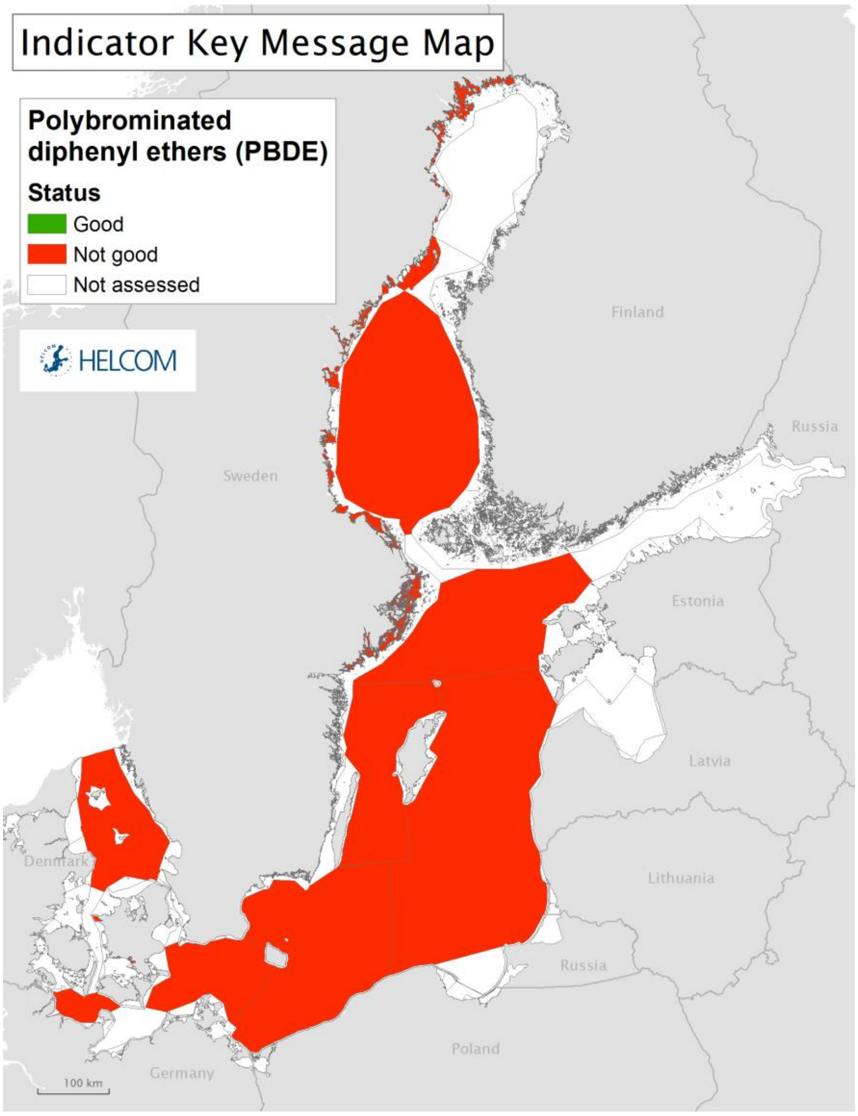
HELCOM core indicator report
July 2017

Polybrominated diphenyl ethers (PBDE)

Key Message

The available data and evaluations show that the concentration of polybrominated diphenyl ethers (PBDEs) is high in biota and sediment trough out the Baltic Sea. The status of the sum of BDE congeners (28, 47, 99, 100, 153 and 154) in fish, during the period up to 2015, shows that the threshold is exceeded at every monitoring site in the Baltic Sea resulting in all monitoring sites being classified as 'not good status' (Figure 1). This core indicator threshold value is the EU Environmental Quality Standard (EQS) 0.0085 µg kg^{-1} wet weight (ww). The threshold is considered to be very low.



Key message figure 1: Status assessment results based on the evaluation of the indicator Polybrominated diphenyl ethers (PBDE). The assessment is carried out using Scale 4 HELCOM assessment units (defined in the [HELCOM Monitoring and Assessment Strategy Annex 4]).

Concentrations of single BDE congeners are declining, but the availability of long time series is limited in the Baltic Sea and concentrated in the western parts of the region.

The confidence of the indicator evaluation is **high**.

The indicator is applicable in the waters of all countries bordering the Baltic Sea.

