Acidification and Eutrophication

NGEA09, 2019

Cecilia Akselsson
Department of Physical Geography and Ecosystem Science
Lund University
The environmental objectives of Sweden

- Reduced climate impact
- A protective ozone layer
- A safe radiation environment
- A varied agricultural landscape
- A magnificent mountain landscape
- Clean air
- A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos
- Good quality groundwater
- Natural acidification only
- Zero eutrophication
- Thriving wetlands
- A good built environment
- A non-toxic environment
- Flourishing lakes and streams
- Sustainable forests
- A rich diversity of plant and animal life

(www.miljomal.se)
### The environmental objectives of Sweden

<table>
<thead>
<tr>
<th>Reduced climate impact</th>
<th>Natural acidification only</th>
</tr>
</thead>
<tbody>
<tr>
<td>A protective ozone layer</td>
<td>Zero eutrophication</td>
</tr>
<tr>
<td>A safe radiation environment</td>
<td>Thriving wetlands</td>
</tr>
<tr>
<td>A varied agricultural landscape</td>
<td>A good built environment</td>
</tr>
<tr>
<td>A magnificent mountain landscape</td>
<td>A non-toxic environment</td>
</tr>
<tr>
<td>Clean air</td>
<td>Flourishing lakes and streams</td>
</tr>
<tr>
<td>A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos</td>
<td>Sustainable forests</td>
</tr>
<tr>
<td>Good quality groundwater</td>
<td>A rich diversity of plant and animal life</td>
</tr>
</tbody>
</table>
Acidification
– how does it connect to land surface processes?

Weathering! Depends on parent material which depends on geomorphological processes
Disposition: Acidification

-Acidification processes: atmospheric deposition

-Present situation and trends

-Acidification processes: forestry

-Acidification in the perspective of land surface processes, rocks and soils in Sweden

-Critical loads – going from science to policies
Acidification processes – atmospheric deposition
Acidification processes – atmospheric deposition

Sulphur

Nitrogen
Sulphur deposition

Main source of S: Combustion of coal and oil. Also industries, ships, etc.

\[ S + O_2 \leftrightarrow SO_2 \]

\[ SO_2 + O_2 \leftrightarrow 2 \text{SO}_3 \]

\[ \text{SO}_3 + \text{H}_2\text{O} \leftrightarrow 2 \text{H}^+ + \text{SO}_4^{2-} \]
Oxidized nitrogen (NO\textsubscript{x}) deposition

Main source of NO\textsubscript{x}: Traffic

\[ \text{N}_2 + \text{O}_2 \leftrightarrow 2 \text{ NO} \]

\[ 2 \text{ NO} + \text{O}_2 \leftrightarrow 2 \text{ NO}_2 \]

\[ 2 \text{ NO}_2 + \text{H}_2\text{O} \leftrightarrow \text{HNO}_2 + \text{H}^+ + \text{NO}_3^- \]
Reduced nitrogen (NH$_3$) deposition

Main source of NH$_3$: Fertilizers

\[
\text{NH}_3 + \text{H}_2\text{O} \leftrightarrow \text{NH}_4^+ + \text{OH}^-
\]

\[
\text{NH}_4^+ + 2 \text{O}_2 \leftrightarrow 2 \text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}
\]
Acidification of soil and water

Acid water from soil surface

Ions transported down in the profile and to surface water

(From www.capensis.se)
Acidification of soil and water

Before acidification

During acidification

Acidified condition

During recovery

Base cations

Large exchangeable pool

Decreasing pool

Small pool

Incr. pool

Naturvårdsverket report 5028
Effects of acidification

- Low pH and high concentrations of toxic aluminium
- Negative effects on fish and other water living organisms
- Risk of negative effects on vegetation
- Increased leaching of nutrients important for trees (e.g. Mg and K) which can lead to nutrient imbalance
- Increased leaching of heavy metals (e.g. Cd and Pb)
Present situation and trends

Photo: Cecilia Akselsson
Acidification status today

- 10% of Swedish lakes and 20% of the forest soils are assessed as acidified.

- In SW Sweden 50% of the lakes and forest soils are assessed as acidified.

- 200 million SEK are spent on lake liming every year

- Measurements and modelling indicate slow recovery
What does the environmental objective assessments say?

