Memo of the HELCOM-EUSBSR Workshop on internal nutrient reserves

Introduction

Huge resources of phosphorus have been accumulated in the bottom sediments of the Baltic Sea during the past decades. Internal load, caused by release of phosphorus from sediments in anoxic conditions, is a factor contributing to its elevated concentration in the Baltic Sea. There are, however, still uncertainties regarding the fluxes and dynamics of phosphorus in the Baltic Sea and their contribution to eutrophication. In addition, climate change enhances the risk of further exacerbating eutrophication.

Although the only long-term solution to combat eutrophication in the Baltic Sea is the reduction of external loading to the sea, a number of sea-based measures to mitigate the impact of the internal phosphorus reserves in the Baltic Sea have been suggested to accelerate the recovery of the Sea. Before full-scale implementation at the deep sea, a number of aspects of sea-based measures need to be addressed. These include political, legal and socio-economic aspects, as well as potential risks associated with such measures.

A joint suggestion from Sweden and Finland to address these issues in a workshop was supported by HELCOM PRESSURE (6-2017) and HOD (52-2017). The workshop jointly organized by Sweden and Finland was a continuation of the work already started in both HELCOM and EU Strategy for the Baltic Sea Region (EUSBSR) policy area Nutri.

The Workshop was attended by 56 participants representing mainly Finland and Sweden but also two representatives of Germany and by one from Latvia and Lithuania. HELCOM observers, scientific and public organization were also widely represented at the Workshop. This memo, made by the organizers, is a brief compilation reflecting the major themes which were discussed at the workshop.

Spatial and temporal dynamics of internal phosphorus reserves and natural and anthropogenic factors affecting the burial and release of phosphorus from bottom sediments

Integrated water management is a tool to interconnect management on land and sea. Historically, it has been focused on upstream actions. The measures and methods that address nutrient reserves at the sea, the so-called sea-based measures, are one way to look at the sea component of the integrated water management system.

The phosphorus (P) resources are stored in the bottom sediments mainly in organic forms or iron III oxide-bound P. The iron-bound P is released into the water column during hypoxic/anoxic conditions. Although oxygenation of the bottom sediments is required to restore the ecosystem, this also triggers biological P mineralization. The magnitude of this process in restored bottom sediments is unknown. In addition, the iron-cycle is largely unquantified leading to further uncertainties regarding the potential for iron to bind phosphorus when the eutrophic conditions are reversed.

The internal reserve of phosphorus has been dominating over the external load since 2000 for the Baltic Sea, and there is an agreement between models in terms of describing the evolution of phosphorus concentrations in the Baltic Sea in the past. However, the scenarios they predict for the future differ significantly, indicating high level of uncertainty in scientific knowledge. Additional data is needed in order to validate models.

There is a number of additional factors which are to be taken into account in assessing internal reserves of phosphorus in the Baltic Sea, such as:

- Phosphorus processes (sources and sinks) in the Baltic Sea are spatially heterogeneous.
  Weather conditions which control stratification of the water column and result in huge variations of the P-concertation in the water (recent studies in the Gulf of Finland).
- Erosion of P-enriched glacial clays leads to suspension of substantial amounts of phosphorus, which can be transformed into bio-available form.
- The form of phosphorus as it enters the sea through rivers.

Finally, the phosphorus reserve in the sea is a dynamic system based on circulation of fluxes between different components of marine ecosystem and affected by various factors, which underestimation might lead to erroneous expectations from undertaken measures.

Approaches to manage internal reserves of phosphorus in the Baltic Sea and potential risks.

Measures in lakes and coastal waters are under development to reduce the release of nutrients from internal sources. The following methods were mentioned at the workshop: aluminum precipitation, marl treatment, oxygenation, and low-flow dredging and biological methods. In order to achieve long-term effects, application of these methods is appropriate only if the external load is reduced.

Aluminum treatment has been performed in lakes and in a bay in Stockholm archipelago that has small water exchange with the sea with a result of reduced P-concentration in the water and increased secchi depth. Erroneous application of the method might cause changes in water pH parameter which might lead to fish deaths, the method must therefore be applied with high precaution.

Application of marl to retain P in the bottom sediments has been tested in laboratory experiments. Treated marl is highly reactive and the effect of introducing of this matter into the marine environment is not known.

