COHIBA

CONTROL OF HAZARDOUS SUBSTANCES IN THE BALTIC SEA REGION

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How to control and manage hazardous substances in the Baltic Sea region?

Final summary report of the COHIBA project

COHIBA project consortium

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List of abbreviations

BAT	Best available technique
BEP	Best environmental practise
BOD	Biological oxygen demand
BPA	Bisphenol A
BREF	Reference document on Best Available Techniques for IPPC and IE Directives
BS	Baltic Sea
BSR	Baltic Sea region
BSAP	Baltic Sea Action Plan
Cd	Cadmium
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COD	Chemical oxygen demand
CSO	Combined sewer overflow
DE	Germany
decaBDE	Decabromodiphenyl ether
DK	Denmark
E-BSR	Eastern Baltic Sea Region
EE	Estonia
ELV	Emission limit value
EQS	Environmental quality standard
EQS	EQS Directive (EU), Directive 2008/105/EC OF the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy,
EoP	End-of-pipe
EROD	Ethoxyresorufin-O-deethylase
EU BSRS	EU Baltic Sea Region Strategy
FI	Finland
HBCDD	Hexabromocyclododecane
HELCOM	Helsinki Commission
Hg	Mercury
HS	Hazardous substances
IMO	International Maritime Organization
IED	Industrial emissions directive (EU), Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)
IPPC	Integrated pollution prevention and control directive (EU), Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008; replaced by IED (above)
IWWTP	Industrial wastewater treatment plant
LOD	Limit of detection

LOQ	Limit of quantification
LT	Lithuania
LV	Latvia
MAC-EQS	Maximum allowable concentration
MBT	Monobutyltin (cation)
MCCP	Medium-chain chlorinated paraffin
MOT	Monooctyltin (cation)
MSFD	Marine Strategy Framework Directive (EU), Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy
MWWTP	Municipal wastewater treatment plant
NH4-N	Ammonium nitrogen
NP	Nonylphenols
NPE	Nonyphenol ethoxylates
OCDD	Octachlorodibenzo-p-dioxin
OCDF	Octachlorodibenzofuran
octaBDE	Octabromodiphenyl ether
OP	Octylphenol
OPE	Octylphenol ethoxylate
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxin
PCDF	Polychlorinated dibenzofuran
pentaBDE	Pentabromodiphenyl ether
PFC	Perfluorinated compound
PFDA	Perfluoro-n-decanoic acid
PFHxA	Perfluoro-n-hexanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanoic acid sulphonate
PL	Poland
PNEC	Predicted No-Effect Concentration
PO4-P	Phosphate phosphorus
POP	Persistent organic pollutant
POPs Convention	Stockholm Convention on Persistent Organic Pollutants
REACH	Registration, Evaluation and Authorisation of Chemicals Regulation (EU), Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
RoHS	Restriction of Hazardous Substances Directive (EU), Directive 2002/95/EC of the European Parliament

	and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment
RU	Russian Federation
SCCP	Short-chain chlorinated paraffin
SE	Sweden
SFA	Substance-flow analysis
Sludge Directive	Sewage Sludge Directive (EU), Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture
SMEs	Small and medium-size enterprises
SPIN	Substances in products in the Nordic Countries
SVHC	Substance of Very High Concern
TBT	Tributyltin
TcyT	Tricyclohexyltin (cation)
TEF	Toxic Equivalency Factor
TEQ TCDD	Toxic Equivalent dioxins
TOC	Total organic carbon
Tot N	Total nitrogen
Tot P	Total phosphorus
TPhT	Triphenyltin
TTBT	Tetrabutyltin
WEA	Whole effluent assessment
WFD	Water Framework Directive (EU), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
WHO TEQ	TEQ calculated with WHO-TEF
WWTP	Wastewater treatment plant

Foreword

Control of hazardous substances in the Baltic Sea region – the COHIBA project endeavoured with aims to develop knowledge, data and information of a prioritised group of hazardous substances in the region, the Baltic Sea Action Plan (HELCOM BSAP) substances. Aims included identification of most important sources and release patterns of the 11 substances or substance groups, innovative methods for pollution control and development of recommendations for management options to reduce emissions and discharges of the substances.

The project was coordinated by the Finnish Environment Institute (SYKE) and run since early 2009 till 2012. The project consortium consisted of 22 partners in Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden. The partners represented various branches including national authorities, municipalities, research institutes, NGOs and an intergovernmental organisation Helsinki Commission (HELCOM). The project had also associated organisations throughout the Baltic Sea region. This report is compiled on the basis of work of the project, and the final reports of the work packages with contents of altogether more than 1000 pages.

Final reports as well as other deliverables of the project are available on the project websites:

www.cohiba-project.net/publications

www.environment.fi/syke/cohiba

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1. Introduction

1.1 Background

Baltic Sea Action Plan

Hazardous substances are one of environmental problems of the Baltic Sea. 11 hazardous substances and substance groups have been taken into consideration in the area and a specific programme established for these substances (HELCOM Baltic Sea Action Plan (BSAP), hazardous substances segment - see Box below). The project Control of hazardous substances in the Baltic Sea region – COHIBA also focused on these eleven substances and groups, with the following main objectives:

- identification of sources in countries around the Baltic Sea
- development of innovative toxicity based cost-effective monitoring
- analysis of flow patterns to the Baltic Sea
- development of recommendations for management measures to reduce discharges
- knowledge transfer of best practices and capacity building.

Box 1. Substances or substance groups of specific concern to the Baltic Sea.	
1.	Dioxins (PCDD), furans (PCDF) & dioxin-like polychlorinated biphenyls
2a.	Tributyltin compounds (TBT)
2b.	Triphenyltin compounds (TPhT)
3a.	Pentabromodiphenyl ether (pentaBDE)
3b.	Octabromodiphenyl ether (octaBDE)
3c.	Decabromodiphenyl ether (decaBDE)
4a.	Perfluorooctane sulfonate (PFOS)
4b.	Perfluorooctanoic acid (PFOA)
5.	Hexabromocyclododecane (HBCDD)
6a.	Nonylphenols (NP)
6b.	Nonylphenol ethoxylates (NPE)
7a.	Octylphenols (OP)
7b.	Octylphenol ethoxylates (OPE)
8a.	Short-chain chlorinated paraffins (SCCP or chloroalkanes, C_{10-13})
8b.	Medium-chain chlorinated paraffins (MCCP or chloroalkanes, C_{14-17})
9.	Endosulfan
10.	Mercury (Hg)
11.	Cadmium (Cd)

Problems of hazardous substances in the Baltic Sea

Almost all open sea areas of the Baltic Sea, except north western Kattegat, are classified as being ‘disturbed by hazardous substances’ (Figure 1, HELCOM 2010). Similarly, 98 of the 104 coastal assessment units are classified as being ‘disturbed by hazardous substances’. Waters near larger cities tend to be classified as having a moderate or poor or sometimes even bad status.

The assessment showed that the levels of “old” substances, the use of which has been banned (e.g. DDT, PCBs and TBT), are still of concern, and the contamination status is partly a result of inputs that primarily took place decades ago. However, there are some encouraging signs of decreasing trends of certain substances and improving health status of some top predators.

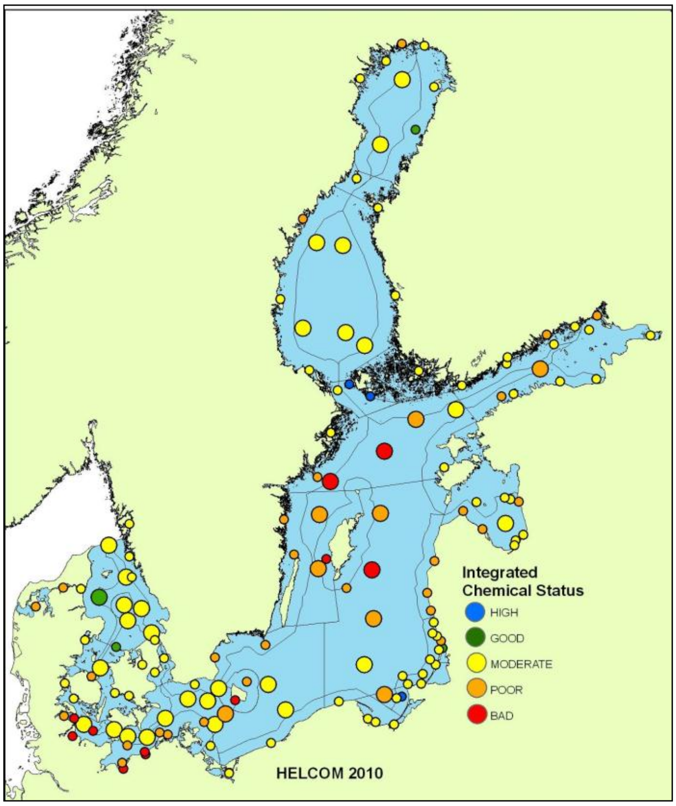

Figure 1. Integrated classification of the hazardous substances status in the 144 assessment units (HELCOM 2010).

Occurrence of hazardous substances in the Baltic Sea ecosystem is due to their use and unintentional production in industrial processes, smaller scale production processes, as well as in households both within and outside the catchment area.

Certain contaminants are not produced within the Baltic Sea region but are imported to the region as finished products and articles.

With HELCOM Baltic Sea Action Plan (BSAP) the HELCOM countries have committed themselves:

- to achieve a "Baltic Sea with life undisturbed by hazardous substances by 2021 and
- to reach the level of hazardous substances in marine environment close to natural.

Current governance

Most of the HELCOM BSAP priority hazardous substances are governed by global and/or EU regulations which either regulate or ban their use.

For a few of the HELCOM priority substances there are neither applicable EU regulations nor global conventions (, MCCP/medium-chain chlorinated paraffins, PFOA, HBCDD, decaBDE). However, currently it is being considered to include PFOS and HBCDD under the Stockholm POPs Convention, and MCCP in the revision of the EU RoHS Directive.

For some substances additional national measures either in the form of regulations or voluntary agreements were established, which have led to stricter national regulations or even bans on the use of the substances (mercury, cadmium, chlorinated paraffins (short-chain), brominated diphenyl ethers).

Promising initiatives

Several countries have established databases to enhance their knowledge on the use of hazardous substances, developments and trends and this has been used as the basis for the establishment of a joint database on the use of substances in products (the on-line database Substances in Products in the Nordic Countries, SPIN).

In some cases the industry has agreed to go beyond current international standards and, while awaiting further regulatory processes, to make voluntary agreements on the substitution and use of less hazardous substances, as is for example the case with brominated flame retardants. Specific countries have also unilaterally banned use and import/export of specific substances, such as mercury.

Awareness raising campaigns have been arranged to promote environmentally friendly small-scale combustion to avoid dioxin emissions and boat-hull washing sites have been established in small harbours/marinas to ensure proper handling and disposal of contaminated wash-water.

In several countries clean-up works have been carried out to rehabilitate old landfills.

No/not enough progress – need for further action

Ratification, implementation and enforcement of available legal instruments

The global conventions, covering the priority hazardous substances (i.e. the Stockholm POPs Convention, the protocols on POPs and heavy metals under the CLRTAP, the IMO Anti-fouling Convention, and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade), need to be ratified by all HELCOM Contracting States. In some cases, BREF documents under the IPPC/IE Directives should be updated to contain necessary information on hazardous substances (e.g. metal surface treatment for PFOS).

Development of knowledge base

Within the field of hazardous substances there is a need to further increase the knowledge as regards:

- the Predicted No-Effect Concentration (PNEC) values in order to support better assessment of the occurrence of hazardous substances in the Baltic marine environment,
- effects on organisms living in the marine environment of a combination of chemicals, including methods for early detection of chemical pollution,
- information on the uses, releases and occurrences of hazardous substances, including the ones prioritized for action in the HELCOM Baltic Sea Action Plan.
- support investigation of the toxicity and environmental fate in the Baltic Sea of decaBDE, medium-chained chlorinated paraffins, octylphenols in order to facilitate necessary restrictions.

Reduction of emissions/discharges from relevant industrial sources of hazardous substances, e.g.

- further investigate possible measures and cost-effective solutions to reduce emissions of dioxins from the iron and steel industry, taking into account the existing regulatory frameworks, such as the EU Directives on Large Combustion Plants and Industrial Emissions and the POPs Protocol to the CLRTAP
- close gaps in legislation, e.g. concerning exempted use of PFOS in metal plating
- stricter control over the disposal of contaminated sediments at sea
- support the use of less harmful substituting substances and existing techniques, promote voluntary agreements with industry for substitution of the use where it is still allowed, and facilitate further use of restrictions and phasing-out, e.g., for decaBDE, medium-chained chlorinated paraffins, octylphenols, and mercury

Tracing and addressing sources of long range airborne transport

- enhance research on the emissions of dioxins, cadmium and mercury and introduction of emission limit values and other abatement measures from industrial combustion in the Baltic Sea catchment area and beyond

Establishing a mechanism for strengthening the control of imported consumer products and articles in order to reduce the “flow” of these substances to the Baltic Sea area

Reduce inputs of hazardous substances by end-of-pipe solutions, e.g., advanced treatment of wastewater, treatment of leachates from landfills and storm waters from urban areas as well as from waste sorting sites.

- introduce techniques, such as activated carbon filtration or ozonation at wastewater treatment plants to prevent discharges of very persistent substances, which are not eliminated by current technology

Generally

- Control and treatment of urban run-off (i.e. storm water). Urban planning and major construction works should include the use of technical solutions for proper handling of storm water like pre-sedimentation dams and local infiltration (e.g. restoration of wetlands). Local authorities and water administrations should introduce programmes to restrict the emissions of hazardous substances to the municipal wastewater systems. The substitution of hazardous substances with less harmful alternatives should be applied to prevent discharges of hazardous substances to the municipal wastewater treatment system.
- **Advanced municipal wastewater treatment** may further contribute to reduction of emission, when emissions from large industrial point sources are already controlled by regulation. These measures target several of the 11 HS simultaneously, as well as other substances of potential concern, such as pharmaceuticals.
- **Enhanced municipal wastewater treatment** may contribute to reduced discharges of pharmaceuticals and hazardous substances, but **upstream precautionary measures are normally more cost-efficient**.
- Industries with high emissions should, as a part of the permit procedure, be requested to introduce enhanced wastewater treatment. For small and medium sized industrial dischargers to public sewers, an appropriate wastewater treatment according to BAT needs to be implemented in all Baltic Sea countries (for instance mercury emissions from dental clinics or cadmium emissions from galvanic industries).

1.2 Aims, work and methods of the project

The specific aims of the project were to:

- identify the most important sources and release patterns of the 11 selected hazardous substances/substance groups (HS), identified as being of specific concern to the Baltic Sea;
- develop innovative toxicity based cost-effective monitoring practices based on the Whole Effluent Assessment (WEA) approach;
- develop recommendations for cost effective management options to reduce the discharges, emissions and losses of the selected hazardous substances;
- provide input to the development of national implementation programmes, serving also the requirements under the EU Water Framework Directive and the EU Marine Strategy Framework Directive;
- provide input to the HELCOM integrated assessments on hazardous substances as a basis for decision making.

