Nitrogen turnover in the Baltic Sea

Work package B – Process Studies and Observations

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Annual AMBER meeting 2011
• What have been measured?

• Results:
  – Objective I: DON uptake along a salinity gradient from the North Sea to the Baltic Sea
  – Objective II: Nitrate turnover during peak outflow of the Curonian and Szczecin lagoon
  – Objective III: Annual cycle: Comparison of environments with contrasting nitrogen loads

• What is still missing?

• Publications

• Relevance of the results for policy and stakeholders
• Sources and turnover of nitrate in the coastal zones
• Role of DON in the N cycle
Aims

- Measurement of phytoplankton and bacteria bulk DON uptake rates along a salinity gradient from the North Sea to the Baltic Sea in summer 2009.

- Comparison of DON uptake rates of heterotrophic bacteria and phytoplankton in the North Sea and the Baltic Sea.

- Give a first estimation on the role of DON as a potential nitrogen source in the Baltic Sea during summer.
Objective 1: DON uptake in the Baltic Sea

- Bronk and Glibert 1993, August, Chesapeake Bay: 140-540 nmol N l⁻¹h⁻¹
- Veuger et al. 2004, August, Randers Fjord: 130-430 nmol N l⁻¹h⁻¹
- This study, August, Baltic Sea: 440-1930 nmol N l⁻¹h⁻¹
Objective 1:
DON uptake in the Baltic Sea

- Positive correlation between DON uptake rates and concentrations
- In environments with higher DON backgrounds plankton has a higher ability to utilize DON
Conclusions

• Both heterotrophic bacteria and phytoplankton exploited components of the DON pool with higher rates in the Baltic Sea than in the North Sea.

➢ DON can be an important nitrogen source in the Baltic Sea during summer when DIN is depleted.

➢ DON can enhances primary production and therefore also fuel eutrophication.
Objective 2:
Nitrate turnover during peak outflow of the Curonian and Szczecin lagoon

Measurements

- $\text{NO}_3^-$ uptake rates in the outflow of the lagoons
- Stable isotopes in $\text{NO}_3^-$

Aims

- Gain a better understanding of the dynamics of nitrate in river outflows during peak outflow of the year
- Source and $\text{N}$-transformation processes identification
- Relate the quantities of nitrate to nitrate uptake rates and budget the fate of the riverine loads.

Source: Baltic Nest Institute
Objective 2:
Nitrate concentrations

Curonian lagoon outflow

- **NO$_3^-$**
- **NO$_3^-$ uptake**
- **Nemunas NO$_3^-$**
- **Baltic Sea NO$_3^-$**

Nitrate concentrations

- Curonian lagoon outflow

Salinity

NO$_3^-$ (µmol l$^{-1}$)

NO$_3^-$ uptake (nmol N l$^{-1}$ h$^{-1}$)
Objective 2: Nitrate concentrations

Szczecin lagoon outflow

Salinity

NO$_3^-$ uptake (nmol N l$^{-1}$ h$^{-1}$)

NO$_3^-$ uptake

Oder NO$_3^-$

Baltic Sea NO$_3^-$

NO$_3^-$ (µmol l$^{-1}$)

0 50 100 150 200 250 300

0 50 100 150 200 250 300 350

Salinity
Objective 2: Nitrate turnover

**Curonian lagoon**

- NO$_3^-$ uptake: 0.5 – 1.2 nmol N/m$^2$\*d (mean 0.7)

**Szczecin lagoon**

- NO$_3^-$ uptake: 0.4 – 11.5 nmol N/m$^2$\*d (mean 5.4)
- Denitrification: 5000 – 7500 µmol N/m$^2$\*d
Objective 2: Nitrate concentrations

Curonian lagoon

Szczecin lagoon

\[ \delta^{15}N \text{ (‰)} \]

\[ \delta^{18}O \text{ (‰)} \]

Depth (m)
Objective 2:
Source identification

$\delta^{15}\text{N} (\%o)$
-20  -10   0    10   20   30   40

$\delta^{18}\text{O} (\%o)$
0     10    20    30    40    50    60    70

Curonian lagoon outflow March 2009
Oder lagoon outflow March 2009

atmospheric nitrate deposition
nitrate-containing fertilizers
nitrate derived from nitrification in soils
Trend during denitrification
nitrate in sewage and manure
Conclusions

- Two environments with high nitrate loads
- Nitrate concentrations do not show any differences between the two environments
- Stable isotopes can distinguish between different processes and sources
Objective 3: Comparison of environments with contrasting nitrogen loads

Source: Baltic Nest Institute

Hägg 2010
Comparison of environments with contrasting nitrogen loads

What is still missing?

- $\delta^{15}$N and $\delta^{18}$O of NO$_3^-$ Kalix river
- $\delta^{15}$N DON for the coastal areas
- Denitrification measurements in spring in the Szczecin lagoon?

Source: Baltic Nest Institute
Posters, talks and publications:

- Korth, F., Deutsch B., Liskow I. and Voss M. (2011) Uptake of dissolved organic nitrogen by heterotrophic bacteria and phytoplankton along a salinity gradient from the North Sea to the Baltic Sea, ASLO meeting, Puerto Rico, talk

forthcoming publications:

- Korth, F. and Voss M.: Stable isotope composition and turnover of nitrate during spring outflow from the nitrate-rich Curonian and Szczecin lagoon
Stable isotopes can be an useful tool to distinguish between different processes and sources

- Different processes take place in the Curonian and Szczecin lagoon
- Different management strategies for different lagoons or coastal areas are needed for N reduction
DON cycle has gained little attention in the Baltic Sea

➢ We found high uptake rates showing that DON can be an important N nutrition

DON is a dynamic component of the N cycle in the Baltic Sea
Thank you for your attention!
Comparison of environments with contrasting nitrogen loads

**Table:**

<table>
<thead>
<tr>
<th>Month</th>
<th>Discharge (m³/s)</th>
<th>Load (t month⁻¹)</th>
</tr>
</thead>
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<tr>
<td>Jan</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mai</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>Sep</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>Jan</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td>Mai</td>
<td>800</td>
<td>400</td>
</tr>
<tr>
<td>Sep</td>
<td>1000</td>
<td>500</td>
</tr>
</tbody>
</table>

**Graphs:**

1. **Kalix**
   - Discharge (m³/s)
   - Load (t month⁻¹)
   - Nitrate (NO₃⁻)
   - DON (dissolved organic nitrogen)
   - Phosphate (PO₄³⁻)

2. **Nemunas**
   - Discharge (m³/s)
   - Load (t month⁻¹)
   - Nitrate (NO₃⁻)
   - DON (dissolved organic nitrogen)
   - Phosphate (PO₄³⁻)

**δ¹⁵N, δ¹⁸O (‰)**

- **Nemunas**
  - NO₃⁻ upatke

**Graphs:**

- Delta isotopes of nitrogen and oxygen over time for different environments.
- Comparison of δ¹⁵N and δ¹⁸O values for nitrate (NO₃⁻) in different samples.