“It is not possible to reach the environmental objective to 2020 with the decided or planned measures. The development is positive.
Sulphur deposition in Småland 1880-2000

Naturvårdsverket report 5028
Reductions of emissions in Europe

A. Sulphur dioxide

IVL, 2015: Krondroppsnätet 1985-2015
Sulphur deposition trends

(Based on data from the SWETHRO network. Modified from Pihl Karlsson et al, 2011, Env. Poll.)
Nitrogen deposition trends

(Based on data from the SWETHRO network, IVL)
Antropogenically acidified lakes

Lakes (> 1 ha) in different effect classes in the year 2010, based on there modelled pH decrease since before industrialization

(Filip Moldan, IVL, www.ivl.se/magiclibrary)
Acidification in soil

% soil in the 2 highest acidification classes

From soil inventory, Johan Stendahl, SLU
Acidification processes - forestry
Acidification processed forestry

\[ \text{H}^+ \rightarrow \text{Ca}^{2+} \rightarrow \text{H}^+ \rightarrow \text{Mg}^{2+} \rightarrow \text{K}^+ \rightarrow \text{H}^+ \]
Acidification in the perspective of land surface processes, rocks and soils in Sweden
Processes affecting acidification

- Chemical weathering
- Sulphur adsorption
- Cation exchange
- Atmospheric deposition
- Nutrient uptake
- Nitrification

*Naturvårdsverket report 5028*
The role of weathering

Acid rain removes base cations and acidifies...

...and biomass harvesting too.

Chemical weathering leads to release of base cations and counteracts acidity.

Ex: \[3 \text{KAlSi}_3\text{O}_8 + 2\text{H}^+ + 12 \text{H}_2\text{O} \rightarrow \text{KAl}_3\text{Si}_3\text{O}_{10} (\text{OH})_2 + 6 \text{H}_4\text{SiO}_4 + 2 \text{K}^+\]
Acidification in the perspective of Swedish rocks, soils and landforms

(From Hess, 2013)

(From Hess, 2013)

(Photo: Jonas Åkerman)
Acidification in the perspective of Swedish rocks, soils and landforms

(From Hess, 2013)
Critical loads – going from science to policies
Critical loads – how much deposition can the soil/water take without harmful effects?

\[
\text{CL (S+N)} = \text{BC dep} + \text{BC weath} + \text{N uptake} + \text{N imm} - \text{BC uptake} - \text{Alk leach}
\]

\[
\text{Exceedance} = \text{Sdep} + \text{N dep} - \text{CL (S+N)}
\]
Critical loads – how much deposition can the soil/water take without harmful effects?

(Modelled by Filip Moldan, IVL)
The environmental objectives of Sweden

- Reduced climate impact
- A protective ozone layer
- A safe radiation environment
- A varied agricultural landscape
- A magnificent mountain landscape
- Clean air
- A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos
- Good quality groundwater
- Natural acidification only
- Zero eutrophication
- Thriving wetlands
- A good built environment
- A non-toxic environment
- Flourishing lakes and streams
- Sustainable forests
- A rich diversity of plant and animal life
- Reduced climate impact
- A protective ozone layer
- A safe radiation environment
- A varied agricultural landscape
- A magnificent mountain landscape
- Clean air
- A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos
- Good quality groundwater
- Natural acidification only
- Zero eutrophication
- Thriving wetlands
- A good built environment
- A non-toxic environment
- Flourishing lakes and streams
- Sustainable forests
- A rich diversity of plant and animal life
Eutrophication – how does it connect to land surface processes?

Transport through erosion and runoff! Depends on soils and runoff patterns.
Disposition: Eutrophication

- Eutrophication processes
- N and P sources
- Present situation and trends
Eutrophication processes

N and P addition

Increased release of N and P

Increased production of algae and plankton

Increased sed. of org. material

Hypoxia and poisonous sulphides

Death of benthic organisms and fish
N and P sources
N and P sources

(From Brandt et al., 2008; NV Report 5815)
N and P sources

Antropogen fosforbelastning för Västerhavets vattendistrikt

Brutto (710 ton)

Netto (481 ton/år)

P

Antropogen kvävebelastning för Västerhavets vattendistrikt

Brutto (30 536 ton/år)

Netto (21 924 ton/år)

N

(www.vattenmyndigheterna.se)
Present situation and trends
What does the environmental objective say?

“It is not possible to reach the environmental objective to 2020 with the decided or planned measures. No clear direction for the development of the environment can be seen.”
Indicator: Addition of nitrogen to the coast

(www.miljomal.nu)
Indicator: Addition of phosphorous to the coast

(www.miljomal.nu)