This project gave methodological support to the implementation of the BSAP. The products of COHIBA are also applicable to the implementation of the EU Water Framework Directive and the EU Marine Strategy Framework Directive. COHIBA is one of the flagship projects of the EU Baltic Sea Region Strategy (Priority 3).

Activities of the project included development of wastewater control methods, and new application of the whole effluent assessment approach based on use of biological tests. Furthermore identification of sources of the target substances, assessment and models of discharges and flows developing recommendations for cost effective management options to reduce the discharges, emissions and losses of the selected hazardous substances, and informing and capacity building of stakeholders and end-users, especially in the eastern Baltic Sea area, were important parts of the project implementation. Main outputs of the project include 3 work package reports and 11 guidance documents on the target substances, a recommendation report on cost effective measures, a modelling report for the Baltic Sea loads and contents and partners reports for partner countries both on case studies of pollution control (WP 3) as well as on sources and emissions (WP 4).

Results focus to various levels:

- increased awareness of the target substances among stakeholders and policy makers
- contribution to the joint assessment in the BSR on the substances
- efficient exchange of information among HELCOM countries
- Information is targeted also to the general public and is useful to be forwarded outside the BSR.

In the first years the COHIBA project devoted concerted effort to case studies in all participating countries. Identification of sources and estimation of emissions was carried out, as well as an inventory of measures to reduce discharges.

A set of case studies was carried out in all participating countries throughout the Baltic Sea region, including sampling programmes for municipal and industrial wastewaters, stormwaters and landfill leachates. Biotests provided basis to develop the Whole Effluent Assessment (WEA) approach for the Baltic Sea Region and a proposal for HELCOM's use was provided (WP 3).

Regional country studies on sources and substance flows were carried out by partners in EU BSR countries (so called substance flow analyses, SFAs). The project elaborated, based on national surveys, a summary of sources and emissions of the selected hazardous substances for Baltic Sea region. Modelling produces further information, i.e. inputs to the Baltic Sea for a set of BSAP substances. Local examples of Stockholm and of Copenhagen including modelling produced information also for the joint assessment of the BSR (WP4).

An inventory of possible measures for the 11 BSAP substances was carried out. It covers 75 measures and their applicability for each of the 11 substances. The measures include technical and non-technical measures in following categories: regulatory measures, economic and financial measures, voluntary agreements, and management and technical measures. Evaluation of measures was carried out and 11 guidance documents and a recommendation report on cost effective measures have been produced (WP5).

Important steps were taken to proceed in information exchange especially in the eastern parts of the Baltic Sea region, in the Baltic States and in Poland. A training concept was planned supported by survey on stakeholders, and a study on awareness-raising. A glossary of terms has been completed and published in the internet in 5 languages, English and 4 native languages of the eastern Baltic Sea region (Estonian, Latvian, Lithuanian and Polish). The glossary available on the project website also includes terminology and information in Russian. Series of information exchange events happened in the eastern parts consisting altogether of circa 40 events with circa 1100 participants. Other communication has included information exchange throughout the BSR including information to HELCOM policy level and expert groups.

Broader introduction to the main work packages of the project is presented below.

Work package (WP) 3 - Innovative approaches to chemical controls of hazardous substances

(Led by the Finnish Environment Institute, SYKE)

The target of WP3 was to contribute to the identification of sources for the 11 hazardous substances in BSAP by performing screening of municipal and industrial wastewaters, landfill leachates and storm waters, in all participating countries. WP3 also had aim to jointly evaluate ecotoxicity of the effluents and to recommend toxic-based discharge limit values based on the WEA approach for the Baltic Sea region. Currently most of the restrictions concerning discharges are based on the determination of chemical concentrations. However, the majority of effluents comprise a mixture of chemicals. It is impossible to identify all these substances and their transformation products or to determine the effects of all individual substances or their synergistic interactions in the environment using chemical analyses. Thus there is a need to characterise and regulate discharges on the basis of direct assessments of their biological effects, to complement the chemical analyses. Also, an important aim of WP3 was to harmonise the chemical and ecotoxicological methods in the Baltic Sea region serving also EU WFD and REACH requirements.

Case studies were planned and representative sites were selected in participating countries by the project partners for screening of municipal and industrial wastewater treatment plants, landfills and urban storm water. For one year every second month 2 municipal WWTPs and 2 industrial WWTPs were sampled from each country. Storm water, landfill leachate and municipal sewage sludge (1 site per each category per country) were sampled twice a year; once during the cold and once during the warm season. Altogether about 30 samples per country were taken, totalling (about) 240 samples.

The Project proved that *effluent assessment by chemical methods* provides quantitative data of concentrations, but does not (necessarily) provide information on transformation products, effects of the compounds, or combined effects of all the chemicals present in the effluent, thus representing *substance-by-substance approach*. At the same time, *effluent assessment by biological methods* provides information on the potential risks to cause adverse effects, while not necessarily giving information on the causative compounds unless further analyses are carried out, thus representing *effect-based approach*. Based on this, it was concluded that taking into account advantages and limitations of both chemical and biological methods; both are not contradictory or conflicting but complementing and in combination enable identification of causative toxicants.

Knowledge and experience of the project in implementing integrated chemical and biological effluent assessment was condensed in a report which provided basis to a draft HELCOM Recommendation on implementing Whole Effluent Assessment (WEA) in the Baltic Sea Region. It was presented in meeting of HELCOM groups (HELCOM LAND 15/2010 and 16/2001; HELCOM MONAS 13/2010 and 15/2011). Both groups supported in general the use of the proposed approach but agreed that the approach contained in the draft recommendation requires further consultation at the national level in HELCOM countries and consideration on cost-benefit analysis of the WEA approach. The most recent version of the draft recommendation as well as supporting material can be obtained here:

http://www.cohiba-project.net/-> WP 3 -> Recommendations

For a number of substances within the hazardous BSAP substances, COHIBA project was one of the first occasions to estimate the discharges to and the concentrations in the Eastern Baltic Sea region. The screening gave new information on the presence of hazardous substances in the Eastern Baltic Sea area. It is also clear that there is a great need for additional measures for treating wastewaters. On the basis of COHIBA results, it is possible to plan future studies, reduction measures and national monitoring for those selected substances.

Results of work have been collected in the Final WP report (Nakari *et al.* 2011). Further information about the results of this WP is available from the project website

More detailed information about the activities in this Work Package is contained in Chapters 2 and 3.

Work package 4 - Identification of sources and estimation of inputs/impacts on the Baltic Sea

(Led by the IVL Swedish Environmental Research Institute)

The objective of Work package 4 (WP4) in the COHIBA project was to assess the release patterns and pathways to the Baltic Sea marine environment of the substances of concern. The aim was also to quantify the inputs of the selected hazardous substances to the Baltic Sea by assessing and using models. In the long term this will facilitate the understanding of the link between the sources and releases of the selected substances and the effects in the marine environment, and introducing the ecosystem approach to the management of the impacts of human activities also with regard to hazardous substances. The results of this work package also provided crucial input to the assessment of management options to reduce discharges, emissions and losses of hazardous substances.

Sources and flows of the target substances were identified using substance flow analysis (SFA). The SFA contains flows of a substance throughout its lifecycle, and finally the emissions of a substance into water, air or soil. As a first step in the project SFAs were adopted using SFAs produced on European scale. The EU SFAs functioned as templates for regional SFAs furthermore adopted in the participating countries, thus making it possible to achieve comparable results. Project partners used national, regional and local data obtained from industry, chemical registers, scientific studies etc. to describe the pathways and to estimate emissions of the target substances from their country. Finally the major sources and flows in the whole Baltic Sea region were assessed based on partners' country studies. More on assessment of sources and flows in the project can be found here: http://www.cohiba-project.net/ -> Sources

The SFAs were coupled with chemical fate assessment in the environment performed through modelling. In these models the chemical and physical characteristics of a sub-set of substances were considered together with the characteristics of the receiving environment. The distribution and fate of the substance is predicted and in this way the final receiving compartment and the environmental persistence of the substance within the system can be assessed. The models serve to synthesise data on emissions and flows – identified and quantified in the SFAs – as well as data on occurrence obtained by measurements to achieve an "overall picture".

Information about the results of this WP, including partners' SFA reports, is available on the project website. Results have been summarised in the final WP 4 report (Andersson *et al.* 2012a).

About the activities in this WP is contained in Chapters 4, 5 and 6.

Work package 5 - Cost effective management options to reduce discharges, emissions and losses of hazardous substances

(Led by the Federal Environment Agency of Germany with support of the Fraunhofer Institute)

Within the COHIBA project WP 5 collected and evaluated (cost-) effective measures to reduce emissions of selected 11 hazardous substances or substance group. Data about activities in HELCOM countries under the Water Framework Directive (WFD) was obtained via a questionnaire. Additional information were utilised from reports of HELCOM and EU-projects, case studies carried out in WP 3 and SFA results of WP4.

Reduction measures were evaluated for each of the target substance groups, and then prioritised in terms of technical feasibility, cost-effectiveness and overall applicability, taking into account specific situations in different countries. This aimed at development of 11 substance specific guidance documents later for use within HELCOM. The documents contain information on major sources in the Baltic Sea region, pathways to the Baltic Sea, reduction measures already implemented or under implementation and additional measures on national, HELCOM and regional level. The project produced a report on recommendations on cost effective management options to reduce discharges, emissions and losses of the target substances in the Baltic Sea region.

Results have been summarise in the final WP 5 report (Mathan *et al.* 2012). Information about the results of this work package of the project, is available here: **http://www.cohiba-project.net/** -> Management

More detailed information about the activities in this Work Package is contained in Chapter 7.

Work package 6 - Capacity building and knowledge transfer

(Led by the Baltic Environmental Forum Estonia)

The aims of WP6 were:

- to accompany the implementation of other work packages by raising the competency of the stakeholders from the Eastern Baltic Sea Region (E-BSR), e.g. through direct capacity building at stakeholders in the E-BSR based on a jointly elaborated concept of the project and with jointly elaborated methods and targets later on adapted to national circumstances;
- to enhance information flow between various parts of the BSR in the project and among stakeholders to enhance the understanding of hazard concepts at international level and give input to future EU and HELCOM work aiming at harmonizing approaches, also in discussion with Russian stakeholders having different legislation and approaches. Practical implementation of the capacity building actions was done by means of seminars and trainings for authorities and industries and other stakeholders, e.g. on hazard concepts, testing methodologies for selected hazardous substances, identification of sources and estimation of quantities of hazardous substances and their possible impacts on the aquatic/marine environment, industrial permitting, etc. The training scope and schedule could be seen here: http://www.cohiba-project.net/ -> Knowledge

WP6 also developed and published in cooperation with other project partners an online glossary of terms on hazardous substances in English and E-BSR languages, brochures for selected industry branches and a technical guidance document for permits addressing the hazardous substances. The glossary is available here: http://hs.befgroup.net/

COHIBA has produced beneficiary information as regards available information in various countries and parts of the BSR, and especially visualised the situation to stakeholders in the E-BSR.

More detailed information about the activities in this Work Package is contained in Chapter 8.

2. Screening of wastewaters

The target of effluent screening in COHIBA –project was to contribute to the identification of sources for the 11 hazardous substances in Baltic Sea Action Plan (BSAP) by performing chemical analyses of municipal and industrial wastewaters, landfill leachates and storm waters, in all participating countries. It was also aimed to evaluate effluent ecotoxicity and recommend toxicity based limit values for effluents discharged into the Baltic Sea (Nakari *et al.* 2011).

2.1 Sampling locations and sampling program

Sampling programme was planned to cover different types of loads to the Baltic Sea from all the participating countries and to take samples simultaneously. According to the project plan, partners in each country selected representative wastewater treatment plants, and effluents were sampled six times during the project. Storm water, landfill leachate and municipal sewage sludge were sampled twice; once during the cold and once during the warm season. Effluent samples were analysed both for the selected chemicals as well as for toxicity, while the municipal sewage sludge was analysed for chemicals only.

Table 1. The highest and lowest annual average values of basic parameters of all, municipal (MWWTP) and industrial (IWWTP) treatment plant effluents, and landfill leachate and storm water samples.

Plant	BOD (mg/l)	COD $_{Cr}$ (mg/l)	Suspended solids (mg/l)	pH	Tot.P (mg/l)	Tot.N (mg/l)	Conductivity mS/m	Efficiency (BOD7, %)	Efficiency (Ntot, %)	Efficiency (Ptot, %)	TOC (mg/l)
MWWTP	2-19	24-113	3-12	6.7-7.7	0.1-2.9	4-41	60-2008	95-99	10-90	79-98	
IWWTP	1-67	14-249	1-13	6.8-9.0	0.1-3.3	1-38	671-2470	96-99	79-84	83-99	
Landfill	5.6 - 610	18 - 2088	< 1.8 - 7936	4.7-8.8	0.02 - 25	6.5 - 2236	3.2 - 6650				< 1.01 - 955
Storm water		24 - 465	4.8 - 221	7.2 - 7.9	0.04 - 80	1.1 - 1500	15 - 2510				5.5 - 15

Effluent and landfill leachate samples were planned to be taken similarly at all sampling locations, as 24 h composite samples adjusted to the flow rate or time, but this procedure was not possible in all cases. Storm water and sludge samples were taken as grab samples. Analyses of the basic parameters; flow rate, pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, total phosphorus, suspended solids and conductivity were partly conducted by the COHIBA partner laboratories and partly results were received from cooperation partners (Table 1).

The flow rate in treatment plants varied according to the size of the plant, handling capacity and seasonal fluctuations. Based on the available data there seems to be annual variation in the effluent quality in most of the treatment plants. Occasional exceeding in the permitting values can be an indication of overloads in treatment capacity. Handling capacity can also be insufficient during heavy rains in treatment plants which also receive urban run-off waters. Obviously, different treatment processes have also impacts on the quality of the effluents, which is indicated as a considerable variation of measured basic parameter values (Table 1).

Results of chemical analyses

Most of the BSAP hazardous substances were found in all sample types included in the screening. In addition, substances that were not originally included in the sampling programme, such as bisphenol A, monooctyltin (MBT), dioctyltin (DBT), perfluoro-n-hexanoic acid (PFHxA) and perfluoro-n-decanoic acid (PFDA) were found in each sample type. The detected frequencies are shown in Table 2. It should be noted that the number of effluent samples was significantly higher than the number of sludge, landfill leachate and storm water samples. Many of the substances were found more often in sludge samples than in effluent samples. Findings in sludge indicate their presence also in the effluents.

Cadmium was generally detected in storm waters. A significantly high in a sampling site of stormwaters in Poland. This may refer to high atmospheric deposition of cadmium due to coal use and industry. In municipal effluents cadmium was generally detected at low concentrations. A high cadmium concentration in the industrial effluents was observed in Germany, where samples were taken from coal power plant.

For mercury, the exceeding of MAC–EQS value (0.07 µg/l) was remarkable in Danish and Polish municipal effluents. In industrial effluents the MAC – EQS value exceeding was observed in Germany, due to specific cooling system and process water, and to some degree in Latvia and Finland. The concentrations in all sludge samples were higher than LOQ. Mercury in wastewaters discharged to Baltic Sea still seems to be a problem in some countries.