Oxygenation/halocline ventilation has never been applied in the large sea scale, but it has been tested in bays with varying results. Iron III oxides are formed under oxygenated conditions and this method of artificial oxygenation could thereby result in binding of phosphorus dissolved in the water column. Oxygenation requires installation of pumping/mixing systems which might cause damage to benthic communities. Water pumping may also cause underwater noise and sea-floor disturbance. Oxygenation of sediments could potentially mobilize other pollutants in the sediments.

Low-flow dredging has been demonstrated in lakes and deep waters of the Baltic Sea. The demonstrations show that it is technically feasible to retrieve top-layer sediments from deep water, but the effects to the ecosystem and long-term nutrient fluxes are poorly studied. Low-flow dredging of bottom sediments might cause direct damage to benthic communities and disturbance by underwater noise.

Biological methods such as mussel farming and management fishing and their potential to mitigate internal nutrient reserves was not presented at the workshop, but brought up in discussion as potential methods to reduce nutrients from the sea.

The workshop raised a concern about unknown risks which can’t be managed. Poorly tested measures may cause unpredictable changes in the ecosystem which might have disastrous consequences if implemented in a large scale.

The remaining potential to achieve HELCOM nutrient load reduction targets

It seems that HELCOM targets for nitrogen reductions are achievable with currently proposed measures within the river-basin management plans and programmes of measures. However, achieving phosphorus reduction targets trough implementation of conventional measures is more challenging, especially taking into account the impact of climate change. Therefore, new measures have to be developed, especially to reduce nutrient loads from agriculture.

Analysis of P surpluses across the region shows that there is a substantial potential to reduce nutrient inputs to the Baltic Sea through closing the nutrient circles. Recent estimation shows that phosphorus resource in manure thrice exceeds phosphorus in sewage. Efficient manure use can reduce import of fertilizers by 100-200 thousand tons per year. Only about one third of phosphorus from sewage is recycled across the region. Sustainable utilization of this resource has a potential to decrease import of P fertilizers by 36 thousand tons.

Legal aspects and costs of potential measures to manage internal nutrient reserves

There is no specific legal definition for sea-based measures. But general principles of the environmental law, such as precautionary principle, no-harm principle and best available techniques, are applicable for the regulation of the activities. Large-scale sea-based measures are potentially a subject to the amendment to the London Protocol regarding geo-engineering at sea to manipulate natural processes. The activities are also partly subjects to other parts of London Convention, UNCLOS, Helsinki Convention and ESPOO Convention.

Both Finnish and Swedish national legislation set environmental permit requirements for application of the sea-based measures with consequent environmental impact assessments.

The workshop discussed a possibility to elaborate common principles for the marine-based activities through HELCOM tools. They should clearly draw a line between small- and large-scale activities and take in to consideration research projects, commercial and other activities.

Presented economic analysis is based on multiple assumptions and omits many factors. Previous projects and pilot tests have tried to estimate the cost-efficiency of the measures but the results are very uncertain and demonstrate huge variability. Further development of measures and estimation of their costs are needed for reliable evaluation of cost-efficiency of the sea-based measures.

Knowledge gaps

Information on phosphorus resources in the bottom sediments is mainly based on models. The data on observed concentrations of P and Fe in sediments as well as its availability for release into water column are rather scarce and scattered through multiple publications. Models often give controversial results and require further development and validation. Thus, there is a need in compilation of data on measurements of P and Fe concentrations in sediments, their forms, as well as physical parameters of sediments.

Ferromanganese (FeMn) concentration is a source of P which is not taken into account in models evaluating P reserves in the sediments. The formation of the FeMn concentrations in the bottom sediments and their decomposition under redox conditions are still poorly studied as well as their role in phosphorus binding.

The effect of transport of phosphorus pool with sediments is poorly studied. The organic matter can be re-suspended into water column and then transported by currents.

The processes of P release are still unclear. Itis much more complicate than just effect of redox conditions. Also microbiological effect should be taken into account. Thus, specific studies of P fluxes are needed to precisely model the dynamic of the system.

Potential effects of large-scale sea-based measures to the Baltic Sea ecosystems are not studied. Also current knowledge is not sufficient to pass the environment impact assessment procedure to legitimate sea-based measures.