Relevance of the core indicator

Polybrominated diphenyl ethers (PBDEs) are toxic and persistent substances that bioaccumulate in the marine foodweb. Increasing concentrations of PBDEs were detected in the environment in past decades as their use as commercial flame retardants increased. The use of most PBDE products have been banned in Europe during the last 10 years, and as a result decreasing concentrations are detected for some of the BDE congeners.

Policy relevance of the core indicator

	BSAP Segment and Objectives	MSFD Descriptors and Criteria
Primary link	• Concentrations of hazardous substances close to natural levels	D8 Contaminants - D8C1 Within coastal and territorial waters and beyond territorial waters the concentrations of contaminants do not exceed the threshold value
Secondary link	• Fish safe to eat	D9 Contaminants in fish and other seafood - D9C1 The level of contaminants in edible tissues (muscle, liver, roe, flesh or other soft parts, as appropriate) of seafood (including fish, crustaceans, molluscs, echinoderms, seaweed and other marine plants) caught or harvested in the wild (excluding fin-fish from mariculture) does not exceed the threshold value
Other relevant legislation: The Water Framework Directive and EC regulation No 850/2004 (and its following amendments) and the Stockholm Convention on Persistent Organic Pollutants.		

Cite this indicator

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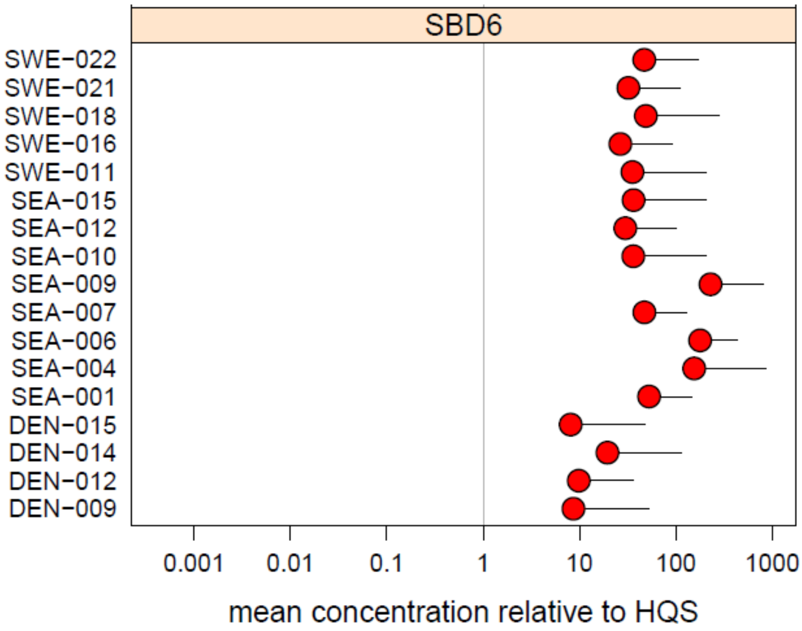
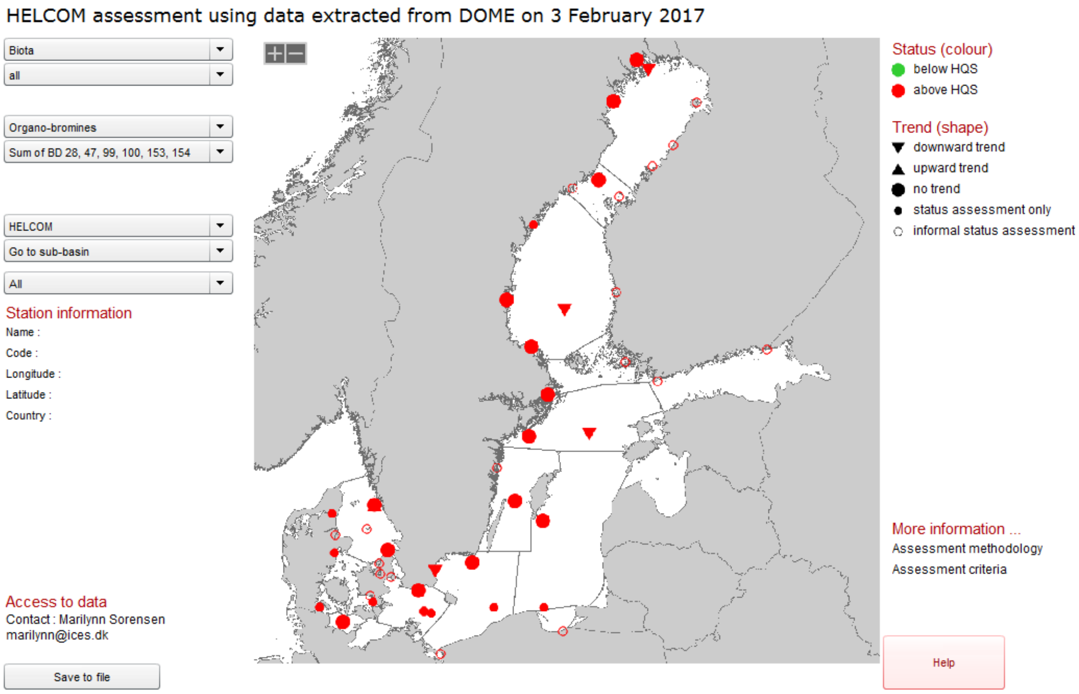
Results and Confidence