For some substances, for example endosulfan and tributyltin (TBT), requirements for the limits of quantifications (LOQs) set by Commission Directive 2009/90/EC cannot be met by the methods used in this project. The most frequently observed organotin compounds were mono- and di-butyltin (MTB and DBT). The concentrations in the municipal effluents and storm waters were about on the same level. Tin compounds were not observed in sludge samples in Denmark, nor in Lithuania in storm water samples.

The highest concentrations of the phenolic compounds were found in Swedish and Latvian storm water samples. Although in municipal effluent the concentrations were usually lower than 2.2 µg/l, the municipal sludge in Estonia and Poland contained, however, quite high concentration of phenolic substances. NPs are usually attached to solid substances and therefore remain in sludge. One additional reason for high NP concentrations in sludge might be transformation of NPE to NP in anaerobic conditions.

Endosulfans were observed in industrial and municipal effluents in Finland, Germany, Latvia and Poland. In these countries, except in Latvia, endosulfans were found also in sludge. In storm waters endosulfans were found only in Finland and Germany. In landfill leachates only endosulfan sulphate was observed in Estonia, Germany and Finland. It should be noted that endosulfan is banned in the EU level.

In industrial and municipal effluents the concentrations of MCCPs and SCCPs were about at the same level, except in Denmark, where MCCP was detected at a very low concentration in municipal effluents. In the effluents MCCPs were prevailing while in the sludge SCCPs were more abundant. The only exception was Denmark where MCCP prevailed also in sludge. MCCPs and SCCPs were also detected in the storm water samples of all the participating countries.

The prevailing polybrominated diphenyl ether (PBDE) congener in almost all sample types was decaBDE. The highest concentration of decaBDEs in municipal effluents and storm waters was observed in Denmark. In industrial effluents the concentration of penta-, octa- and decaBDEs were highest in Lithuania. In landfill leachates also pentaBDE was detected quite frequently.

The highest concentrations of perfluorinated compounds were found in Finnish effluents. In municipal effluents the most probable source was the influent from metal plating industry, and in industrial effluent the use of flame retardants and fire fighting foams. The other sources were not identified as clearly e.g. the high concentrations in Danish storm waters and Swedish landfill leachates.

For a number of substances within the BSAP hazardous substances, COHIBA project was one of the first occasions to estimate the concentrations and the discharges from the Eastern Baltic Sea region. The screening gave new information on the occurrence of hazardous substances in that area and based on the results, changed the prevalent opinion that there are no problems with hazardous substances in Eastern Baltic Sea region. It is also evident that there is a great need in future to improve the wastewater treatment processes.

Table 2. Summary of detection frequencies (concentration above limit of detection, LOQ) of substances and groups of substances. The differences in LOQs between laboratories have influenced the detection frequency.

Substance / substance group	Detection frequency (%)				
	municipal effluent	industrial effluent	storm water	landfill leachate	sludge
Cadmium, Cd	6	26	67	38	83
Mercury, Hg	68	46	73	62	100
MBT	59	50	33	60	79
DBT	50	39	40	26	79
TBT	7	2	27	20	79
TPhT	1	0	0	0	26
MOT	13	13	13	33	79
DOT	5	2	13	13	79
TCyT	0	0	0	0	26
Nonylphenols, NP	73	78	67	67	100
Nonylphenol ethoxylates, PE	39	36	40	40	86
Octylphenols, OP	45	36	20	47	64
Octylphenol ethoxylates, PE	17	16	27	33	36
Bisphenol A, BPA	58	45	93	100	27
Endosulfan	20	10	14	0	53
Endosulfan sulphate	24	20	14	29	33
Dioxins and furans , PCDD/F	74	65	89	75	69
Dioxin-like PCB, co-PCB	72	61	89	88	69
SCCP	92	91	93	93	100
MCCP	93	98	80	62	50
pentaBDE	26	21	60	67	91
octaBDE	2	6	20	40	91
decaBDE	65	68	67	67	91
HBCDD	52	44	53	21	85
PFOS	86	62	87	73	100
PFOA	98	95	87	93	82
PFHxA	76	58	53	87	100
PFDA	58	15	40	73	55

Hexabromocyclododecanes (HBCDDs) were analysed in Denmark and Sweden as a sum parameter, while in all other countries the results were analysed as isomer concentrations (α-, β- and γ-HBCDD). Therefore the results were not comparable. The prevailing isomer in municipal and industrial effluents was the γ-isomer, in sludge, landfill leachate and storm water the isomer distribution was more variable.

2.2 Ecotoxicity tests

One goal of the project was to track toxicity of effluents, leachates and storm waters discharged to the Baltic Sea by using the whole effluent assessment (WEA). WEA means simply testing biological effects using the samples as such, preferably without any manipulations, or after as little manipulations as possible. In general, pH adjustment, aeration, or other minor pre-treatment may be unavoidable to assure the welfare of test organisms.

It was determined in the project application that *Vibrio fischeri* luminescent bacteria test, *Daphnia magna* acute toxicity test and algae growth inhibition test would be the obligatory acute test, which all participating countries should arrange either by performing or by purchasing tests as service. Laboratories used their own validated test methods. Finland performed all these obligatory tests for Denmark, and *Vibrio fischeri* luminescent bacteria tests for Estonia, while the Swedish samples were not tested for acute toxicity at all. The obligatory tests were performed according to standardized test methods (ISO 11348-3, 1999, ISO 6341, 1986 and ISO 8692, 1989).

Vibrio fischeri, luminescent bacteria test is one of the most common toxicity test used for wastewater toxicity assessments. This method is suitable for many kinds of aqueous samples; surface and ground water, wastewater, water extracts and leachates etc. Instead of the luminescent bacteria test, Latvia performed *Artemia salina* (brine shrimp) mortality test by using commercial ArtoxKit method. The *Daphnia magna* standard describes a method for the determination of immobilisation of the animals during 24 or 48 hours. Algae growth inhibition test specifies a method for the determination of the growth inhibition of unicellular green algae by substances and mixtures in water or wastewater. The growth inhibition test can be performed either in small volume cells, microplates, or in Erlenmeyer flasks.

The participants were encouraged to use also optional tests for the detection of possible hazardous effects of the effluents. Finnish and Lithuanian samples were tested with a number of optional tests (see results in Table 3). In addition, two effluent samples from each country were tested in the Finnish laboratory with five long-term optional tests. More information of these test methods is available in the partners' WP3 case reports (www.cohiba-project.net -> WP3).

WEA differs from the chemical substance-specific approach, because it is not limited to a pre-selected compound or group of compounds, but the test organisms are exposed to mixture of substances present in the sample. It is well-known that the BSAP substances are not at least acutely toxic at the concentrations they are normally observed in the effluents. Nevertheless, there were indications of toxic effects in the treated effluents.

Results of ecotoxicity tests

The short-term toxicity tests showed occasionally acute toxicity in the effluents. In Table 3 results of municipal, industrial landfill leachate and storm water samples are sorted by country. In general, the results of the biotests showed that the quality of the effluents varied greatly from sampling time to sampling time. This was also observed in relation to the basic parameters of the effluents. Obviously, the toxicity testing should be repeated more frequently to confirm the results for individual plants.

Based on the results of the acute toxicity tests, the algae growth inhibition test seemed to be the most sensitive for both municipal and industrial effluents, and also for the storm waters. In many cases, at low concentrations in particular, there was stimulation of the algae growth. This growth stimulation is a common observation concerning effluents, and it might overpower the effects of toxins.

Table 3. Number of municipal (MWWTP) and industrial (IWWTP) effluents, landfill leachates (LL) and storm waters (STW) samples sorted by country colour coded by toxicity. Green colour denotes no effects; yellow, toxicity below the recommended limit, and red colour denotes toxicity above the recommended limit value, and white means that no samples were tested.

Municipal effluents																								
Obligatory tests	DK			EE			FI			DE			LV			LT			PL			SE		
***Daphnia magna*, acute**	4			10	1	1	16	2		14			14	2		14			11	7				
Algae growth inhibition	1	1	2	8	1	3	13	1	4	14			11			10		4	18					
Luminescent bacteria test	4			10	2		18			14						8			16	1	1			
Optional tests																								
Genotoxicity, umu-test*	1	1					16	2			2		2			1			15	2	1	2		
Egg-larvae-test	2						18			1	1		2			1			1			2		
***D. magna*, reproduction**							18			2														
Lemna minor	1	1					11	5						2		1			1			1	1	
Vitellogenin test			2						18			2			2			1			1			2
Hepatocyte EROD activity			2						18			2			2			1			1			2

Industrial effluents																								
Obligatory tests	DK			EE			FI			DE			LV			LT			PL			SE		
***Daphnia magna*, acute**	4			11			5	1		11	1	2	9	5	2	14			2	1	3			
Algae growth inhibition			4	5	5		3		3	11	2	1	4	5	3	11		3	6					
Luminescent bacteria test	2	2		11	1		5	1		14						8			6					
Optional tests																								
Genotoxicity, umu-test*				2			4	2								1			6					
Egg-larvae-test					1	1	5		1							1			1					
***D. magna*, reproduction**							18																	
Lemna minor				1	1		4	2								1				1				
Vitellogenin test						2			6									1			1			
Hepatocyte EROD activity						2			6									1			1			

	Denmark						Estonia						Finland						Germany					
Obligatory tests	LL			STW			LL			STW			LL			STW			LL			STW		
***Daphnia magna*, acute**			2	1					2	2			1		1	2			1			1	1	
Algae growth inhibition			2			1		1	1	1	1				2	1		1	1			2		
Luminescent bacteria test			2	1					2	2					2	2			1			2		
Optional tests																								
Genotoxicity, umu-test*													2			2								
Egg-larvae-test															2	1	1							
***D. magna*, reproduction**													1		1	2								
Lemna minor														1	1	1	1							
Vitellogenin test															2			2						
Hepatocyte EROD activity															2			2						

	Latvia						Lithuania						Poland						Sweden					
Obligatory tests	LL			STW			LL			STW			LL			STW			LL			STW		
***Daphnia magna*, acute**			1	1			2			2					2			2						
Algae growth inhibition							2			2					2	1		1						
Luminescent bacteria test							1			1					2	2								

* In umu-tests the yellow values are from concentrated samples

Both optional tests with aquatic crustaceans *Artemia salina* and *Thamnocephalus platyurus* were more sensitive for tested effluents than was *Daphnia magna* immobilization test (partners' case reports of Latvia and Lithuania). Low toxicity can be identified with protozoa and rotifers kit tests. Relatively high detection and quantification potential has been demonstrated with freshwater macrophytic algae tests (partner's report, Lithuania). In spite of limited number of effluents tested, the data obtained throughout the project suggest that optional tests can also be useful for effluent toxicity control in distinct countries.

Aquatic animals are sensitive to exogenous chemical substances during reproduction. Also in this study, effects on organisms' reproduction were observed in the long-term *Daphnia magna* water flea test and zebra fish egg-larvae test. *In vitro* tests with fish hepatocytes exhibited estrogenic and disturbed detoxification metabolism of xenobiotics by the majority of the effluent samples. These effects were most obvious in the municipal wastewater effluents (Table 3). Estrogenicity of effluents is perhaps one reason for the results observed in *Daphnia magna* reproduction tests; exposed Daphnids produced significantly more eggs or offsprings than the control animals.

Original effluents did not show genotoxicity when assayed by umu-test, but after sample concentration to 30 fold there where indication of genotoxicity. Ames test, however, showed genotoxicity even without concentration (partner's report, Poland). These tests measure different mechanisms of genotoxicity. Therefore, the observed effects are not directly comparable between effluents. The positive results in umu-test after concentration of the samples are an indication of the risk that these samples contain compounds, which by bioaccumulation may have adverse effects on aquatic organisms.

All toxicity test results are presented in more detail in partners' WP3 reports.

3. Control methods of hazardous substances in wastewaters

Wastewater treatment plants receive a myriad of chemical substances in the sewage. Purification systems are challenged in term of techniques and capacity. Besides the many well-known chemicals, the unknown transformation products of chemical substances, either entering the treatment plant or produced there during the treatment process by microbial activity, may exhibit harmful properties. Some of the chemical compounds or their transformation products are persistent, bioaccumulating and potentially toxic (PBT). Wastewater treatment techniques may not be optimized to tackle these compounds at low concentration since the main focus has been on the removal of nutrients and organic matter.

The management of some common hazardous substances has been effective, but there are new threats caused by emerging, poorly known substances. Even though individual compounds were found at low concentrations, the mixture of many persistent compounds may lead to detrimental effects on the marine biota. The problem with policy instruments based on the single chemicals approach is that they leave the discharges of many potentially hazardous substances uncontrolled and do not address the possibility of combined effects. Banning or restriction of the use of one hazardous substance does not necessarily prevent from replacing it with another, equally hazardous substitute, or with a substitute carrying unknown properties.

High quality analytical methods are valuable in controlling individual chemicals and identifying specific substances of restricted use or even substances that are already banned. Since wastewaters (especially municipal) are a mixture of various substances, approach were effluent quality is evaluated only substance by substance will become extremely expensive. WEA offers a practical and flexible tool for assessing the effluent quality in a cost effective way. It enables the assessment of potential risks and effects for both identified and unidentified substances. By combining ecotoxicity tests and chemical analyses it is possible to identify sources of hazardous substances and to plan preventive actions. This procedure should be an effective tool to increase the level of protection of the Baltic Sea and enhance its ecological status.

(http://www.cohiba-project.net/ -> WP 3)

3.1 Recommendations for analytical work

In order to achieve high-quality results the whole chain-of-custody should be well planned, executed and documented. Analytical performance, well established quality control procedures and skilled personnel are highly valued in the laboratory work. Applied methods shall be properly validated and method performance should be known and documented (*e.g.* sensitivity, selectivity and accuracy). Methods sensitivities shall also meet the legislative and permission requirements. The representativeness of the samples is the key to reliable results and further actions.

Some general remarks could be made regarding most of the analytical work. There is a need for guidance on *i)* selection of analytical techniques, *ii)* usage of internal standards, *iii)* data handling and result interpretation. Following recommendations cover these issues:

- For internal standard, specifically when analysing the organic compounds, the best choices are ^{13}C-labelled analyte analogies since they are presumed to behave like analytes (labelling in carbon skeleton). If ^{13}C-labelled standards are not available ^{3}H-labelled or ^{18}O-labelled internal standards should be used. Compounds with similar properties *e.g.* molecular structure, size or nature should be used as internal standards only if mass labelled compounds are not available.
- Isotopic dilution technique is recommended in the analysis of complicated sample matrix. Otherwise matrix matched calibration is needed.
- Careful sample pre-treatment and efficient chromatographic separation is needed for specific determination of for example different isomers or congeners of PBDEs, HBCDDs, PFCs and Aps.
- The results should be recovery corrected.

In future, analytical methods should be streamlined, especially regarding LOQ (not higher than 30% of EQS values), extraction and clean-up methods should guarantee acceptable level of analyte recovery. Laboratories should participate regularly in proficiency tests to improve and maintain the high analytical quality.

3.2 Recommendations for whole effluent assessment

Scientific knowledge about combined effects of chemicals is still rather limited. The majority of the knowledge about the toxic effects of chemicals is only valid for single compounds. From the environmental point of view exposure to a single compound is an artificial situation.

