SPEEDING UP THE ECOLOGICAL RECOVERY OF THE BALTIC SEA

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Photograph: Janne Gröning

SPEEDING UP THE ECOLOGICAL RECOVERY OF THE BALTIC SEA

- Assessment of:
 - the contribution of internal nutrient storages to the eutrophied state of the Baltic Sea and
 - 2. potential measures to mitigate the internal nutrient leakage from bottom sediments
- Client: Ministry of the Environment
- Team of experts from Finland, Sweden, Lithuania and Estonia



EUTROPHICATION DEVELOPMENT OF THE BALTIC SEA (1)

- For decades, the Baltic Sea has been experiencing severe eutrophication caused by excessive external nutrient inputs.
- The objective is to reach a good status of the Baltic Sea by the end of 2020 in accordance with the targets of the EU Marine Strategy Framework Directive.
- Finland has committed to the nutrient reduction targets of the HELCOM Baltic Sea Action Plan.
- Phosphorus discharges from cities and industrial plants have significant decreased in the catchment area since the 1980s. Water quality has improved locally. However, the state of the Baltic Proper continues to deteriorate.



Total inputs of N and P to the Baltic Sea (Gustafsson et al. 2012)

EUTROPHICATION DEVELOPMENT OF THE BALTIC SEA (2)



Integrated status assessment of eutrophication of the Baltic Sea (HELCOM 2017)



Spatial distribution of bottom hypoxia and anoxia over time (Carstensen et al. 2014)

EUTROPHICATION DEVELOPMENT OF THE BALTIC SEA (3)

- In order to rapidly reach a good status of the Baltic Sea as concerns eutrophication, it is likely that there is a need to address also internal nutrient reserves, in addition to the current measures aimed at significantly reducing external nutrient inputs to the sea.
- Even if the HELCOM Baltic Sea Action Plan nutrient reduction targets are achieved, model simulations indicate that it will take decades for the marine environment to recovery.
- Climate change slows down the recovery process of the Baltic Sea.



Time development of inorganic winter nutrient concentrations in the Baltic proper surface waters. The grey bars with associated curves represent the case with inputs as in the reference period (1997-2003) during the whole scenario, and the red represents inputs reduced to MAI by year 0 (HELCOM 2017)

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NUTRIENTS INPUT AND INTERNAL RELEASE

- The Baltic Sea annually receives a total of 36,900 tonnes P and 910.000 tonnes N from the catchment area (inputs in 1997-2003, HELCOM 2013).
- The annual inputs from Finland to the Baltic Sea are a total of 3,840 tonnes P and 90,300 tonnes N (2011-2016, Räike and Knuuttila 2018).
- Malmaeus and Karlsson (2012) estimated that the total amount of mobile P in the entire Baltic Proper sediments below 65 m water depth is between 55,000 tonnes and 156,000 tonnes representing the maximum amount of P that could possibly be released to the water column from these areas.



ASSESSMENT OF POTENTIAL MEASURES TO MITIGATE THE INTERNAL NUTRIENT LEAKAGE FROM BOTTOM SEDIMENTS

- Technical, socio-economic, political, legal and institutional assessment of the measures
- Potential measures assessed:
 - Oxygenation
 - Chemical treatment
 - Aluminium
 - Other potential precipitants
 - Removal of sediment
- Focus on the Finland's marine waters
- Application either in coastal waters or open sea



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OXYGENATION OF BOTTOM WATER (1)

- Oxygen depletion results in release of phosphorus from sediments. Targets of oxygenation is to improve near-bottom oxygen conditions, remove a part of the nutrients from the water column and decreases benthic nutrient release.
- Either aerators bringing air or oxygen to the bottom water or mechanical mixers bringing aerated surface water to the bottom water layer can be used.
- Applied in lakes of various sizes, piloted in sea in Finland, Sweden and US



Schematic picture of experimental setup with forced oxygenation of the deepwater of the anoxic By Fjord, Western Sweden. (Stigebrandt et al, 2015).



OXYGENATION OF BOTTOM WATER (2)

- Risks and uncertainties, e.g.
 - risk of changing water circulation by changing salinity
 - risk of release of pollutants from sediments
 - enough Fe(III) required to bind the phosphorus in bottom
 - How long time of oxygenation is required
- Cost: 2-4 EUR/kg P (Stigebrandt 2014), 30-32 EUR/kg P (Rantajärvi et al. 2012)



Schematic presentation of technical arrangement of the oxygenation method as presented in the Proppen report (Saarijärvi et al. 2012)

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ALUMINIUM TREATMENT

- Binds phosphorus in bottom and decreases benthic nutrient release
- Does not have (direct) effect on the oxygen conditions in bottom waters
- Aluminium hydroxide has very low solubility at circumneutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish.
- Applied in lakes, piloted in sea in Sweden
- Cost: 58-318 EUR/kg P (Rydin & Kumblad 2014)



Schematic figure of remediation using aluminium treatment in Björnöfjärden (Rydin et al. 2017)

OTHER CHEMICALS

- Ferrous chemicals require oxic conditions to precipitate phosphorus.
- E.g. clay, modified bentonite or marl tested only in laboratory or lake environment



Limestone byproduct pile of Nordkalk AB in Storugns, Lärbro (Blomqvist and Björkman 2014)

SEDIMENT REMOVAL (1)

• Technically well established, whereas only a few experiences in mitigation of internal nutrient leakage



Grab dredge



TechMarket AB's technology



SEDIMENT REMOVAL (2)

- Removes nutrients from the sea, whereas it does not have (direct) effect on oxygen conditions in bottom waters. However, recovering the recently settled organic material from the sea bottom decreases the oxygen consumption in the bottom water.
- Risks and uncertainties, e.g.
 - Uncertain whether the method has effect on benthic nutrient release
 - Potentially damages benthic marine organisms and seabed morphology
 - Risk of release of pollutants from sediment during dredging
- Cost: 32 EUR/kg P (total cost 120 EUR/kg P, income 88 EUR/kg) (Simonsson 2014)



CONCLUSIONS (1)

- For coastal waters, there is rather good understanding and experience of oxygenation and aluminum treatment and the short-term effects of these measures.
- More research is needed on other methods, such as sediment removal and especially more novel methods like clay or marl treatment.
- In coastal waters, risks are manageable and local scale projects can be continued:
 - to improve environment locally
 - gather knowledge on long-term effects
 - to further develop methods.

CONCLUSIONS (2)

- Sea-based measures are most likely to be successful when
 - the bottom and current conditions are favorable
 - chemical nutrient retention capacity are favorable
 - when the differences between brackish and lake conditions are taken into account in the planning of mitigation measures.
- The costs of the different measures and cost estimates vary greatly, from a few euros to hundreds of EUR per removed kg of P. The cost is largely affected by local conditions.

RECOMMENDATIONS

- Regional mapping of potential coastal water areas for local sea-based measures
- Careful ecological, technical and economic feasibility studies, including assessment of risks and positive effects prior to every sea-based restoration project
- R&D and small scale applications to be continued in international cooperation
- Regular independent review of the projects
- Separate financing of long-term monitoring
- More research and possibly also new financing instruments needed for larger scale applications
- International co-operation to agree on the main principles relating to implementation of sea-based measures at the HELCOM-level





THANK YOU!

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The assessment report can be downloaded here:

https://vahanen.com/en/references/sp eeding-ecological-recovery-baltic-sea/