Evaluation of costs of measures is currently based on multiple assumptions and demonstrate a high level of uncertainty. There is a need for further evaluation of the cost and benefits of the measures.

Change of climate parameters affects nutrient fluxes both on land and in the sea. The respond of the marine ecosystem to climate change as well as potential changes in nutrient inputs from land are not known and requires further investigation.

What is the potential of measures to manage internal nutrient reserves?

Reduction of external input of nutrients according to HELCOM requirements, Water Framework and Marine Strategy Framework Directives for the EU countries, is the way to achieve the good environmental status of the Baltic Sea. The models show, however, that it will take decades until the good status will be reached.

The workshop concluded that there could be potential in sea-based measures to manage internal nutrient reserves to speed of the recovery of the sea, although it is currently unclear where and what type of measures could be undertaken. Implementation of measures at large scale in the Baltic Sea have high risks, due to unpredictable changes in the ecosystem. Systematic ecosystem-based approach, taking into account all aspects of the problem, should be applied when considering sea-based measures. The analysis of adverse environmental effects should take into account the Marine Strategy Framework Directive descriptors as well as HELCOM indicators. The measures to mitigate internal P load should not cause additional pressure on ecosystems or lead to deterioration of its components.

Anoxia and hypoxia of the bottom areas are currently affecting bottom communities including bottom fish species in the depth over 65 meters which calls for the urgent measures. However, current lack of knowledge prevents safe implementation of large-scale measures at open sea.

Suggestions by the Workshop:

The discussion at the workshop revealed multiple gaps in the knowledge base regarding internal nutrient reserves in the Baltic Sea, their dynamics and effects of measures for its management. A pan Baltic research project involving experts in various scientific disciplines was suggested to make a comprehensive assessment and elaboration of a scientifically sound concept for large-scale management of internal nutrient reserves in the Sea. The workshop encouraged HELCOM to continue discussion on the matter involving all HELCOM member states to formulate a joint vision of such a project proposal.

Measures for managing the internal phosphorus resources may be implemented when adequate measures to minimize the external load to the catchment have been implemented. The workshop thus acknowledged the possibility to elaborate solutions for management of the internal nutrient reserves and perform pilot tests in coastal waters and lakes. However, the long-term sustainability and potential adverse effects of the measures on aquatic ecosystems must be thoroughly evaluated.

In addition, the workshop identified a need to develop regional principles serving as a guidance for large-scale measures in the open sea.

Annex 1 List of Participants

Representing	Name	Organisation	Email address
Moderators			
Sweden	Philip Axe	Swedish Agency for Marine and Water Management	
Sweden	Lena Viktorsson	Swedish Meteorological and Hydrological Institute	
Finland	Vivi Fleming-Lehtinen	Finnish Environment Institute	
Participants			
Finland	Sanni Turunen	Ministry of the Environment, EUSBSR PA Nutri	sanni.j.turunen@ym.fi
Finland	Laura Saijonmaa	Ministry of the Environment of Finland	laura.saijonma@ym.fi
Finland	Esa Salminen	Vahanen Environment Oy	esa.salminen@vahanen.com
Finland	Mikael Wennström	Government of Åland	mikael.wennstrom@regeringen.ax
Finland	Brita Bohman	Centrum Balticum	brita.bohman@abo.fi
Finland	Jouni Lehtoranta	Finnish Environment Institute	jouni.lehtoranta@ymparisto.fi
Finland	Vivi Fleming-Lehtinen	SYKE	vivi.fleming-lehtinen@ymparisto.fi
Germany	Wera Leujak	German Environment Agency	wera.leujak@uba.de
Germany	Detlef Schulz-Bull	Leibniz Institute for Baltic Sea Research Warnemuende (IOW)	detlef.schulz-bull@io-warnemuende.de
Latvia	Ieva Branicka	Ministry of Agriculture	Ieva.Branicka@zm.gov.lv
Lithuania	Svajunas Plunge	Environmental Protection Agency	s.plunge@aaa.am.lt
Sweden	Lars Sonesten	Swedish University of Agricultural Sciences	Lars.Sonesten@slu.se
Sweden	Lena Viktorsson	SMHI	lena.viktorsson@smhi.se
Sweden	Magnus Karlsson	IVL Swedish Environmental Research Institute	magnus.karlsson@ivl.se
Sweden	Elin Almroth-Rosell	Swedish Meteorological and Hydrological Institute	elin.almroth.rosell@smhi.se
Sweden	Robert Almstrand	Swedish Agency for Marine and Water Management	robert.almstrand@havochvatten.se
Sweden	Emil Rydin	BalticSea2020	emil.rydin@balticsea2020.org
Sweden	Linda Kumblad	BalticSea2020 & Stockholm University	linda.kumblad@balticsea2020.org
Sweden	Kari Eilola	SMHI	kari.eilola@smhi.se
Sweden	Karin Wall	Swedish Agency for Marine and Water Management	karin.wall@havochvatten.se
Sweden	Anders Stigebrandt	Univ of Gothenburg	anders.stigebrandt@marine.gu.se
Sweden	Martin Larsson	Ministry of Environment and Energy	martin.h.larsson@regeringskansliet.se
Sweden	Philip Axe	Swedish Agency for Marine and Water Management	philip.axe@havochvatten.se