By using WEA it is not possible to find out the causative chemical or mixtures of chemicals unless all the results were verified by similar tests using known chemicals and the same concentrations as had been in the original effluent samples. This would be an enormous task and practically impossible. However, further analyses using WEA in combination with chemical analyses and fractionation of the effluent sample it is possible to identify the hazardous substances (toxicity tracking), and hence, to plan necessary actions. This procedure should be an effective tool to increase the level of protection of the Baltic Sea and enhance its ecological status.

WEA and laboratory test comparison results were used to derive a proposal for toxicity-based discharge limits. The proposal is available at the HELCOM web pages. The principle of the toxicity limits was to ensure, that effluents discharged into the Baltic Sea should not cause acute toxicity and only moderate long-term toxicity when assessed by the recommended methods.

The proposed limits for maximum allowable acute toxicity were the following:

- 30% inhibition of algae growth at 80% test concentration,
- 20 % immobility of *Daphnia magna* at 95% test concentrations (48 h exposure), and
- 30% inhibition of luminescent bacteria (30 min exposure) at 80 % test concentration.

When toxicity test results of the COHIBA –project were compared with these limit values, the results indicated that the quality of municipal wastewater effluent varied greatly and acute toxicity was detected from time to time. The variation of the effluent quality was apparent by both chemical and biological methods. If the principle is accepted that acute toxicity should not be observable at all, the results should lead to further actions, and at least to confirm the results the results by repeated tests.

In general biotests should be conducted with several (preferably 3-5) different organisms on different trophic levels/functional groups (e.g., bacteria, phytoplankton, invertebrates and fish). There are several reasons for this. Firstly, there is variation between the sensitivity of the different species, and therefore using several species increases the reliability of the tests. Secondly, no single species can indicate all the substantial end-points. This is a way to obtain a better view of the effects on ecosystem functioning and on different trophic levels.

The limited availability of ecotoxicity test services and doubts of arising costs due to additional work has been one reason for the rather limited use of WEA. Because chemical and biological methods do not measure the same phenomenon, detailed comparisons are not well justified. In general, laboratory facilities for biotesting are quite simple. Analytical equipment for ecotoxicity tests are relatively simple, such as microplate readers, spectrophotometer, luminometer, and relevant facilities for culturing the test organisms. Pre-treatment of samples is simple; adjustment of pH, filtration or centrifugation and aeration. During the COHIBA –project it came out that the availability of biotest capacity would be built-up quite soon if there were demand on the services. Laboratories in different countries are fully capable of adopting at least the acute toxicity test methods.

4. Identification of sources and assessment of emissions

Sources and pathways within the Baltic Sea catchment area of the BSAP substances/groups of substances, were assessed mainly by substance flow analysis (SFA). The SFAs were conducted in Sweden, Finland, Estonia, Latvia, Lithuania, Poland and Germany and the results are reported in partners' summary reports for each participating country (available on www.cohiba-project.net -> WP 4). In Denmark and Russia special case studies were carried out instead of SFAs (see Chapter 6 below).

The basic idea of an SFA is to make industrial, service-life and waste related as well as environmental flows of a substance visible and comparable, and to facilitate identification of the major sources. The emissions from the sources were estimated for the environmental compartments air, land and surface water. The SFA for polybrominated diphenyl ethers (penta- ,octa-, deca BDE) for the BSR is exemplified in Figure 2.

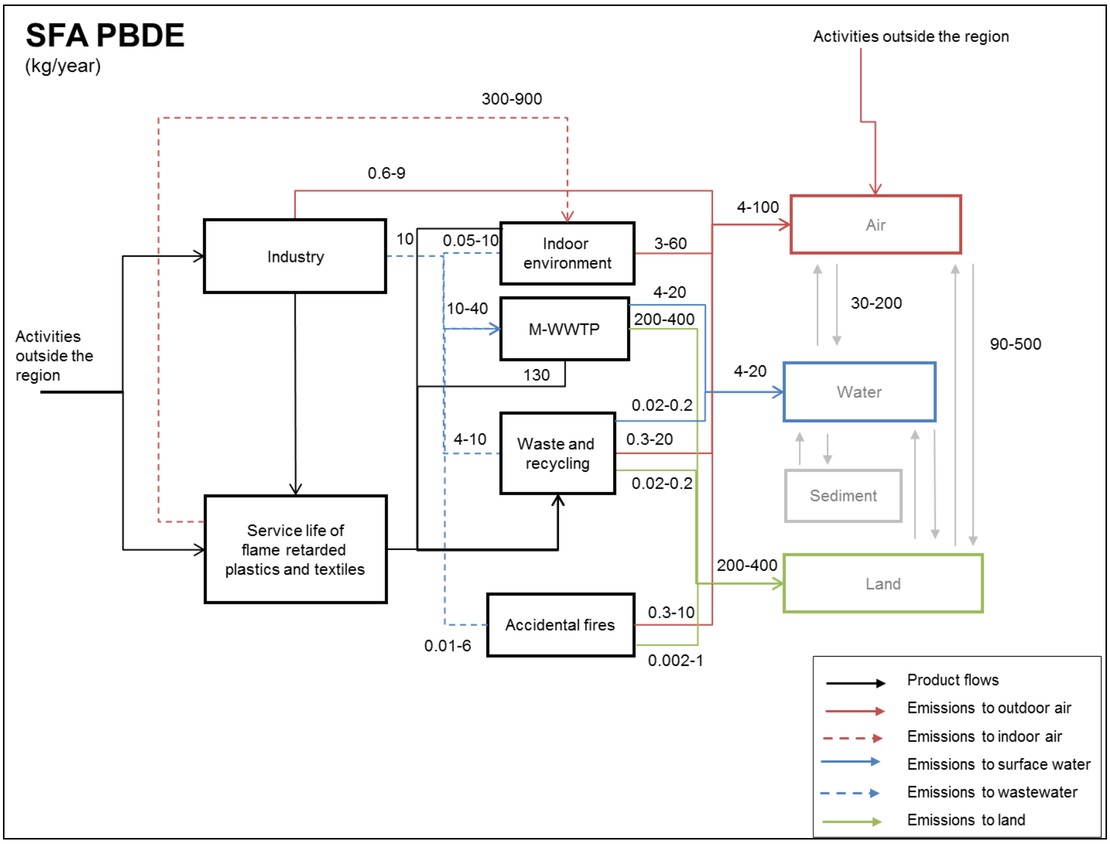

Figure 2. Simplified substance flow analysis (SFA) for PBDE in the Baltic Sea Region

The methodologies used and how they were applied in COHIBA are further described by Andersson et al. (2012 a, b) in the WP4 background paper. By conducting SFAs in almost all Baltic Sea countries a unique dataset of emission estimates for substances listed in the Baltic Sea Action Plan have been created.

4.1 Major sources

The emissions reaching the environment (air, surface water and land) from major source categories for the 11 substances (groups) are summarised in Table 4.

Table 4. ***Total emissions and emissions shares from main source categories for the 11 substance groups.*** *(Emitted volumes: a= < 1 tonne, b= 1- 100 tonnes, c >100 tonnes, Share of emissions: xxx> 50%, xx 10-50%, x 1- 10%, empty cells mean < 1% or no estimates)*

Substance (group)	Total emissions	Sources					
		Historic contami-nation	Industry	Service life	Waste and recycling	M-WWTP	Other
PCDD/PCDF/ dioxin-like PCBs	a*	xx	xx		x		xxx[1,2]
TBT	a	xx? [7]	x	xxx		x	
PBDE	a		x	?	x	xxx	x?[2]
PFOS/PFOA	a		x	x	x	xx	xxx[3]
HBCDD	a		xx	x		x	xxx[4]
NP/NPE	b		xxx	x		xx	x[5]
OP/OPE	b		x	xxx		x	xx?[5]
MCCP/SCCP	c		xx	xxx		xx	
Endosulfan	a		x			xxx	x[5]
Mercury	b	?	xx	x	x	x	xxx[1]
Cadmium	b	x	xxx	x	x	x	xx[1,6]

*Expressed as toxic equivalent (TEQ)
[1-5]Main sources in category 'other': [1]combustion, [2]accidental fires, [3]use of fire fighting foam, [4]construction and demolition, [5]use of pesticides [6]use of contaminated fertilisers. [7]lack of data

Emissions are highest for the MCCP/SCCP and lowest for endosulfan and PCDD/PCDF/dioxin-like-PCBs. Industrial point sources are still relevant for most compounds and are, according to the SFAs, the main sources, directly to the environmental compartments, for NP/NPE (mainly leather industry) and cadmium (energy production in paper and wood processing, production and processing of metals). Data set collected in the project indicates that the share of emissions during service life for TBT (biocide treated timber, products containing organic tin compounds as catalysts), OP/OPE (abrasion of tyres) and SCCP/MCCP (wastes in the environment, e.g. particulates of polymeric products, paints and sealants containing chlorinated paraffins).

Both industry connected to M-WWTP and service life contribute to a large extent with emissions into and out of M-WWTP. Hence, the use of sludge from M-WWTPs in agriculture or landscaping transports the substances of concern from wastewater to land areas. M-WWTPs constitute the main emission pathway for PBDEs (originating mainly from the indoor environment, adsorbed to dust) and endosulfan (residues on foodstuff) into the environment, respectively. It is also an important pathway for PFOS /PFOA emissions originating mainly from metal plating industry, service life and waste or recycling.

In the category 'other', combustion (energy sector: individual heating systems, power plants, electric transformers) and accidental fires are the main sources for PCDD/PCDF/PCBs and for mercury. Use of fire-fighting foam was the main emission source for PFOS to the environment while construction and demolition (of building material) is the main source for HBCDD. Agriculture can be a relevant direct source for OP/OPE (pesticides) and cadmium (mineral fertilisers).

According to the SFAs direct emissions from waste, recycling and historical contamination are not main sources for any of the substance groups, but they contribute for most substances and there are big question marks regarding the estimated emissions from these sources (e.g. TBT, dioxins, cadmium, mercury) coming from historic contamination.

4.2 Distribution of emissions between environmental compartments

According to the SFAs, different substances are emitted to different compartments, which are illustrated in Figure 3. In order to take the best decisions on where measures should be applied it is important to know to which compartment the substances are emitted.

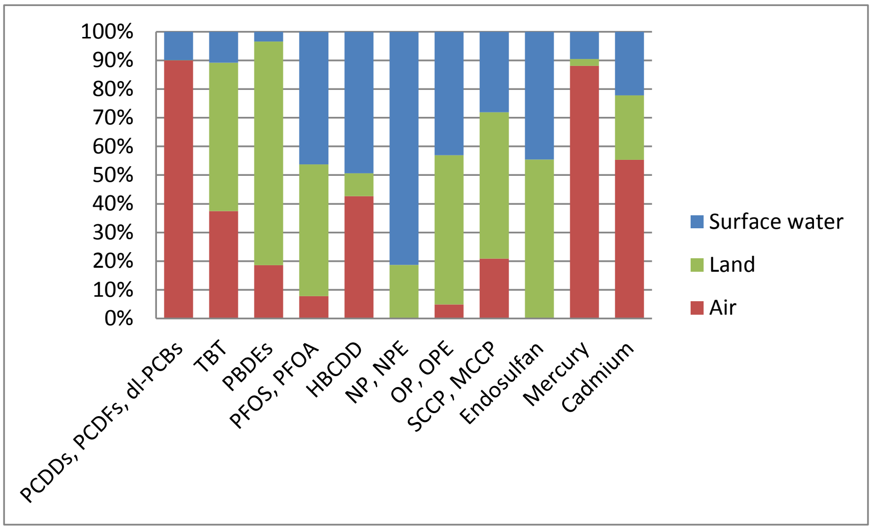

Figure 3. The relative distribution to different environmental compartment for the emissions of different substances

Dioxins and the metals are mainly emitted to air (from combustion) while NP/NPE are mainly emitted to surface water, directly from service life and via MWWTPs (originating from service life and industry). PBDEs, organotins and MCCP/SCCP are mainly emitted to land via sludge, while the emissions of PFOS/PFOA, OP/OPE and endosulfan are emitted in about equal amounts to surface water and land.

4.3 Conclusions on identification of sources

Although the emission data in the SFAs are associated with high levels of uncertainty, the substance flow analysis has proven to be a useful tool for finding the most important sources for emissions of substances into the environment, a tool that can be recommended when considering measures for the BSAP-substances as well as for other substances.

Industrial sources remain relevant within the region, but diffuse sources (including emissions during the service life of consumer articles) are becoming increasingly important. M-WWTPs are important conveyors of emissions and it is therefore important to track upstream sources. It is also important to find demolition techniques which reduce emissions of hazardous substances in e.g. building material. Combustion facilities for energy/heating (especially residential) and to some extent waste are important sources for which measures should be proposed in order to decrease emissions to air.

5. Flows, pathways and assessment of inputs to the Baltic Sea

To get an 'overall picture', as well as to highlight the most important flows for the occurrence of selected BSAP-substances in the Baltic Sea and its region a chemical fate model was applied. To further add to the picture, the loads to surface waters and land areas due to atmospheric deposition were estimated with the use of monitoring data.

5.1 Inputs and regional differences based on the results from the model exercise

A modified version of model POPCYCLING-Baltic (Mattila and Verta, 2008) was applied to provide a link between the estimated emissions of selected substances within the catchment of the Baltic Sea and the inputs to the Baltic Sea. The model was further used to study spatial patterns of the contamination in the marine environment and to investigate the effect of changing scenarios. The emissions from the SFAs together with physical-chemical properties of the substances were used as input parameters to the model and steady state concentrations in various matrices were recorded. Emissions as estimated in the SFAs were also used to extrapolate emissions from countries in the drainage area that were not partners within the COHIBA. The selected substances for this modelling exercise were PBDE (congeners 47, 99 and 209), HBCDD, NP/NPE and endosulfan. For each chemical two emission scenarios the low and the high were modelled. The following assumptions were made: The emissions estimated within COHIBA have been constant over the modelled time period; The environment is considered to be at steady state – i.e. there is no change in concentrations or net flows over time; There is no net transport of chemical into, or out from, the Baltic region, i.e. the inflow from outside equals the outflow from inside. For further details about the model, such as input parameters, boundaries, assumptions, see Palm Cousins (2012).

The fate modelling exercise indicated that direct sources contribute more to the regional input of PBDEs, HBCDD, NP/NPE and endosulfan into the Baltic Sea than indirect releases via rivers and the atmosphere. It should, however, be noted that this assessment did not take into account atmospheric deposition due to long-range transport from outside the Baltic Sea region. The modelling study also indicated that for the marine areas in the open Baltic Sea, the atmosphere was the main input pathway, but that these flows were small in comparison to the direct releases on the coast. Southern Baltic Proper and Gulf of Finland were the regions indicated to receive the highest loads of the selected BSAP-substances. For pentaBDE atmospheric deposition was predicted to give a high contribution to the input in the Baltic Proper, especially in the high scenarios. Overall, it appeared that in-land emissions had little impact on the regional input of the six modelled contaminants in the Baltic Sea.

5.2 Atmospheric transport and deposition

The substance flow analyses have identified air as a major receiving environmental compartment for emissions of several BSAP-substances and for which atmospheric transport and deposition may constitute an important pathway into the Baltic Sea and its catchment area. In addition, several of the BSAP-substances are persistent and they may enter the Baltic Sea region via atmospheric long range transport. Data from deposition measurements have been used to estimate the importance of atmospheric input of hazardous substances into the Baltic Sea and its region.