The overall status of concentrations of polybrominated diphenyl ethers (PBDEs) shows not good status (Results figure 1). Data is available and shows that the concentration of PBDEs is high in biota trough out the Baltic Sea.



Results figure 1. Aggregated mean concentrations per HELCOM assessment unit. The threshold value is exceeded in all areas.



Results figure 2. PBDE measurements per station in the Baltic Sea.

The threshold value of 0.0085 µg/kg ww defined by the Environmental Quality Standard (EQS) is exceeded everywhere, but there are regional/local differences (Results table 1).

It is important to be aware that the majority of the monitored stations included in the indicator are considered as reference stations regarded as unaffected by local pollution. There are most likely local areas within the Baltic Sea where the pollution load of PBDE is higher than presented in the evaluation outcome of this indicator.

Mean values for the monitoring stations ranges from 0.03 to 0.82 ng/g ww in fish muscle (Results table 1). However, the PBDE levels in a single, widespread species, e.g. herring seems to vary less throughout the Baltic Sea than for other substances such as for example PCBs. Generally, PBDEs show higher concentrations in herring muscle in the Baltic compared to the Swedish west coast in the North Sea (Bignert et al. 2016).

The monitoring has gaps in Estonian, Latvian and Russian waters. In other areas, e.g. Finland, Lithuania and Poland, the monitoring period is too short to evaluate the concentration levels with high confidence.

Finland and Poland experienced data reporting issues, and substantial improvements are expected when the report is updated to include 2016 data.

Results table 1. The estimated concentration in the most recent year of monitoring of four BDE congeners (BDE4) (47, 99, 100 and 153) in fish from different areas of the Baltic Sea (presented from North to South). Stations with different basis of calculation are separated; a) wet weight and b) lipid weight.

a)

Station name	SUM BDE4 (µg/kg ww)	species
Tornion edusta	0.30	*P. fluviatilis*
Skomakarfjärden	0.19	*P. fluviatilis*
Kemin edusta Ajos Poh	0.61	*P. fluviatilis*
Simonniemen edusta 1	0.49	*P. fluviatilis*
Hailuoto	0.14	*P. fluviatilis*
Kalajokisuun edusta	0.24	*P. fluviatilis*
Bothnian Bay	0.77	*C. harengus*
Kalajoki 1	0.13	*C. harengus*
Kokkola Trullevin edusta	0.19	*P. fluviatilis*
Mikkelinsaaret	0.10	*P. fluviatilis*
Bothnian Sea 2	0.12	*C. harengus*
Bothnian Sea 1	0.54	*C. harengus*
Pori 1	0.16	*C. harengus*
Pihlavanlahti	0.21	*P. fluviatilis*
Southwest Vekara	0.16	*C. harengus*
Virolahti Suuri Lakasaari	0.14	*P. fluviatilis*
Gulf of Finland	0.39	*C. harengus*
Kotka	0.09	*C. harengus*
Airisto Seili	0.15	*P. fluviatilis*
Seurasaarenselkä	0.47	*P. fluviatilis*
Tvärminne	0.10	*P. fluviatilis*
Northern Baltic Proper	0.19	*C. harengus*

