-offs so far not fully quantifiable

- largest reduction potential in agriculture, high cost-effectiveness
  - management measures & economical instruments are cheap and have high reduction potential
  - agricultural „m & i“ show large synergies

- within transport and energy sector a lot of cost-effective „m & i“ already implemented

- changed consumers’ behaviour potentially effective
### Optional agricultural measures (examples)

<table>
<thead>
<tr>
<th>Agricultural measures</th>
<th>NO&lt;sub&gt;x&lt;/sub&gt;</th>
<th>NH&lt;sub&gt;3&lt;/sub&gt;</th>
<th>NO&lt;sub&gt;3&lt;/sub&gt;/NH&lt;sub&gt;4&lt;/sub&gt;</th>
<th>N&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>Reduction potential [Gg N]</th>
<th>Cost effectiveness [€ / kg N]</th>
<th>Legal implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased consultancy of farmers for use of fertilisers</td>
<td>°</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>45</td>
<td>high</td>
<td>Instructions of farmers by administrations, chambers of agriculture, consultants</td>
</tr>
<tr>
<td>Quotation of mineral fertilizer due to fertilization plans (accredited experts)</td>
<td>°</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>n.q.</td>
<td>n.q.</td>
<td>Tightening of Fertilisation Ordinance Administrative consulting for fertilization plans</td>
</tr>
<tr>
<td>Increased fertilisation efficiency</td>
<td>°</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>n.q.</td>
<td>n.q.</td>
<td>Administrative consulting for fertilisation; chambers of agriculture, consultants</td>
</tr>
<tr>
<td>N reduced feedingstuff adjusted to the N demand of the animals</td>
<td>°</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>14</td>
<td>high</td>
<td>Restoration and licensing of housing: certification of n-adjusted feeding (claim for TA Luft Nr. 5.4.7.1 c); consultation of the farmer by animal nutrition consultant</td>
</tr>
<tr>
<td>Air purification in pig housing</td>
<td>-</td>
<td>++</td>
<td>°</td>
<td>-</td>
<td>16</td>
<td>n.q.</td>
<td>Licensing TA Luft (Nr. 5.4.7.1 d); instructions for farmers</td>
</tr>
<tr>
<td>Covered storage (min. 6-8 month capacity) (pigs)</td>
<td>°</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>high</td>
<td>Licensing TA Luft Nr. 5.4.7.1 h)</td>
</tr>
<tr>
<td>Covered storage (min. 6-8 month capacity) (cattle)</td>
<td>°</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>medium</td>
<td>Licensing TA Luft Nr. 5.4.7.1 h)</td>
</tr>
</tbody>
</table>

[www.uba.de/luft-e/index.htm](http://www.uba.de/luft-e/index.htm)
Is the evaluation of measures and instruments integrated?

- Listing of „m & i“ for all relevant emitters ✓
- Evaluation w.r.t. abatement potential, abatement costs, synergies/antagonisms ✓
  - but costs and synergies/antagonisms not fully quantitative x
- Guidelines for generic assessment of „m & i“ ✓
- Realizability of „m & i“ (?)
Realizability of measures and instruments

• Regulated by law vs. optional √

• General criteria for success of m&i:

<table>
<thead>
<tr>
<th></th>
<th>Combustion</th>
<th>Agriculture</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOₓ</td>
<td>NH₃</td>
<td>NO₃</td>
</tr>
<tr>
<td>Few stakeholders</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology driven</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Low costs</td>
<td>x</td>
<td></td>
<td>(x)</td>
</tr>
<tr>
<td>Cost to consumers</td>
<td>x</td>
<td>(x)</td>
<td></td>
</tr>
<tr>
<td>Knowledge extensive</td>
<td></td>
<td>(x)</td>
<td></td>
</tr>
<tr>
<td>No yield loss</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Does the M&I evaluation take into account the N cascade? (1)

- multi-source?
- multi-effect?
- multi-media?
- multi-scale?

van der Hoek et al., 1998
Multi-source

ok!
Multi-effect, multi-media

• Evaluation takes into account
  ➢ transfer between different N forms
  ➢ cross-media effects (indirectly)

BUT

• Synergies and pollution swapping not fully quantified

• There is no „evaluation currency“:
  ➢ 1 kg NH$_3$-N = 1 kg N$_2$O-N?
  ➢ If not: how else?