Measured deposition and estimated total emissions were in the same order of magnitude for PCDD/PCDF/dioxin-like PCBs indicating that there was balance between output and input in the region. For cadmium, mercury and endosulfan on the other hand, there appears to be a net transport into the region since the deposition was higher than the total sum of estimated emissions in the region. Also for PBDEs there was a gap between emissions to air according to the SFA and measured deposition indicating transboundary influence. Parts of this gap could possibly be explained by underestimation of the releases from indoor air to outdoor air. According to Swedish measurements, there is also atmospheric long-range transport of PFOS/PFOA, but the importance of the deposition as a pathway could not be estimated (Armitage 2009).

5.3 Conclusions

Direct coastal emissions to the Baltic Sea, such as effluents from MWWTP appear most important for 'within-region' sources for the substances included in the modelling. This indicates that locally high inland emissions in individual countries do not necessarily have a large influence on the Baltic Sea as a whole, in particular not if these are directed to land.

Atmospheric deposition seems to be important for the occurrence of several of the BSAP-substances in the Baltic Sea and in the Baltic Sea catchment area. Furthermore, atmospheric transport is an important pathway for several of the substances into the region.

6. Hot spots of BSAP hazardous substances and gaps of knowledge

A hot spot can relate to, major sources causing emissions of the BSAP-substances (see Chapter 4 and 5), geographical areas with high emissions, areas in the Baltic Sea with high concentrations of the substances but also to substances of high concern for the region based on emitted amounts and inherent properties. Use and emission patterns of the substances of concern show regional differences (different kinds of hotspot areas). Regional differences and the importance of urban areas as source areas of BSAP substances to the Baltic Sea have been investigated in case studies carried out in Stockholm, Copenhagen and St Petersburg and Kaliningrad region.

6.1 Countries

In general the estimated yearly loads differed a lot between countries, but not as much if presented as emissions per capita. The SFAs showed that Poland generally had the highest total emission, but Poland also has most habitants in, and a large areal part of, the catchment area of the Baltic Sea. The pattern therefore became different when emissions were calculated per capita. For endosulfan, dioxins and HBCDD, the largest total emissions were estimated to come from Poland but on a per capita basis the highest emissions for endosulfan were from Germany and Latvia, for dioxins Finland and Latvia had similar or higher emissions as Poland and for HBCDD emissions were higher in Estonia, Finland and Germany. The highest PBDE emissions in the Baltic Sea region originated in Finland, Poland and Sweden, while on a per capita basis, the largest emissions were estimated to derive from Estonia, Finland and Sweden. The yearly loads of OP/OPE differ a lot between countries, with the highest amounts released in Poland, and still so if presented as emissions per capita.

Data gaps on use and emissions of a substance in a country were treated differently between the countries. Countries that had available data to report (or tried to make expert judgments of emissions) seemed to end up with higher emissions compared to countries that simply used question marks or left blank when the emissions were not known. For instance the use of timber treated with TBT as a biocide was indicated to be a source in Estonia, Poland and Sweden, but only Sweden reported emissions land accordingly had the highest emissions.

6.2 Local areas - cases studies

Densely populated areas have higher emissions of substances especially from diffuse sources and the emission patterns are expected to be similar between such areas, which means that these emissions/sources are suitable for common measure strategies between areas. According to the case studies, Stockholm appeared to be a source for NP/NPE (originating from washing of textiles and concrete), PBDEs (from indoor air) and HBCDD (demolition of buildings) to the Baltic Sea. Large amounts of the substances emitted to wastewater in Stockholm are transported with the sludge to other areas in Sweden. The Danish modelling work indicated that out of the 11 BSAP-substances, land-based point sources were important for PFOS/PFOA, NPE and mercury in the Copenhagen area. The main sources were urban run-off and combined sewer overflows (CSO), industrial zone, rivers and MWWTPs.

In the St.Petersburg and Kaliningrad region the main emission sources for almost all substance groups turned out to be consumption and use of final products and articles, followed by long-range transport and deposition. However, there are large data gaps for these SFAs and reasons are i) Russian authorities lack information and legal frame to gather data on HELCOM substances or the substances have been totally banned for emissions, thus assuming that no emissions exist and ii) the use patterns (and not emissions) of chemicals in individual enterprises is considered as a commercial secret in Russia.

6.3 Hotspot areas in the Baltic Sea according to the fate modelling

The highest concentrations in surface water for all modelled substances (PBDEs, HBCDD, NP/NPE, endosulfan) were predicted to be found in Neva Bay (easternmost part of Gulf of Finland), followed by the South Baltic Proper. Also for sediments, modelled concentrations were highest in Neva Bay for HBCDD, NP/NPE and endosulfan. The second most important area was the coastal South Baltic Proper followed by the entire Gulf of Finland and in the case of nonylphenol also the Skagerrak area. The 'low scenario' for PBDEs showed also highest concentrations in Neva Bay, for BDE 209 slightly higher in the coastal South Baltic Proper. In the high scenario for the PBDEs, the coastal areas of South Baltic Proper and Swedish Baltic Proper stood out as the key areas of interest, but relatively high levels were also predicted in the entire Gulf of Finland and in the Skagerrak area.

However, the modelled results showed inconsistencies with available data on measured concentrations in the different environmental compartments. Reasons for this could be e.g. underestimated deposition rates by the model or unrepresentativeness in the monitoring data used for comparison. Comparison with available monitoring data for biota summarised by HELCOM (2010) showed that the highest concentrations of BDE-47 (scattered data, no data for Neva Bay) was found in the South Baltic Proper and second highest were coastal waters in The Danish Straits, Western Gotland Basin, Bothnian Sea and Bothnian Bay. Coastal waters in Gulf of Finland and in Gulf of Riga showed lowest concentrations. Similar patterns were found for HBCDD. NP/NPE was below detection limits in most biota samples while sediment concentrations were highest in The Danish Straits (very few data available for Gulf of Finland and the South Baltic Proper).

6.4 Conclusions on hot spots and knowledge gaps

To obtain more homogenous data for all countries there is a need for national chemical product registers and emission registers. For some substances there is imbalance between countries regarding main emissions sources. How different countries have dealt with data gaps is one reason for differences in emissions from the different countries. Poland has the highest total emissions, but this is mainly due to its relatively higher share of the drainage area. Some industrial areas and densely populated areas, like big cities, are hotspots for emissions. According to the modelling exercises the southern part of the Baltic Proper and the Neva Bay of the Gulf of Finland are potential 'hotspot areas' regarding concentrations of the (modelled) substances in the Baltic Sea.

Overall uncertainties and gaps of knowledge for BSAP hazardous substances

The input data to the SFAs originate from a multitude of sources (literature as well as measurements conducted in the project) and have varying inherent uncertainty and relevance for the region. There are differences in availability of national data between the countries. For instance only Sweden, Denmark and Finland have national product registers.

- The status of emission registers also varies between the countries and they do not cover all of the BSAP-substances. Large uncertainties are related to emissions during service life and for the waste sector, e.g. chemical composition of solid waste or leachates as well as number and areas of landfills. Some countries have made expert judgments when national information on a possible source was missing, while other countries have indicated a data gap or zero emission.

Extrapolations from the EU SFAs, which were undertaken for all the BSAP substances, have to a large extent been the basis for national emission estimates. Uncertainty is added when data are extrapolated and there are

- Very few analytical data are available for verification of emission estimates
- Data on emissions from historically contaminated sites are almost completely lacking.

Where possible the emissions from a specific source were quantified with a "low" and "high" emission estimate - aggregated these created a low and high emission scenario. The low and high emission scenarios give, only to some extent, an indication of the uncertainty of the data. As a range of emission factors were not available.

Modelled concentrations in the Baltic Sea showed inconsistencies with measured concentrations. Perfect model/measurement agreement was not expected, since certain processes (e.g. long-range atmospheric transport) were not considered. However, the fact that levels were sometimes overestimated and sometimes underestimated could possibly be a result of inaccurate model descriptions of certain processes, e.g. the atmospheric scavenging applicable to PBDEs. It could also be a result of unrepresentativeness in monitoring data leading to a skewed comparison.

There is a need for more harmonised monitoring data on concentrations of hazardous substances in the Baltic marine environment and for chemical analyses with lower detection limits.

The quality of the input data to the SFAs varies considerably. Differences in estimated emissions between the countries in aggregated data could thus be due to actual differences but also to a large extent to missing information or differences in handling of data gaps. Product registers and emission registers in all countries would improve the estimation of emissions considerably.

7. Management measures of BSAP hazardous substances

7.1 Methodology

In order to identify appropriate measures for reducing emissions of hazardous substances to the Baltic Sea a pragmatic approach was applied. Sources and measures promising a large reduction potential were pre-selected. For the identification of large reduction potential two criteria are taken into account: firstly the load at the source and secondly the effectiveness of the applied measure. In a second step these pre-selected measures were analysed in detail and compared. If appropriate data on effectiveness and costs were available a quantitative assessment of the cost-effectiveness of measures was performed by using the following evaluation criteria:

- **Effectiveness**: The effectiveness of a measure at a given source relates to the reduction it achieves in the emissions of a given hazardous substance. In combination with the load on the respective source, the effectiveness is expressed as load reduction in kilograms.
- **Costs**: The evaluation of costs is subdivided in direct costs and running costs.
- **Cost-effectiveness analysis**: For calculations of cost-effectiveness of the different measures, expressed by the ratio of cost to the reduced load of hazardous substances, different scenarios (low load reduction effectiveness – high costs and high load reduction effectiveness – low costs) were estimated.

The quantitative assessment is subject to high uncertainties, as costs and loads may vary between locations. The cost-effectiveness scenarios are meant to indicate the ranges and to compare measures to each other. The quantitative assessment is complemented by a qualitative evaluation to include sustainability aspects, mainly based on experts' estimates rather than on empirical data. For this additional assessment the following qualitative aspects were taken into account:

- *Secondary environmental effects*: Besides positive and negative secondary environmental effects were assessed, such as effects on emission reduction of other hazardous substances or nutrients.
- *Technical feasibility*: The ease of technical implementation of the respective measure under different boundary conditions, e.g. time needed for the technical implementation of the measure.
- *Secondary socio-economic effects*: There are also secondary socio-economic effects, such as indirect costs, effects on employment and product prices caused by the measure.
- *Geographical and time scale of effects*: Effects on a local, regional, national or international level as well as immediate and long-term effects of the measures.
- *Political enforceability*: The alignment of measures with other political targets considering both possible conflicting interests and the acceptance by existing interest groups.

7.2 Substance-specific measures

The following conclusions regarding substance-specific measures are drawn from the COHIBA Guidance Documents, which are available from the project website: www.cohiba- project.net).

1. **Dioxins (PCDD), furans (PCDF)** and dioxin-like polychlorinated biphenyls (PCBs): Concerning the reduction of PCDD/F air emissions in the residential sector the replacement and retrofitting of household furnaces is the most important measure. This measure should be combined with improving building energy performance like thermal insulation. For industrial air abatement, technical measures with improved combustion and clean up techniques are the most cost-effective. This includes the improvement of BAT and revision of the BREF document concerning small particle (PM 2.5) emission reduction for different industry branches (power plants/energy sector, metallurgical sector, waste incineration) on a SME level.

   Contaminated soil and sediments are local problems and should be treated on a case by case basis. Suitable technical measures are dredging and on-site combustion or on-site capping. Those should be applied to highly contaminated soil or sediments.

2. **Tributyltin compounds (TBT), triphenyltin compounds (TPhT)**: Measures regarding sediment management especially in harbours like environmental dredging, ex-situ solidification and stabilisation and no dumping in the Baltic Sea are effective but often very costly. Therefore more information on the

location of contaminated hot spots of TBT would be required to determine the places which should be treated first.

National legislation regarding possible technical implementation measures and creating linkage between different EU legal acts defining use/application of organotins and dredged material are still needed.

3. **Pentabromodiphenyl ether (pentaBDE), octabromodiphenyl ether (octaBDE)**, decabromodiphenyl ether (decaBDE): Substitution of PBDEs (mainly decaBDEs, because penta- and octaBDE are already well regulated) at the source – in polymers, textiles and construction material – starting from replacing PBDEs with different flame retardants up to re-design of the product in a way that eliminates the need for flame retardants as such seems to be the most cost-effective measure and is easy to implement.

4. **Perfluorooctane sulfonate (PFOS), Perfluorooctanoic acid (PFOA)**: For PFOS, substitution in metal plating is very cost effective. As polyfluorinated substitutes cause concern, additional end-of-pipe measures or the development of a better substitute should be considered. BREF needs updating and there is a gap in the regulations for SMEs, e.g. metal plating.

   There are only few data on industrial uses for PFOA, due to a lack of regulation. Therefore, calculation of cost effectiveness of substitution in manufacture of semiconductors and of photographic material is subject to high uncertainties.

5. **Hexabromocyclododecane (HBCDD)**: The use of mineral wool as a substitute for HBCDD-containing insulation boards in the building sector is a cost-effective measure but it cannot be applied in all applications where polystyrene boards are used. Re-design of the construction, controlled demolition of buildings and recycling as measures regarding waste management are the main recommendations.

6. **Nonylphenols (NP), nonyphenol ethoxylates (NPE)**: A EU-wide ban of NPEs is primarily recommended for the following usages (manufacture, marketing & use): in industrial, professional and domestic cleaning products and textiles and secondarily, the EU-wide absolute ban of NP and NPEs for the use in the leather and the metal sector. Thus, those usages which are only conditionally banned since 2005 (directive 2003/53/EC) should be banned completely.

   The alcohol ethoxylates are environmentally less harmful, cost-effective and already used as substitutes for NP and NPE in the above mentioned applications. The substitution of NP and NPE with alcohol ethoxylates is possible for a relatively small additional cost for example in cleaning products. These measures would significantly facilitate authority control and elimination of emissions from the above mentioned significant NP and NPE emission sources.

   Additionally, the ban of NP and NPE in textile goods imported from outside of the EU is recommended.

7. **Octylphenols (OP), octylphenol ethoxylates (OPE)**: Substitution is available for instance in textile printing but in some cases it is difficult to realise, e.g. in tyre production. End-of-life tyres should not be crushed but disposed of by controlled incineration as a waste management option to prevent OP emissions.

   Voluntary agreements of the industry to a more restricted use are recommended to accelerate the substitution process.

8. **Short-chain chlorinated paraffins (SCCP), medium-chain chlorinated paraffins (MCCP)**: Restrictions on the use of SCCP could be extended to include the remaining areas of application like rubber, paints and varnishes.

   Since substitution of SCCP has proven to be possible in most areas of application, the knowledge regarding substitution should be transferred to regions outside EU where SCCP are still produced and used in large amounts (reduction of emissions via long range transport).

   The use of MCCP as a substitute for SCCP should be avoided. Possible restrictions and a substitution of MCCP (e.g. in emulsion and oil-based metal cutting fluids) need to be evaluated further, since the industry and the use of products containing MCCP seem to be the dominant sources of MCCP emissions to the environment. As only few regulations have been issued for MCCP not directly up to now, this type of measure should have a significant impact on the reduction of MCCP emissions to the environment.

