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Groundwater status in Denmark based on environmental objectives for ecosystems and EU legislation

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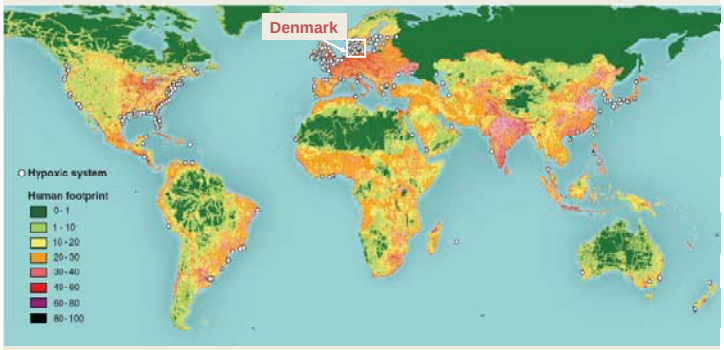
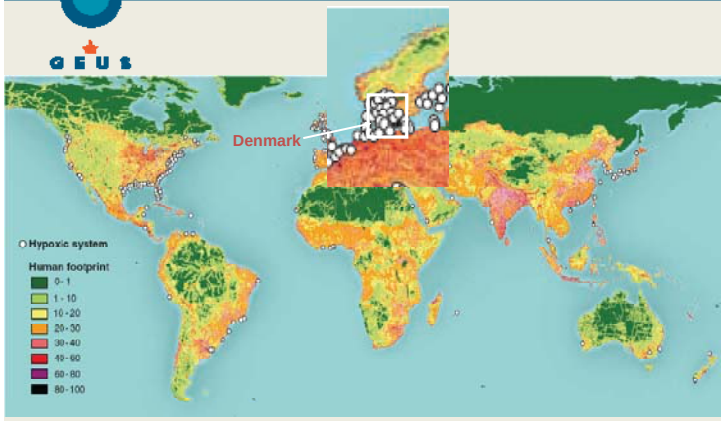
CONTENT

- Status of marine ecosystems
- Good status objectives of the EU Water Framework Directive and the most important substances responsible for EU groundwater bodies is at risk
- A global assessment of nitrogen gross balances in agriculture
- Required reductions in N-load to ecosystems
- Resulting consequences for groundwater status in Denmark
- Climate change impacts on N-loads to marine ecosystems

Global review of hypoxia (oxygen depletion) in coastal marine waters



Diaz and Rosenberg, 2008. Science, 321, 926-929



Diaz and Rosenberg, 2008. Science, 321, 926-929

Sea Floor Anoxia (Horsens Fjord Estuary, Denmark)

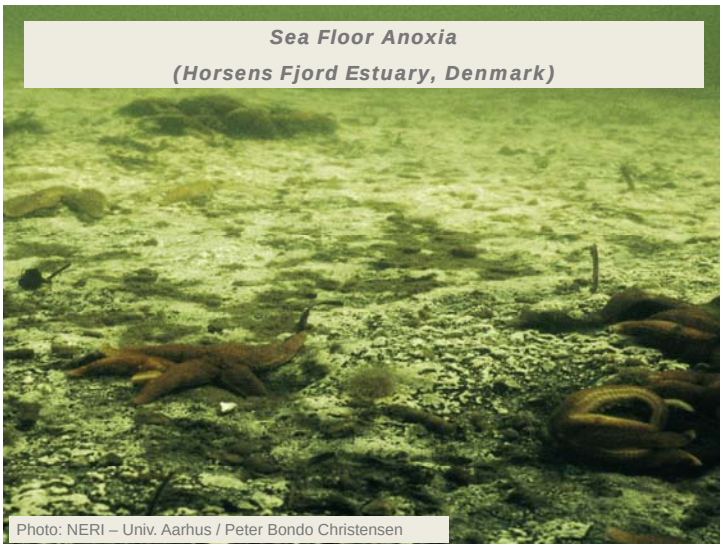
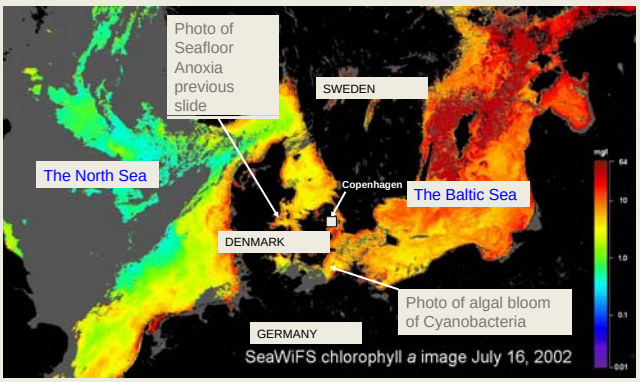