• Evaluation target: eutrophication, climate change etc. or ecosystem services?
Multi-scale

• “m & i” are defined on national/continental level but take effect locally / regionally

• “global perspective is critically important to public perception!”

• How to assess (spatial and temporal) scale of effects:
  $\text{N}_2\text{O}-\text{N}$ (global, 100 years) vs. $\text{NH}_3\text{-N}$ (local/regional, days to years)?
Does the M&I assessment take into account the N cascade? (2)

- multi-source ✓
- multi-effect, multi-media (√)
- multi-scale ?

<table>
<thead>
<tr>
<th></th>
<th>General</th>
<th>Global</th>
<th>Transboundary</th>
<th>National</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidification from NH₃</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Eutrophication from NH₃</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>NH₄⁺ aerosol as a global coolant</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Effect of NH₃ on atmos. transport of SOₓ &amp; NOᵧ</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Global warming from N₂O</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NO₃⁻ leaching</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

Results of DELPHI analysis by Angus et al. (J. Env. Man. 2003)

Structure

1. Effects in relation to the N-Cascade

2. Nr related policies and quality targets

3. National Nitrogen budget

4. Evaluation of measures & instruments in relation to quality targets

5. Policy recommendations
N budgets are a useful policy instrument!

- Communication and issue building

- Priorisation of fluxes for policy information
  (e.g. air vs. water; agriculture vs. industry; ...as compared to EQOs)

- Various scales:
  - Sectoral (e.g. farm / field / soil budgets)
  - Local (NEU 4: Cellier et al)
  - National (NL, D, CH, ...)
  - Europe (ENA)
  - Global (e.g. Erisman et al 2008)

- Optional coupling to C, P, ... budgets (Galloway & Gruber 2007)

- Identification of control/intervention points where
  - N efficiency can be improved (z.B. N efficient fertilization)
  - Nr losses are large (z.B. waste water treatment)
Needed: Dynamic N Budgets

- **Dynamic flux / effect model** (after Galloway et al. 2008)
  - How much Nr enters the system?
  - How long does it stay in a compartment?
  - What are the effects?
  - What are the accumulation / loss rates?
  - How much Nr is transported where & in which form?

- **Aim: Prognoses, Scenarios** (ENA 5b)
  - How, where and when do m&i / policies change fluxes & accumulation rates?
  - How, where and when do m&i / policies change effects?
  - … as compared to EQOs?
Global Fertiliser Consumption 1900-2100

Erisman et al., Nature Geoscience (2008)
Impact analysis of individual m&i

US Nitrogen Budget: Revised [Tg N yr\(^{-1}\)]

The numbers on this slide have been modified, assuming the actions at control points were effective.

Galloway et al. (2008)
Emission reduction towards sustainability: Swiss strategy I

N fluxes Ø 1985-1995 [Gg N/a]

Sustainable N fluxes fulfilling O₃ and CL(N) targets; required reduction vs. 1990

Source: Projektgruppe N-Haushalt Schweiz/INFRAS 1996
Swiss N emission reduction strategy II: emission reduction need vs. 2002
International cooperation is indispensable!

- Multilateral exchange of methods, data, M&I
- Europe: TFRN (fed by ENA et mult.al.) for CLRTAP; EU
- Global: UNEP / INI / CSD …
  - Global policies on environment, agriculture, food security, sustainable development, climate, biodiversity, …
Outlook

• **Spatial and temporal scales**
  ➢ Methods to generalize and evaluate M&I / effects on various scales

• **Strengthen links between effects, targets and M&I**
  ➢ Dynamize budgets
  ➢ Links to ecological targets (e.g. WFD – good ecological state? Ecosystem services?)
  ➢ Indicator development
    ➢ Linking farm balances, national budget, CLexc, …
    ➢ regional / national Nr – emission caps?
  ➢ Better cooperation with agricultural / food health and security policies

• **Adequate monitoring**
  ➢ N budgets, N efficiency, biodiversity effects etc.
  ➢ Link existing monitoring systems
Summary

Integrated approach aims at
0. Issue building and communication
1. Limiting Nr production, import and consumption
2. Increasing N efficiency
3. Increasing „unused“ Nr conversion to N₂
Summary

Integrated approach consists of

1. EQO oriented analysis of effects
2. N budgets
3. M&I assessment
   a) Abatement potential
   b) Synergies/pollution swapping
   c) Abatement cost
4. Policy recommendations
5. International cooperation
6. Monitoring
Thank you for your attention!

www.uba.de/luft-e/index.htm

from Oene et al.