9. **Endosulfan**: A global ban of endosulfan according to the decision of the Stockholm Convention would be the most effective measure since endosulfan is still in use in India and parts of Africa. Substitution is

available and very effective. Besides that for the Baltic Sea region improvement of control and a ban of contaminated foods is recommended as a precautionary measure

10. **Mercury**: The improvement of BAT and revision of BREF for combustion power plants and for the chlore-alkali industry are recommended. The substitution of mercury in dentistry is highly recommended and the use of dental amalgams should be considered further in the HELCOM recommendations, because the problem is not yet solved.

    The EU mercury strategy should be implemented further to reduce the use in products like batteries, electrical and electronic equipment and thermometers.

11. **Cadmium**: The biggest reduction potential can be expected from measures concerning air emission abatement in the residential and industrial sectors. On the one hand upgrading and retrofitting of burners in individual households is potentially a cost-effective measure, on the other hand the improvement of BAT and a revision of the BREF document (ferrous, non-ferrous, metal and energy sector) for industrial air abatement is recommended. Small and medium companies should be included in the BREF process by lowering or skipping threshold values.

    The treatment of contaminated sediments and soils is important for selected regions were the soil and sediment pollution is high. Another option seems to be the reduction of Cd-content in fertilisers.

    A complete ban of Cd-Ni batteries is another effective measure.

Substitution or changes at technical processes are generally preferable but due to product life span, highly specific applications, long range transport etc. maybe not sufficient to achieve the targets laid out in the BSAP. Therefore end-of-Pipe measures are also important as they reduce a lot of substances simultaneously.

7.3 Measures with cross substance effects

Measures such as advanced wastewater treatment, sewage sludge treatment, waste management and treatment of urban run-off reduce the emissions of a multitude of hazardous substances simultaneously.

Advanced wastewater treatment

Apart from wastewater from households, municipal wastewater treatment plants (MWWTP) often also receive wastewater from SMEs (indirect dischargers), urban run-off or landfill leachate. A state of the art three-stage MWWTP is designed to reduce organic matter and nutrients, but is not equipped to eliminate persistent substances with a low biodegradability, such as the 11 hazardous substances and other micro-pollutants. Therefore, an advanced treatment step to eliminate persistent substances is discussed in many European countries. Ozone treatment or activated carbon processes are available, and can be integrated in existing MWWTPs (BAFU 2009).

Costs of advanced wastewater treatment depend above all on the size of the MWWTP and the concentrations of hazardous substances/amount of ozone or activated carbon that is necessary for the treatment. To calculate overall costs in the BSR, a wide cost range of 5 to 20 Euros per year and person was used. Taking into account that in the BSR 195 MWWTPs are bigger than 100,000 person equivalents and serve approx. 41.3 million people (PLC-5), the annual total cost for all 195 plants for this measure can be estimated between 200 and 825 million euros. Cost effectiveness lies between 17,000 and 69,000 Euros per kg emission reduced (detailed information is included in the WP 5 recommendation report, Mathan *et al.* 2012)

Sludge treatment

While most hazardous substances are not degraded in conventional wastewater treatment plants, they often tend to adsorb onto sludge generated in the wastewater treatment process due to their low solubility and high sorption potential (e.g. endosulfan, HBCDD, OP, NP, SCCP/MCCP and heavy metals), leading to an accumulation of hazardous substances in sludge. The sludge from the wastewater treatment process is often applied to land to allow a re-use of contained nutrients or disposed of in landfills or by incineration. Hazardous substances contained in sewage sludge can reach surface or groundwater e.g. via leaching or erosion, but can also be retained in the soil. For very few of the hazardous substances (e.g. NP) a reduction could be observed after biological stabilization with sufficient retention times and sludge application to the soil (Donner *et al.* 2010).

Measures targeting sewage sludge have a lower direct influence on concentrations in water than measures targeting effluent of MWWTPs, which represents a direct pathway to the aquatic environment. Anyhow, to prevent emissions to the environment from hazardous substances contained in sludge (e.g. via application to land or from leachate of landfills), proper sludge management and handling is crucial. An agricultural and landscaping application of contaminated sludge cannot be recommended and should be avoided. The EU-Directive 86/278/EC (Sewage Sludge Directive) gives only limit values for heavy metals Cd (20 – 40 mg/kg) and Hg (16-25 mg/kg) in sludge up to now.

Controlled land filling of sewage sludge means that the site needs to be fitted with a leachate barrier system and leachate collection and treatment system. Leachate treatment can be conducted by applying processes of advanced wastewater treatment.

From the perspective of reducing potential emissions of hazardous substances from sludge, incineration is one of the most effective options, as it practically eliminates all traces of most organic pollutants in the sludge, thus preventing further emissions. Incineration can be a very costly option, especially if no local/regional incinerators are available. Costs can vary considerably depending on specific local and regional conditions. Generally speaking, the highest costs are investments to build an incineration facility. Operating costs can vary depending e.g. on amounts of sludge incinerated, water content of sludge, whether there are other types of waste incinerated as well. In the long term investments might pay back and become more feasible, especially if the incinerator can generate heat or electricity which can be sold to consumers and if sludge otherwise has to be transported over long distances or exported for utilisation.

Costs for co-incineration can be assumed to be 250-300 Euros per tonne dry matter (Schaum *et al.* 2010, Disposal and recycling routes for sewage sludge 2002), and for mono-incineration 350-400 Euros per tonne dry matter (Schaum *et al.* 2010). The costs of incineration are highly variable due to design aspects and regarding energy recovery, as sales of both electricity and heat can generate substantial revenue that can cover some of the incineration costs. Cost effectiveness for removal of all described hazardous substances by sludge incineration can be estimated to be in the range of 13,000-20,000 Euros per kilogram removed substance (for detailed information see WP 5 recommendation report, and Mathan *et al.* 2012).

Urban run-off management

Since urban run-off is a highly relevant source for some substances (PFOS, NP/NPE), it is recommended that an overview of the urban run-off emissions is elaborated on regional level and sufficient control and measures should be implemented.

7.4 Regional perspective

Measures for reduction of emissions proposed by the project have been based on cost efficiency and highest reduction potential. However, for different regions surrounding the Baltic Sea their efficiency may greatly vary due to specific regional conditions.

For technical measures, which in most cases focus on substitution of hazardous substances and wastewater treatment options, the applicability of measures does not differ too much from country to country, as currently applied technologies are similar in the entire region. Of course, different social and economical boundaries persist in these countries, especially when comparing eastern and western coasts of the sea but such differences are usually reflected in the household/municipal rather than in the industrial sector, which, in many cases, is working with an internationally accepted plant engineering practices.

In some cases, E-BSR countries can be in an advantageous position as particular specific hazardous substances have not been used for purposes thought to be innovative 10 to 15 years ago and readily applied in western countries, and have been or will be included in different legal lists of restricted substances.

However, from the perspective of enforcement of legal measures there is quite a substantial gap between western and eastern regions of the Baltic Sea, with E-BSR still lacking complete practical implementation of IPPC and BAT principles in EU Member States and with a very differing permission and control system in the Russian Federation.

A similar situation can be noted regarding the informal pathways of substance emissions: in E-BSR burning of waste, littering, leakage from sewers or wrongly connected sewer pipes are still likely to play a significant role in the total emission load by diffuse emissions from households/urban sources. The behaviour of citizens (consumption and disposal behaviour) and the state of urban infrastructures (especially for wastewater, combined sewer overflow and surface run-off) is also to be taken into account.

Connected to this situation another important local boundary condition is the relative importance of industrial sources vs. com- munity/urban/household sources. Experiences from W-BSR show a time trend: as industrial sources become better regulated and the total load of hazardous substances decreases, the relative importance of community/urban/household sources increases. For the E-BSR region it is still too early to determine definite trends in this perspective as the present information so far is insufficient for making a quantitative assessment.

Economic measures and voluntary agreements seem to have an effect on regions where general public awareness on hazardous substances is on a high level and has lasting traditions. As a result this seems to be more demanding in the E-BSR region as general awareness on this topic both within the industry and the general public is rather low and lacking good local examples.

As far as legal measures are concerned the situation is slightly different due to geopolitical reasons – not all countries around the Baltic Sea are EU Member States – two regions of the Russian Federation (St. Petersburg/Leningrad region and Kaliningrad) are adjacent to the Baltic Sea as well. The legal system of chemicals management in Russia has developed differently than it has in the EU. It puts more emphasis on substances which pose acute toxic risks not so much stressing persistence and bioaccumulation. As a result nationally and regionally set restrictions do not cover exactly the same substances that are included in different EU legal acts. This also applies to the 11 HELCOM BSAP substances, especially taking into account that only a small part of Russia is located within the catchment area of the Baltic Sea which makes the implementation of recommendations more complicated and more regional. This could be a potentially significant gap for emissions of substances which are currently not regulated in Russia (like OP or PFOS), especially taking into account, that industries which are likely to emit these hazardous substances are definitely present and operate both in St. Petersburg and Kaliningrad (e.g. metal plating, production of cleaning agents and detergents, finishing of textiles, leather tanning, etc.).

7.5 Reduction strategies

7.5.1 Strategies to close gaps in regulations

Action on international, EU and HELCOM level is needed to close gaps in the regulation.

Additional international regulations need to be considered for those substances which still reach the Baltic Sea Region via imported products or via long range transport - like a global ban of manufacturing and use of endosulfan or control of imported goods containing e.g. PBDEs, TBT, NP/NPE. The inclusion of PFOA and HBCDD and further active risk reduction work within POP Convention is highly recommended.

On an EU level, it is recommended to nominate PFOA as a REACH candidate and to put it on the list of substances of very high concern (SVHC), which means further substance restriction. This has already successfully been done for OP (December 2011) and HBCDD. Additional research is necessary to substitute and ban these substances completely. For PFOA and MCCP even less information is available especially on industrial sources and the corresponding emission factors, because no reporting duties exist. An EU-wide ban of NP and NPE is primarily recommended for usages like cleaning, textiles, and secondarily for leather and metal working. Those usages, which were only conditionally banned since 2005 (directive 2003/53/EC) are recommended to be totally banned. It is recommended to extend the restricted uses in the regulations on other remaining uses for SCCP. The usage of MCCP in emulsion and oil based metal cutting fluids should be restricted, since this application is one of the main contributors to total emissions from industry.

Despite of existing bans or regulations on an EU level, some of the hazardous substances continue to be found in water samples throughout the BSR. Therefore there is a need to search and identify further sources. Then reduction measures on the sources are recommended like the improvement of BAT and the revision of BREF under the IPPC-Directive e.g. now for energy production, the metallurgical sector and waste incineration regarding PCDD, PCDF and PCBs, for metal surface treatment regarding PFOS, for combustion power plants regarding Hg, for industrial air abatement and waste treatment regarding Cd.

Although a great number of different EU regulations on the use of the substances exist, a better linkage between these and national legislation is still needed especially in the eastern Baltic Sea countries (e.g.

TBT). In addition emphasis should be put on the control and enforcement of the existing regulations. There is a need for further harmonisation of a criteria system, which facilitates the selection of substances as hazardous substances simultaneously in e.g. HELCOM, WFD, REACH etc.

It seems necessary to create incentive systems to increase data quality and dissemination to the public, e.g. by including the St. Petersburg region in the Pollution Release and Transfer Register system.

Finally it is recommended to support and promote the ongoing strategies for PCDD/PCDF, PCB and mercury of the European Commission and the global mercury initiative.

As in HELCOM also non-EU countries are contracting parties, HELCOM recommendations regarding emission reduction play an important role in implementing common goals. In accordance with the HELCOM recommendations it is recommended:

- The revision of HELCOM Recommendation 25/2 "Reduction of Emissions and Discharges from Industry by effective use of BAT", to develop e.g. Emission Limit Values for heavy metals (air and water emissions), PM10 and dioxins.
- The further progress of the implementation of HELCOM requirements concerning proper handling of waste / landfilling (Recommendation 31E/4), because illegal landfills are still an issue in the Baltic Sea region especially in the eastern Baltic Sea countries and in Russia (see country-specific survey in the WP5 Final Report Mathan *et al.* 2012).
- The revision of HELCOM Recommendation 28E/8 "Reduction of dioxins and other hazardous substances from small-scale combustion" as stated in the BSAP, to develop specific efficiency requirements and emission limit values for small scale combustion appliances (deadline was 2008 already). This is especially important with a focus on Poland and other East Baltic Sea Countries regarding PCDD, PCDF, PCBs.
- The HELCOM Dentistry Recommendation 6/4 should be kept and revised because the COHIBA project findings indicate that the use of amalgam containing Hg in dentistry is still an issue in the Baltic Sea Area.
- The further step-by-step reduction of the Cd-threshold in fertilisers is recommended. Therefore a revision of the Recommendation 31E/3 on Cadmium in fertilizers should go further and come up with a region-wide value compromise.

7.5.2 Strategies for industries including small and medium enterprises

For most of the 11 hazardous substances, regulations with respect to production and use restrictions as well as on the use of modern abatement technologies have been adopted and have already been implemented or are currently under implementation (namely IPPC). However, a detailed analysis in the E-BSR shows that the practical implementation of IPPC and BAT principles still has deficits in these countries. Therefore emphasis should be put on the improved implementation of IPPC/BAT.

As outlined in the previous paragraphs, there are gaps in regulation, regarding PFOA, MCCP, HBCDD and decaBDEs. As these substances are not or almost not regulated, there are no reporting duties. Therefore, information on production and use is scarce, especially on amounts used in industry, emission factors and corresponding load to the environment. It is recommended to make the information available for these purposes by REACH.

For other substances like NP/NPE, PFOS, SCCP, Cd, Hg gaps in existing regulations have been identified and should be closed. These refer for example to obsolete exemptions from bans, IPPC size thresholds and necessary BREF updates. For regulated substances there is more information available than for the non-regulated substances mentioned above. But often this information is not up-to-date and highly aggregated (e.g. national or EU-27 level).

The relevance of SMEs, which do not fall under the IPPC-regime, also increases when the emissions from big industrial sources are strongly reduced. Regarding SMEs' emission of hazardous substances, there are large gaps in data base and regulation. SMEs often discharge to public sewer systems respectively to MWWTP, which are not designed to eliminate hazardous substances. It is usually more cost-effective to implement additional EoP measures in the SME compared to a MWWTP. Therefore an appropriate wastewater (pre) treatment (according to BAT or even beyond) needs to be implemented in all Baltic Sea countries. Examples are targeting Hg emissions from dental clinics or Cd emissions from galvanic industries.

In addition to closing these regulation gaps, additional action by local, regional and national authorities is needed to improve the efficiency of implementation of existing regulations or even go beyond. Environmental permission is a valuable instrument to control and monitor emissions from industrial sources. Monitoring is also a necessary prerequisite to eliminate the emission of hazardous substances from industrial sources via non regulated pathways. These can be accidental mismanagement, such as uncontrolled dust emission or uncollected leachate from industrial waste sites, or even criminal mismanagement.

On the individual facility level, emission reduction can be achieved by substitution or by EoP measures. Substitution is the preferable measure. It eliminates both on-site and off-site emissions via products contributing to urban stock to prevent discharges of hazardous substances to the municipal wastewater treatment system. Substitution of hazardous substances typically follows the Pareto principle, with "early" substitutions being considerably more cost effective than "later" substitutions in more specialized applications. It is recommended to support the use of less harmful substituting substances and techniques by promoting also voluntary agreements with industries for substitution of the use where it is still allowed and while awaiting further regulatory processes.