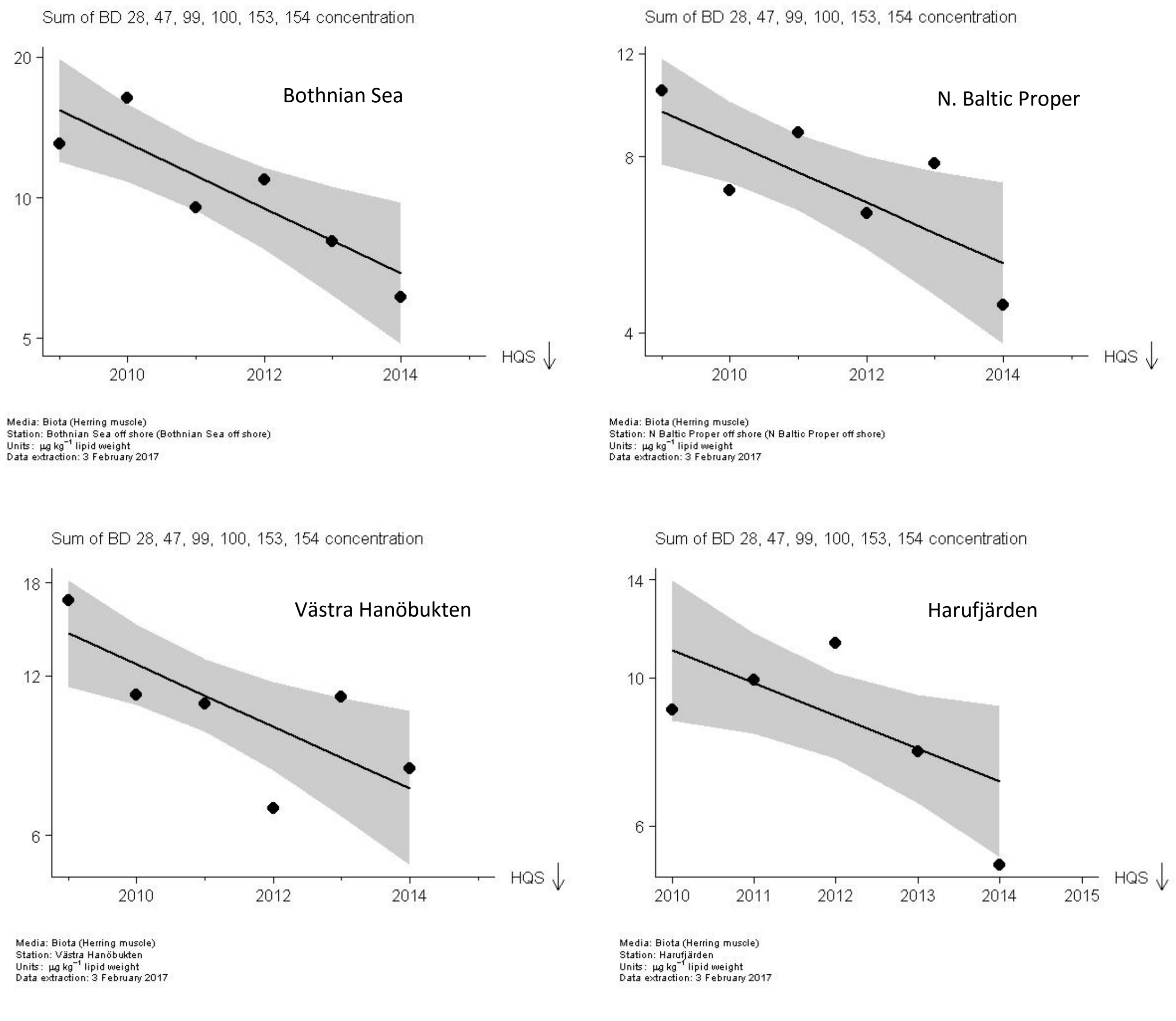
LIM-3716-1	0.06	*Z. viviparus*
ARH230066	0.12	*Z. viviparus*
Anholt	0.13	*Z. viviparus*
ARH170009	0.17	*Z. viviparus*
MCR230010	0.07	*P. flesus*
FRB 65	0.09	*Z. viviparus*
473	0.03	*P. flesus*
DMU 2R	0.07	*Z. viviparus*
DMU KB 2	0.12	*Z. viviparus*
DMU KB 1	0.23	*Z. viviparus*
475	0.05	*G. morhua*
STOS39	0.03	*P. flesus*
STO0102400	0.08	*Z. viviparus*
STO0101400	0.06	*Z. viviparus*
STO0901017	0.08	*P. flesus*
SJY FFML5014	0.06	*Z. viviparus*
SJY FFML5012	0.10	*Z. viviparus*
LKOL	0.76	*C. harengus*
LWLA	0.79	*C. harengus*
FOE-B10 c	0.37	*C. harengus*
FOE-B10 b	0.36	*C. harengus*
FOE-BMP	0.14	*C. harengus*
FOE-B10 a	0.82	*C. harengus*
ZPOM	0.26	*P. flesus*
ZGDA	0.18	*P. flesus*
LZWI	0.03	*P. fluviatilis*
LZSZ	0.07	*P. fluviatilis*
Finland 1	0.04	*P. fluviatilis*
Poland 1	0.06	*P. fluviatilis*