Sweden	Bengt Simonsson	Teknimarknad	bengt.simonsson@teknikmarknad.se
Sweden	Karin Wesslander	SMHI	karin.wesslander@smhi.se
Sweden	Sven Blomqvist	Stockholm University	sven.blomqvist@su.se
Sweden	Lovisa Zillén Snowball	Geological Survey of Sweden	lovisa.zillen@sgu.se
Sweden	Jakob Granit	Swedish Agency for Marine and Water Management	jakob.granit@havochvatten.se
Sweden	Mats Svensson	Swedish Agency for Marine and Water Management	mats.svensson@havochvatten.se
HELCOM Secretariat	Dmitry Frank-Kamenetsky	HELCOM	dmitry.frank-kamenetsky@helcom.fi
HELCOM Observer	Anja Nysten	NEFCO	anja.nysten@nefco.fi
HELCOM Observer	Marjukka Porvari	John Nurminen Foundation	marjukka.porvari@jnfoundation.fi
HELCOM Observer	Anders Alm	WWF, Sweden	anders.alm@wwf.se
HELCOM Observer	Mikael Malmaeus	IVL Swedish Environmental Research Institute	mikael.malmaeus@ivl.se
HELCOM Observer	Miina Mäki	John Nurminen Foundation	miina.maki@jnfoundation.fi
HELCOM Observer	Nardine Stybel	EUCC - The Coastal Union Germany	stybel@eucc-d.de
HELCOM Observer	Kaisa Kononen	BONUS	kaisa.kononen@bonuseeig.fi
Other organization	Bo Gustafsson	Baltic Nest Institute	bo.gustafsson@su.se
Other organization	Daiva Semėnienė	VAHANEN ENVIRONMENT OY/ Center for Environmental Policy(AAPC)	daiva@aapc.lt
Other organization	Lars M. Svendsen	DCE - Danish Centre for Environment and Energy, Aarhus University, Denmark	lms@dce.au.dk
Other organization	Duncan Hume	Geological Survey of Sweden	duncan.hume@sgu.se
Other organization	Milja Vepsäläinen	Vahanen Environment Oy	milja.vepsalainen@vahanen.com
Other organization	Annika Svanbäck	Baltic sea Centre at Stockholm University	annika.svanback@su.se
Other organization	Dennis Hamro-Drotz	NEFCO	dennis.hamro-drotz@nefco.fi
Other organization	Michelle McCrackin	Stockholm University Baltic Sea Centre	michelle.mccrackin@su.se
Other organization	Ernst Witter	Örebro County Administrative Board	ernst.witter@lansstyrelsen.se
Other organization	Mathias Bergman	Baltic Sea Action Group (BSAG)	mathias.bergman@bsag.fi
Other organization	Lena Tasse	Region Östergötland	lena.tasse@regionostergotland.se
Other organization	Ottilia Thoreson	WWF Baltic Ecoregion Programme	ottilia.thoreson@wwf.se
Other organization	Sofia Hjalmarsson	DHI	sohj@dhigroup.com

Other organization	Cecilia Gustafsson	DHI	cegu@dhigroup.com
Other organization	Peter Wallenberg	LRF	Peter.Wallenberg@lrf.se