During a time lag due to development time for substitutes, additional EoP measures can also reduce emission of substances in the mean time. Therefore, substitution and EoP measures are measures that complement each other.

Following the polluter pays principle, industry sources should be targeted as a priority. Industries with high emissions should, as a part of the permit procedure, be requested to improve wastewater treatment. This can be fostered by voluntary agreements and economic incentives.

With information from monitoring, accurate and up-to-date emission inventories of industrial sources, emission factors and corresponding loads to the Baltic Sea can be built on smaller geographical scales. The picture needs to be completed with an inventory of urban sources (e.g. landfills, MWWTP). With a detailed and up-to-date inventory of hazardous substances in a region, it is possible to find the most cost-effective measures and to build a strategy for a region that suits its source pattern (as was demonstrated in COHIBA case studies of Copenhagen and Stockholm). The COHIBA guidance documents and other sources of information can help to build the necessary knowledge base for local, regional and national authorities. Exchange of data and experiences from different regions is very important.

7.5.3 Strategies for urban areas

Targeting urban sources may further contribute to a reduction of emission, especially if emissions from large industrial point sources are already controlled by regulation and effective reduction measures have been implemented.

When targeting urban sources, a local or regional perspective is important, taking into account local boundary conditions of the settlement and its hinterlands. This includes the technical state of urban infrastructure systems (sewers, MWWTPs, landfills), pattern of indirect dischargers to municipal sewer system (SMEs), pollutant load from urban surfaces (industrial parks, roofs, streets etc.), as well as consumption and disposal patterns of products containing hazardous substances.

Firstly, the technical status of urban infrastructure systems has to be assessed, including the degree of implementation of UWWTD. It is recommended to focus on the implementation of the UWWTD in the BSR and to begin assessing the situation with respect to the emissions of hazardous substances from non-regulated pathways at the same time.

The most important parts of urban infrastructure systems are MWWTPs. They receive municipal wastewater from private households, as well as from small and medium sized enterprises and from other indirect dischargers. In addition, MWWTPs may receive urban run-off (in case of combined sewer systems) and landfill leachate. Therefore, the MWWTPs influent can contain a multitude of hazardous substances like the 11 hazardous substances in focus of BSAP, pharmaceutical substances and endocrine disruptors. The existing process of wastewater treatment is not sufficient for the treatment of such persistent chemicals. Hazardous substances are only partially degraded, and the remains are partitioned to air, effluent and sludge.

To eliminate hazardous substances from effluents of large MWWTPs, advanced technologies such as ozonisation or activated carbon treatment are available. The choice should be assessed for individual MWWTPs, because it depends strongly on the kind and load of pollutants in wastewater. If one particular hazardous substance shows elevated levels due to an indirect discharger, EoP measures at the source should be implemented, which it usually more cost effective. This also follows the polluter pays principle. Advanced wastewater treatment has a large cross substance effect, as it targets several of the 11 hazardous substances simultaneously, as well as other substances of concern. In addition to the cross substance effects, due to the economy of scale bigger scaled MWWTPs show more favourable cost-effectiveness than the small ones. More than half of the total wastewater discharges to the Baltic Sea comes from MWWTPs which represent more than 100,000 person equivalents. Therefore it is recommended to start the assessment and a possible implementation of advanced wastewater treatment on this plant size.

Local authorities and water administrations should introduce programmes to restrict the emissions of hazardous substances to the municipal wastewater systems. Since urban run-off is a highly relevant source for some substances, it is recommended that an overview of the urban run-off emissions is elaborated and sufficient control and treatment implemented on local or regional level.

For highly contaminated sewage sludge it is recommended for it not to be applied to agricaltural and landscaping applications. The most effective measure to reduce the content of hazardous substances is to incinerate the sludge. A side effect would be to generate substantial revenue from energy recovery.

For landfill leachates appropriate wastewater pre-treatment needs to be implemented. Further clean-up work should be carried out to rehabilitate old landfills. The costs of measures for urban infrastructures have to be paid by the community. Problem awareness is an important prerequisite for acceptance of these measures. They should be implemented as part of an integrated strategy, which also includes measures at industrial sources and raising awareness.

7.5.4 Strategies for raising awareness

Public awareness of hazardous substances is often rather low, due to the complexity of the issue. At the same time, awareness campaigns focusing on relevant stakeholders (users, SMEs, trade associations, etc.), e.g. on buying imported products, proper use of products or possible product substitutions, can limit emissions in urban areas and must be always be part of a “Cleaner City Campaign”.

Successful methods of increasing public awareness can include the promotion of new legis-lation, eco labels like the “blue angel” or the “white swan”, supervision of implementation of existing legislation and providing information to specific groups of consumers and retailers. These methods can be enforced by media attention, economic subsidies and in the generation of development areas (Wickman 2011). A positive example for successful awareness campaigns is the information in and to shops selling artist material regarding cadmium contained in artist paints, how to avoid cadmium containing paints and how to handle products if necessary (Wickman 2011). According to Wickman amounts of cadmium sold in artist paints decrease as well as the resulting cadmium concentrations in sewage sludge. Another example is a Swedish campaign for the reduction of mercury from dental clinics (reduction of mercury due to economic subsidies for decentralized mercury removal devices) (Wickman 2011). Similar campaigns can be implemented in other states or cities in the BSR and to the fields of PFOS and PFOA (teflon pans, impregnated jackets, mist suppressant in metal plating) or PCDD/F (promotion of good practices in maintenance of burners and boilers, discouraging illegal conduct e.g. in collecting and processing of metal scraps, agricultural field burning). Other awareness campaigns have been arranged to promote environmentally friendly small-scale combustion to avoid dioxin emissions and boat-hull washing sites have been established in small harbours/marinas to ensure proper handling and disposal of contaminated wash-water.

Awareness campaigns are often considered to be merely addressing the public as consumers. However, there are several examples where dialogue and information directed towards other stakeholders are effective.

Costs of single and simple actions (leaflets, brochures, posters, internet information) undertaken by local municipalities, regional NGOs and other institutions can be relatively low. Costs for similar country-wide campaigns are assumed to be medium.

Local continuous activities focusing on special target groups, such as young people or women, are especially promising. Sectoral (agriculture, recycling) campaigns are also important. Experiences show that the potential effectiveness of awareness campaigns is rather low in the short term. However, voluntary economic instruments (voluntary agreements, eco labels etc.) do not seem to be working in Russia, mainly because of the general public awareness level and lack of demand for cleaner or safer products. Nevertheless, as changing the attitudes of people takes long time, effects can normally be expected in the long term.

7.6 Conclusions on cost-efficient measures

There is no "one size fits all" strategy. Of course, as a basis it is necessary for the assessment of measures that the "core measures" like the urban wastewater directive or the IPPC directive are implemented. On top of these measures and depending on local boundary conditions, an adapted set of additional measure combinations must be found. This is an iterative process starting with measures promising a big reduction at reasonable costs. The progress made and the selection of measures should be reviewed regularly. Such a boundary condition is for example the source pattern (which industries are present, how large are the emissions, how important are urban sources compared to other sources in the area etc).

Following the polluter pays principle, industry sources should be targeted first. Action on EU and/or HELCOM level is needed to close gaps in regulations. On the one hand this refers to not yet regulated substances and on the other hand to gaps in existing regulations (IPPC thresholds, BREF update etc.). Simultaneously, action on a local/regional level is needed in order to advance the degree of implementation of existing regulations or even go beyond.

Issuing environmental permits is a valuable instrument to control and monitor emissions from industrial sides. The emission monitoring data can be supplemented by estimations from urban sources in order to compile an inventory of emissions of the hazardous substances into the aquatic environment of the region. With a detailed and up-to-date inventory of hazardous substances in the region it is possible to find the most cost-effective measures from the substance-specific guidance documents for the particular substance of concern and to build an adapted strategy for the region.

As MWWTP normally is a large source for hazardous substances, advanced wastewater treatment could be an appropriate measure to reduce emission. Such measures could become cost-effective for most of the evaluated substances taken the cross substance effect into account. But it has to be considered who pays for the measure. It does not necessarily follow the polluter pays principle, but normally costs have to be paid by citizens. The original polluter is not involved in paying the costs. Therefore in addition of the implementation of technical measures raising awareness is important to achieve acceptance for such kind measure.

Reducing emission is a moving target, as more new substances will be in focus especially with the REACH implementation. The introduction of advanced municipal wastewater treatment will also reduce the emissions of many other hazardous substances like for example pharmaceuticals.

Additionally, emission reduction strategies should take into account synergies and negative effects with other environmental goals set by BSAP, such as reduction of nutrients and with global environmental goals, such as reduction of greenhouse gas emissions, as well as with economic and social implications.

8. Information exchange with stakeholders and end-users

8.1 Why information exchange with stakeholders was needed?

The awareness on risks from HELCOM hazardous substances has a longer tradition in Sweden, Finland, Germany, and Denmark than in Estonia, Latvia, Lithuania and Poland. Data and information as well as regular environmental monitoring on the target substances has been taking place in those countries since years and also industry has been responsible for emission reduction and taken this responsibility. In eastern Baltic Sea region (E-BSR) BSAP substances are still considered "exotic" as the occurrence of those substances in the environment has not been proven and consequently public debate on these substances has been absent. Information flow between different stakeholders has not happened to a significant extent in the E-BSR.

8.2 Summary of activities and results:

In the beginning of the project an assessment of training needs was carried out. It was the aim to evaluate the level of current knowledge and level of interest of different target groups with relation to certain topics such as elements of chemicals control, identification of sources and estimation of quantities of hazardous substances, management tools and options for reduction of hazardous substances. For assessing the training needs in specific countries a questionnaire was elaborated and the analysis was formulated into country specific reports and was used as input to elaborate a concept for a training programme.

As a result it could be stated that interest on the topic was relatively high and knowledge on most topics was not yet wide. Practical implementation of the capacity building actions was done by means of seminars and training events for stakeholders (authorities, industries, wastewater treatment plant managers, experts). Three series of training events have been organised:

- Elements of control of substances which are hazardous to the aquatic environment (testing methodologies for selected hazardous substances, WEA approach);
- Identification of sources of hazardous substances and estimation of the quantities discharged into water bodies;
- Management tools and options for the reduction of pollution by hazardous substances (industrial permitting; treatment methods and measures for WWTPs; management measures for substance reduction/substitution at selected industry branches).

Within the project there were altogether held ca. 40 training events in E-BSR countries and ca. 1100 participants attended the events. Training was carried out taking into account a jointly elaborated concept and according to national and target group needs.

The training scope and schedule could be seen here:

http://www.cohiba-project.net/ -> Knowledge.

In conclusion participation in the trainings was unexpectedly high and feedback from the trainees was positive. Many different stakeholders expressed their high interest to project activities and results. COHIBA provided valuable and new information about potential instruments for reduction of hazardous substances to all stakeholder groups in the E-BSR. National authorities were very interested in reduction measures of hazardous substances, industry was interested in substitution possibilities, WWTP specialists were interested in different "end of pipe" measures. The main feedback from trainings was that a lot of improvements are needed in the region in order to implement and enforce different measures on hazardous substances. Competency of different stakeholders rose visibly after the training as well as the potential for improving the management of the hazardous substances.

Also two international seminars were organised within the project:

- The first international seminar was organised in Tallinn, Estonia 18-19.01.2011 "First findings from COHIBA project and implementation of the Baltic Sea Action Plan's hazardous substance segment in the Eastern Baltic Sea Region" with goal to share the experience among stakeholders of the Baltic States, Poland and Russia on HELCOM BSAP implementation and to present preliminary findings of

COHIBA project. Seminar was very successful - 55 participants attended from 8 different countries: Estonia, Latvia, Lithuania, Poland, Russia, Finland, Sweden and Denmark.

- The second international seminar was organised in Riga, Latvia 8-9.12.2011 “Seminar on experience exchange between stakeholders from eastern Baltic Sea region on options for reduction of hazardous substances. Findings from COHIBA project.” where 83 participants from five E-BSR countries: Estonia, Latvia, Lithuania, Russia, and Poland as well as COHIBA project partners from Denmark, Germany, Sweden, and Finland were present.

Russian stakeholders were involved marginally in the capacity building as they were not partners to the project. However, high interest in these capacity building measures was expressed also by Russian stakeholders in international seminars other context and the project emphasised these events in the work as much as possible.

WP6 developed and published in cooperation with other project partners an online glossary of terms on hazardous substances in English and in Estonian, Latvian, Lithuanian and Polish, and also with Russian terms included. The glossary is available here: http://hs.befgroup.net/

Also brochures for selected industry branches on hazardous substances substitution for 4 E-BSR countries in 4 languages were published. Topics are: production of building and construction materials, metal processing industry and galvanic processes and production of plastic products.

Technical guidance for industry on management of substances hazardous to water environment was published in 4 countries. It gives an overview of 10 BSAP hazardous substances (endosulfan is excluded because it was considered non-relevant for the region) - general information of substances, regulatory status, properties, use, pathways and overview on measures for reduction.

9. Conclusions

9.1 Regional conclusions: COHIBA and the HELCOM Baltic Sea Action Plan

9.1.1 Background

Main objectives of the COHIBA project matched specific actions in the HELCOM Baltic Sea Action Plan (2007):

- identification of sources of the selected hazardous substances or substance groups

o screening of the sources of selected substances in municipal and industrial wastewaters as well as landfill effluents and storm waters,

o evaluation of the practical introduction of the whole effluent assessment (WEA) approach to monitoring of complex discharges of hazardous substances into the HELCOM framework

o identification, estimation and reduction of the discharges, emissions and losses from sources within the identified potential sectors and main uses

- development of cost-efficient measures to reduce pollution by selected hazardous substances

o ban or restrictions on the use of identified relevant hazardous substances or substance groups;

o substitution of the selected hazardous substances or substance groups with less hazardous substances;

o development of technical guidance documents for environmental permitting addressing hazardous substances;

- capacity building for authorities and industries with regard to identification of hazardous substances and the possibilities for elimination of the use of substances as well as application of BEP and BAT;

- raising awareness among consumers by arranging campaigns and disseminating information about environmentally friendly products

These objectives were largely connected to the problems and prevailing situation in the Baltic Sea region described in the introduction of this report. These objectives were achieved through consistent work of experts from all participating BSR countries, in 4 main work packages of the COHIBA project. Main findings on the work packages are presented in chapters 2 – 8 and highlighted below.

The project established links to the working bodies of HELCOM to ensure adequate feedback and durability of results. The progress of the project was presented and considered by HELCOM Land-based Pollution (LAND) Group and HELCOM Monitoring and Assessment (MONAS) Group in 2010-2011, to ensure that input from all countries is taken into account, providing a holistic and integrated approach to the project. Interim results of the project were also presented at the level of HELCOM Heads of Delegation and the Helsinki Commission to keep the policy-making level of HELCOM updated about the project activities and contribution.

Activities of the project were also widely communicated to a broad range of national, regional and European stakeholders at various policy and scientific events. Communication of the project activities to the Russian audience and stakeholders took place through annual presentation at the Baltic Sea Day International Environmental Forum in St. Petersburg and dissemination of some of project material i.a. in Russian language.