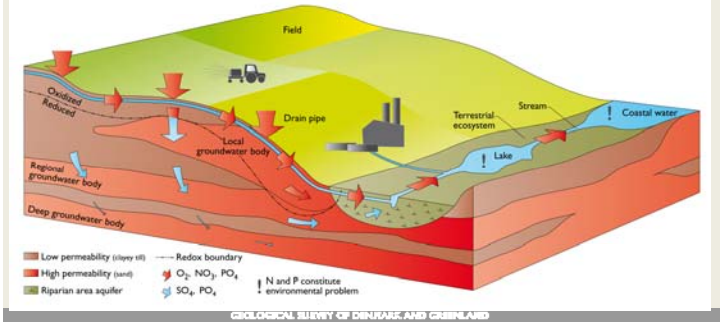
Photo: NERI – Univ. Aarhus / Peter Bondo Christensen

Satellite image of algal blooms around Denmark / eutrophication

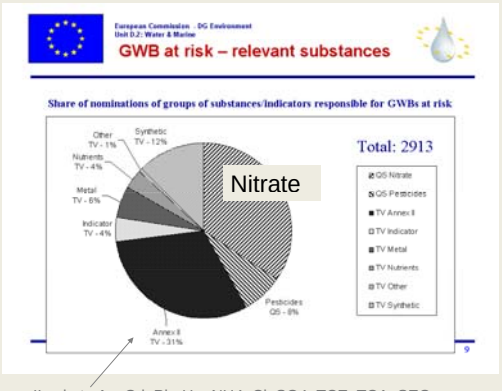


Courtesy GRAS A/S, University of Copenhagen / DHI Water and Environment

The EU Water Framework and Groundwater Directives stipulate that groundwater chemical status is poor if it results in poor status for associated ecosystems, and that all water bodies should have good status in 2015.



Main contaminants responsible for aquifers being at risk in the EU:

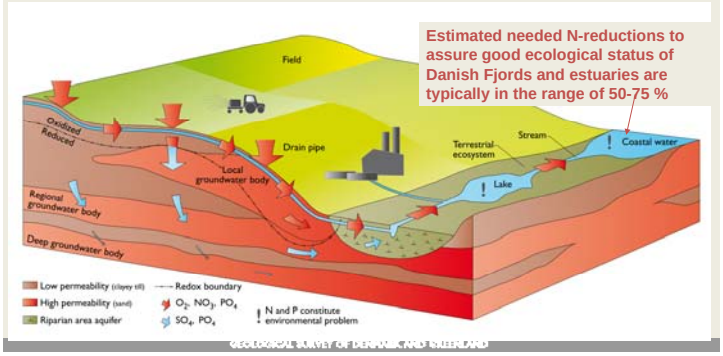


Annex II subst.: As, Cd, Pb, Hg, NH4, Cl, SO4, TCE, TCA, SEC

What are the sustainable N loads to the environment that can assure good ecological status of terrestrial and aquatic ecosystems???

Foto: Klaus Hinsby, GEUS

Needed N-reductions



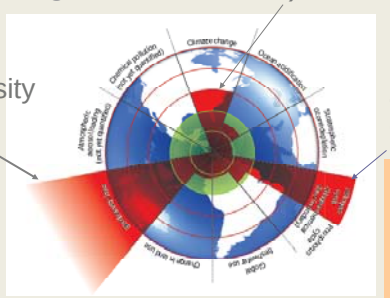
Planetary Boundaries:

- **Are transgressed for[1,2]:**

3) Climate Change

1) Biodiversity loss

2) Nitrogen cycle



Rockström et al. (~30 env. Scientists from Europe, USA and Australia) suggest to reduce the human N-input to **25 %** of the present input

1. Rockström et al., Nature, 461, 472-475, 2009 and
2- Rockström et al., Ecology and Society, 14 (2): 32, 2009.

Examples of required N-reductions for protection of ecosystems:

- Rockström et al. 2009: – ~75 %
(suggestion for average global reduction)

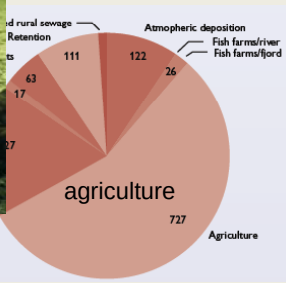
- Markager S. et al. 2010: - ~50 %
(NERi Report for Horsens Fjord estuary, DK)

- Ministry of the Environment, 2010: - ~65 -75%
(Draft River Basin Management Plan for the Lillebælt/Jylland catchment)

How can we reduce the N-loads to groundwater and ecosystems ???

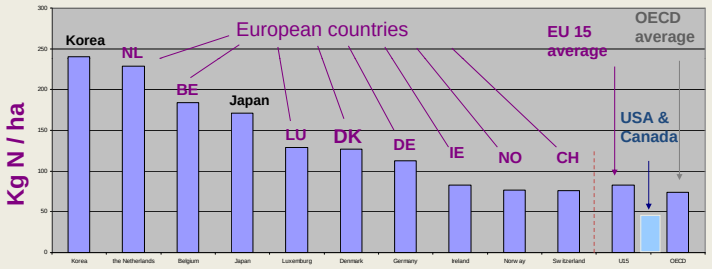
E.g. how can we restore the natural Horsens Fjord ecosystem?

N sources to the Horsens Fjord Estuary



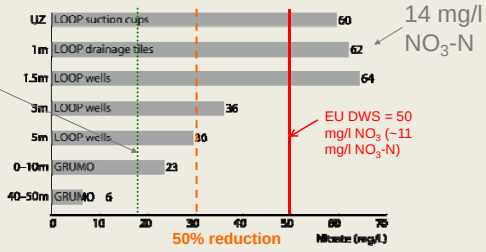
Thorling et al., 2008

Nitrogen gross balance i.e. potential transfer of excess Nitrogen into water, soil and air in selected countries in 2002-2004 according to the OECD:



source: OECD (2008), *Environmental Performance of Agriculture in OECD countries since 1990*, Paris, France, www.oecd.org/tad/env/indicators

Average nitrate concentrations in the unsaturated zone and groundwater at different depths below agricultural monitoring sites in Denmark



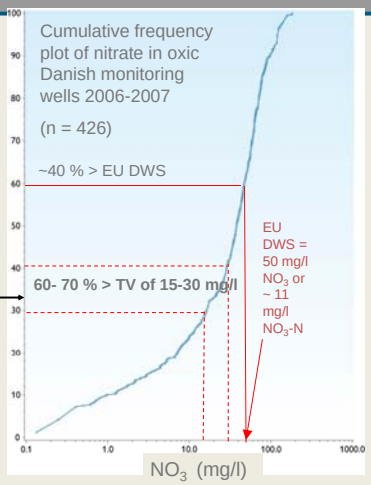
14 mg/l NO_3-N

TV = 18 mg/l NO_3 (~4 mg/l NO_3-N) for oxic groundwater in Odense PRB – Hinsby et al., Sci. Tot. Env., 40, 1-20, 2008.

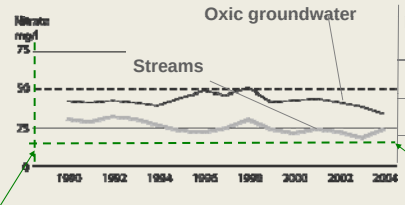
EU DWS = 50 mg/l NO_3 (~11 mg/l NO_3-N)

(modified from Hinsby and Jørgensen, 2009 In: Ph.Quevauviller et al. (eds) Groundwater Monitoring. Wiley-Blackwell, 2009).

With an estimated needed reduction of 50-75 % to meet good status objectives for ecosystems 60-70 % of DK oxic gw does not comply with EU directives



Average nitrate concentrations in oxic groundwater and streams in Danmark, 1990 - 2004 show decreasing trends



Danish action plan for the aquatic environment adopted in 1987

Modified from Hinsby and Jørgensen, 2009. In: Ph. Quevauviller et al. (eds), Groundwater Monitoring, Wiley-Blackwell, 2009

Suggested groundwater threshold value ~ 4 mg/l NO3-N for oxic groundwater

Hinsby et al., Sci. Tot. Env., 40, 1-20, 2008

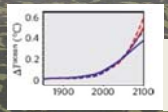
Climate change, Eutrophication and sea floor anoxia/hypoxia

Climate models predict:

1) increasing winter precipitation result in increasing tile drain & river discharge, and hence nutrient export (~ 8% in the A2 scenario according to Andersen et al., Sci. Tot Environ, 365, 2006)

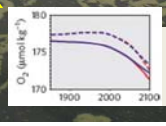
Relative change in river discharge at station 55.01 (Zealand) for the A2 and B2 emission scenarios compared to present. Modified from van Roosmalen et al., Vadose Zone Journal, 2007.