COHIBA has produced beneficiary information as regards available information in various countries and parts of the BSR, and especially visualised the situation to stakeholders in the E-BSR. The following broad region-wide conclusions could be drawn as an outcome of COHIBA work packages:

9.1.2 Screening of sources

• For a number of substances within the hazardous BSAP substances, COHIBA project was one of the first occasions to estimate the emissions in Baltic Sea region and the concentrations in the eastern and south-western Baltic Sea region.
The screening gave new information on the presence of hazardous substances in the Baltic Sea region and those results could contribute to consider the prevalent opinion that there are no problems with hazardous substances in that area. It is also clear that there is a great need for additional measures for treating

wastewaters. On the basis of COHIBA results, it is possible to plan future studies, emission reduction measures and national monitoring for those selected substances.

9.1.3 Identification of sources and pathways of hazardous substances

- The work with identification of the major sources and flows of the BSAP-substances contributes to an increased awareness in the region, of the importance and complexity of source tracking.
- Use and emission patterns shows regional differences as well as differences between the substance groups - southern Baltic proper and Gulf of Finland are the regions indicated to receive the highest loads of selected BSAP substances.
- Locally increased levels of several BSAP substances were identified in and around urban areas.
- Diffuse sources (including emissions during the service life of consumer articles) are increasingly important but industrial sources remain to be relevant within the region.
- Bans and restrictions of substance use have effects on emissions. Long service life of articles does however lead to the build-up of stocks; this can cause delays in the decrease of emissions.
- Long-range atmospheric transport is an important pathway into the region for several of the substances.
- There is a need for chemical product registers and emission registers covering the BSAP-substances.

Direct coastal emissions to the Baltic Sea, such as effluents of MWWTPs appear most important sources. Thus, locally significant inland emissions do not necessarily have a large influence on the Baltic Sea.

9.1.4 Emission reduction measures

Source-oriented

- For most of the 11 HS, regulatory measures have recently been implemented. These have changed the emission pattern: in general with lower emissions of large industrial point sources, the total load to the environment is reduced. The picture becomes more complex, as non-industrial emission sources, e.g. urban stock or contaminated sediments, become relatively more important. MWWTPs were identified as important emission sources for many of the 11 HS. Due to this more diffuse distribution of sources, measures for emission reduction tend to become more complicated than those targeting large industrial point sources.
- For some HS long range transport plays an important role. To reduce the load of these substances to the Baltic Sea, besides emission reduction measures on Baltic Sea catchment scale, additional measures on a global level are required.
- Gaps in regulation were identified for PFOA, OP, HBCDD and MCCP. A relatively large potential for emission reduction at industrial sources was identified for these substances and also for PFOS and NP/NPE. For the industrial sources, the advantages and disadvantages of substitution vs. end-of-pipe technologies were compared. In some cases, an update of the BREF document was recommended. Although most of the 11 HS are regulated or banned in EU countries, some substance specific regulation gaps were identified which should to be addressed by the EU (e.g. exemptions for PFOA/PFOS, MCCPs).
- Waste and wastewater is an important pathway for several hazardous substances such as PBDEs, PFOSs, NP/NPE, SCCP/MCCP and endosulfan. Advanced municipal wastewater treatment may further contribute to reduction of emission, when emissions from large industrial point sources are already controlled by regulation. These measures target several of the 11 HS simultaneously, as well as other substances of potential concern, such as pharmaceuticals.
- Additional regulations should be implemented for those substances which reach the Baltic Sea via imported products or via long range transport (e. g. total ban of NP/NPE, global ban of endosulfan)
- To evaluate substitution of hazardous substances, the information on the environmental performance of substitutes is crucial. For example, polyfluorinated substitutes for PFOS also give cause for concern. But if a relevant substitute is available, the substitution is a cost-effective measure in several cases.

- Substance specific emission reduction measures are important but not sufficient to reach the targets laid out in the BSAP – cross-cutting measures are also important.
- When all cross substance effects are included into calculations, some of EoP-measures with cross substance effects (activated carbon or ozonisation) may show favourable cost-effectiveness, depending on local conditions. Due to the economy of scale and cross substance effects, an advanced wastewater treatment and sludge management (e.g. incineration of sludge) in larger scaled MWWTPs show more favourable cost-effectiveness than the smaller. More than half of the total wastewater discharges to the Baltic Sea comes from municipal WWTPs, which represent more than 100 000 person equivalents. Therefore it is recommended to start the assessment and a possible implementation of advanced wastewater treatment on this plant size class
- For small and medium sized industrial units discharging to public sewers, an appropriate wastewater treatment according to BAT needs to be implemented in all Baltic Sea countries (e.g. targeting mercury emissions from dental clinics or cadmium emissions from galvanic industries).

9.1.5 Public awareness and information on hazardous substances

- Results of presence and concentrations of targeted BSAP hazardous substances in wastewater, in landfill leachates and in storm waters in the eastern Baltic Sea region was efficiently informed and presented to stakeholders and also highlighted how project results showed substance groups that were found to be of a higher concern than the rest, e.g. organotin compounds in harbour areas and phenolic substances in wastewater effluents.
- COHIBA provided valuable and new information about potential instruments for reduction of hazardous substances to stakeholders in the E-BSR – but the project also showed that a lot of improvements are needed in the region to really implement and enforce different measures.
- Participation in the information exchange was unexpectedly high and feedback from the participants was very positive; many different stakeholders expressed their high interest to project activities and results.
- Competence of different stakeholders was obviously enhanced, stakeholders became more aware about the emissions from the target substances to the Baltic Sea, and on the total their knowledge about the 11 BSAP hazardous substance groups increased – as well as the potential for improving the management of the hazardous substances.
- High interest in these capacity building measures was expressed also by Russian stakeholders and the E-BSR partners arranged seminars targeted also to Russian stakeholders, as well as other project events provided information exchange with Russian water managers or experts. Good contacts and new networks among stakeholders were established in the E-BSR region and will lead to strengthened capacities in issues of HS.

9.2 Conclusions on methods and tools

The project served as an important testing ground for various new and novel methods and techniques at region-wide scale. The following conclusions could be drawn on this basis.

- There is a need for measured data both with regard to environmental concentrations and emissions. These data gaps introduce high uncertainties in the assessments.
- Thorough planning for sampling and organising the practical arrangements along with a complete documentation are the basis for good-quality samples and results concerning both chemical and biological analyses. Considering the final interpretation of the results the proper documentation of the sampling methods such as grab vs. composite sample, sample containers, pre-treatment of samples e.g. filtrations, preservation, and storage (time, conditions, temperature etc.) are essential information. The representativeness of the samples is a key to further appropriate actions.
- High quality analytical methods are valuable and important cornerstone in risk assessment and risk reduction of hazardous substances. Analytical performance, well established quality control procedures and professionally skilled personnel are highly valued in the laboratory work. Applied methods shall be properly validated and performance should be known and documented (e.g. sensitivity, selectivity and accuracy). Methods sensitivities should meet the legislative and permission requirements. Regarding both chemical and

toxicity test methods; methods development and testing of applicability to effluent control should be continued.

- WEA approach presented a practical and flexible tool for assessing the effluent quality in an effective way. It enables the assessment of potential risks and effects for both identified and unidentified substances. By using WEA in combination with chemical analyses it is possible to identify sources of hazardous substances and to plan preventive actions. This procedure should be an effective tool to increase the level of protection of the Baltic Sea and enhance its ecological status.
- By conducting substance flow analyses (SFA) in most Baltic Sea countries participating in the project a unique compilation of information of emissions for substances of the BSAP substances was created and this provides a useful basis for further investigations for the countries.

9.3 New proposals on the selection of BSAP substances

Risk is generally the combination of intrinsic properties of substances and their concentration levels in the environment. While information on the environmental behaviour of substances is regularly gathered from research and monitoring as well as from implementation of chemical legislation, data on the concentrations in the environment of new or "emerging" substances are often scattered and rare. Scientific initiatives like the NORMAN-Network (www.norman-network.net) try to address the problem from the scientific angle (e.g. monitoring methodologies, reference materials, exchange of information). In order to collect the necessary data for bigger regions, however, coordinated monitoring efforts are required. To that extent, the EU Commission has put forward in their recent proposal for an amendment of the EQS Directive the idea of a so called "watch list", i.e. substances with harmful intrinsic properties but insufficient information on environmental concentrations to include them into the list of priority or priority hazardous substances. HELCOM should consider the idea of participating in that effort with special focus on the situation in the Baltic region. This would clearly help in amending the list of BSAP substances with those substances which pose a high risk to the marine environment.

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10.2 Additional material

(Links are visible in electronic format)

- COHIBA Final Conference Proceedings, COHIBA Project Consortium, 2012
- Innovative approaches to chemicals control of hazardous substances; Final report of COHIBA Work Package 3, COHIBA Project Consortium, 2011
- Major sources and flows of the Baltic Sea Action Plan hazardous substances; Final report of COHIBA Work Package 4, COHIBA Project Consortium, 2012
- Cost effective management options to reduce discharges, emissions and losses of hazardous substances; Recommendations report of COHIBA Work Package 5, COHIBA Project Consortium, 2012

Work package 3 - Identification and control

- Whole Effluent Assessment. Proposed recommendations for the use of toxicity limits, Finnish Environment Institute, 2010
- Daphnia magna acute toxicity test, algae growth inhibition test and luminescent bacterium test; Ring-test report of the COHIBA project WP3, Finnish Environment Institute, 2010

The following ring-test reports of chemicals are now available:

- Cadmium, Ringtest report, Estonian Environmental Research Centre, 2011
- PBDEs, HBCDDs, PFCs and APs, Ringtest report, Finnish Environment Institute, 2011
- Ring-test results for SCCPs and endosulfans, Institute for Ecology of Industrial Areas, Poland, 2011
- Mercury, Ringtest report, IVL Swedish Environmental Institute, 2010
- Organotins, Ringtest report, IVL Swedish Environmental Institute, 2010

Final Partner's reports of WP3 "Innovative approaches to chemical controls of hazardous substances" are available here:

- Partner Report Denmark
- Partner Report Estonia
- Partner Report Finland
- Partner Report Germany
- Partner Report Poland
- Partner Report Lithuania
- Partner Report Latvia
- Partner Report Sweden

The final outcomes of Work package 3 based on the above reports resulted in the following final publications:

- Investment plan report
- Harmonization of chemical analysis
- WP3 Final report

Work package 4 - Sources and Flows

- WP4 Final report
- WP4 background paper

Partners' reports summarise the results of the Substance Flow Analyses.

- Draft WP4 Partner Report Poland
- Final WP4 Partner Report Estonia

- Final WP4 Partner Report Sweden
- Draft WP4 Partner Report Latvia
- Draft WP4 Partner Report Denmark
- Final WP4 Partner Report Finland
- Draft WP4 Partner Report Germany

Case-studies reports are presented below:

- WP4 Stockholm report
- WP4 St.Petersburg and Leningrad Oblast report
- WP4 Case study Kaliningrad

The results of modelling are presented in the following report

- COHIBA Model report

Work package 5 - Management measures

The Guidance documents for specific substances are available below:

- Endosulfan
- Hexabromocyclododecane
- PBDEs
- Dioxins, furans, dioxin-like PCBs
- PFOA-PFOS
- NP-NPE
- OP-OPE
- SCCP-MCCP
- TBT-TPhT
- Cadmium
- Mercury

A report on management measures "Copenhagen case study on end-of-pipe measures for urban run-off, CSO and UWWTPs" was delivered by Denmark.

Inventory of measures was compiled using information from a questionnaire, literature studies and workshops.

- Preliminary Inventory of measures to reduce discharges and emissions of hazardous substances (excel)

Reports on evaluation of available measures

- COHIBA report on evaluation of measures.pdf
- Background Paper: Sources, measures and evaluation of measures

The report on final recommendations of the Work Package 5

- Cost Effective Management Options to Reduce Discharges, Emissions and Losses of Hazardous Substances

Work package 6 - Knowledge transfer

- Stakeholder mapping in the Eastern Baltic Sea region countries
- Electronic glossary of terms related to hazardous substance management in the European Union and Russia

List of partners

Project partners - Control of hazardous substances in the Baltic Sea region (COHIBA)

FINLAND

Finnish Environment Institute

- Control of hazardous substances in the Baltic Sea region

DENMARK

The Copenhagen Municipality

- "Cohiba-projektet" - Ren Østersø

Copenhagen Waste Water Treatment Plants

- Internationalt projekt om reduktion af farlige stoffer i Østersøen

Copenhagen Energy

- COHIBA

Techical University of Denmark

- COHIBA

ESTONIA

Baltic Environmental Forum Estonia

- Läänemere piirkonna programmi projekt "COHIBA"

Estonian Marine Institute, University of Tartu

Estonian Environmental Research Centre

Tallinn University of Technology

GERMANY

Federal Environment Agency of Germany

- Das Projekt COHIBA

supported by Fraunhofer Institute for Systems and Innovation Research ISI

Mecklenburg-Vorpommern Ministry for Agriculture, Environment and Consumer Protection

- Das INTERREG-Projekt COHIBA (Control of hazardous substances in the Baltic Sea region) in M-V

LATVIA

Baltic Environmental Forum Latvia

- Bīstamo vielu kontrole Baltijas jūras reģionā

Latvian Institute of Aquatic Ecology

LITHUANIA

Baltic Environmental Forum Lithuania

- Pavojingų medžiagų valdymas Baltijos jūroje

Environmental Protection Agency, Ministry of Environment of Lithuania

- Pavojingų medžiagų valdymas Baltijos jūroje
- Center of Marine Research
- Nature Research Centre

POLAND

Institute for Ecology of Industrial Areas

SWEDEN

IVL Swedish Environmental Research Institute

Swedish Chemicals Agency

City of Stockholm

- Miljögifter i Östersjön

HELSINKI COMMISSION

Baltic Marine Environment Protection Commission - HELCOM

- Control of hazardous substances in the Baltic Sea region - COHIBA

The COHIBA project (Control of hazardous substances in the Baltic Sea region) was part-financed by the EU Baltic Sea Region Programme 2007-2013 and running since early 2009 till 2012. The project was coordinated by the Finnish Environment Institute (SYKE) and the project consortium consisted of 22 partners from all eight EU countries around the Baltic Sea.

The specific aims of the project were:

- **to identify the most important sources and release patterns** of the 11 selected hazardous substances and substance groups, identified as being of specific concern to the Baltic Sea in the Baltic Sea Action Plan (BSAP);
- **to develop innovative toxicity based cost-effective monitoring practices** based on the Whole Effluent Assessment (WEA) approach;
- **to develop eleven substance-specific guidance documents and recommendations for cost effective management options** to reduce the discharges, emissions and losses of the selected hazardous substances;
- **to provide input to the development of national implementation programmes of the BSAP**, serving also the requirements under the EU Water Framework Directive and the EU Marine Strategy Framework Directive;
- **to provide input to the HELCOM integrated assessments on hazardous substances** as a basis for decision making.

More information:

http://www.cohiba-project.net/, www.environment.fi/syke/cohiba

COHIBA

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Baltic Sea Region
Programme 2007–2013