2) increasing Baltic Sea temperatures - and



Simulated T in the Baltic Sea in the A2 and B1 scenarios, Shaffer et al. Nature Geoscience, 2009

3) Increasing risk of algal blooms and oxygen depletion **(=> increased Sea floor anoxia)**



Simulated dissolved O2 in the Baltic Sea in the A2 and B1 scenarios, Shaffer et al. Nature Geoscience, 2009

Foto: Klaus Hinsby

Conclusion:

- There is a strong need for estimation of sustainable nutrient loads to ecosystems and for derivation of groundwater threshold values protecting ecosystems
- Important tools for derivation of groundwater threshold values include integrated hydrological models and sound physical and chemical descriptions of the interface between groundwater and ecosystems especially when climate change impacts also have to be assessed

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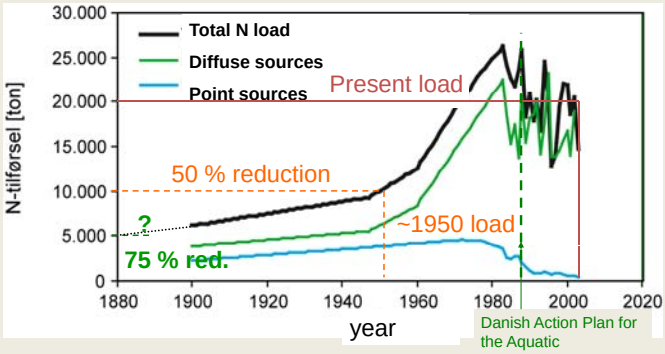
Thank you for your attention ☺

Algal bloom (cyanobacteria) in the Baltic Sea between Denmark and Germany, Foto: Klaus Hinsby

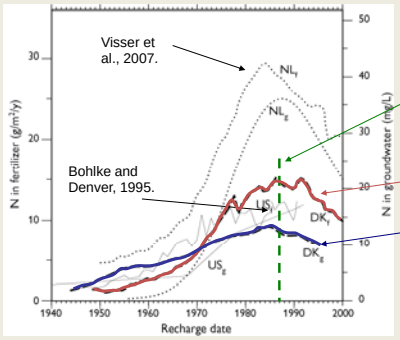
Total N application in DK (ton), 1900-2003



Danish Action Plan for the Aquatic Environment adopted in 1988

Markager, S., 2010, pers.comm.

Nitrate-N in groundwater in DK, US and NL at different recharge years estimated by CFC and $^3H/^3H$ dating



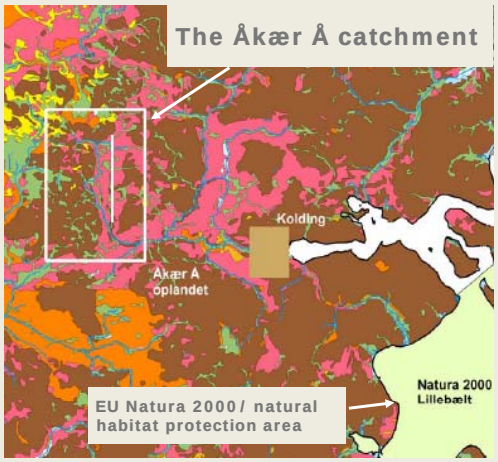
Danish Action Plan for the Aquatic Environment adopted in 1987

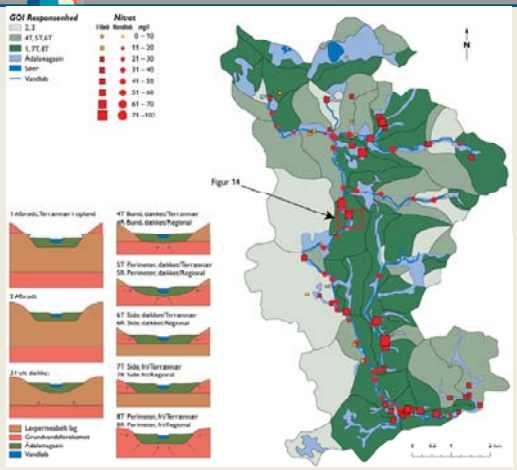
Trend in fertilizer use

Trend in NO3-N concentrations in groundwater

Modified from Hinsby et al. Groundwater quality and age. In P. Quevauviller (ed.) Groundwater Science and Policy. RSC Publishing, London, 2008.

The Åkær Å catchment





Groundwater and surface water status with threshold value based on ecosystem objectives according to the WFD and GWD.