b)

Station name	**SUM BDE4 (µg/kg lw.)**	**species**
Rånefjärden	7.74	*C. harengus*
Harufjärden	8.94	*C. harengus*
Kinnbäcksfjärden	10.65	*C. harengus*
Holmöarna	6.67	*C. harengus*
Örefjärden	4.49	*P. fluviatilis*
Gaviksfjärden	7.25	*C. harengus*
Långvindsfjärden	6.62	*C. harengus*
Bothnian Sea off shore	8.38	*C. harengus*
Ängskärsklubb	5.54	*C. harengus*
Lagnö	7.96	*C. harengus*
N Baltic Proper off shore	6.91	*C. harengus*
Landsort	5.93	*C. harengus*
Kvädöfjärden	6.28	*Z. viviparus*

Byxelkrok	7.03	*C. harengus*
E/W Fladen	3.76	*C. harengus*
Kullen	3.00	*C. harengus*
Utlängan	7.96	*C. harengus*
Västra Hanöbukten	9.17	*C. harengus*
Abbekås	7.34	*C. harengus*

Concentrations of BDEs in the marine environment are declining (Bignert et al. 2016). Concentrations of PBDE show decreasing trend in herring muscle in 4 monitoring stations in the Baltic Sea (Results figure 3).



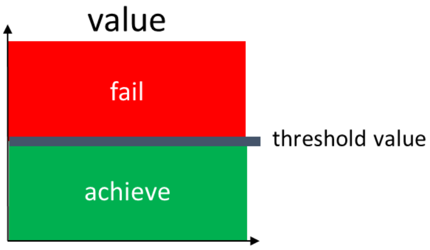
Results figure 3. Temporal trend of BDE concentration (ng/g wet weight) in herring muscle from the Bothnian Sea, the north Baltic Proper, Västra Hanöbukten and Harufjärden (grey colour- confidence level 95% range (see Assessment protocol)) [source: http://dome.ices.dk/HELCOMHZ2016/main.html].

Confidence of the indicator status evaluation

The confidence of the status evaluation is considered **high**. Data is available from several regions covering a time period of several years.

Good Environmental Status

The threshold value applied for PBDEs is 0.0085 µg/kg fish wet weight (ww). The threshold value is an Environmental Quality Standard (EQS) for biota, where human health is considered the most critical for PBDEs and therefore is defined for edible parts of fish. The value is a sum of PBDE congeners 28, 47, 99, 100, 153 and 154, mainly representing penta- and octa- but not decaBDE.



Good environmental status figure 1. Schematic representation of the threshold value which indicates good status if the concentration is below the threshold value. The threshold value is $_{\text{EQS biota human health}}$ 0.0085 µg/kg fish wet weight (ww).

Good Environmental Status (GES), in accordance with the Marine Strategy Framework Directive 2008/56/EC (MSFD), is defined as “concentrations of contaminants at levels not giving rise to pollution effects” (OJEC No. L164 25.6.2008, 2008). PBDEs are included on the priority list under the Water Framework Directive (2000/60/EC) under which the Quality Standards (QSs) have been developed. All QS are based on ecotoxicological studies and derived to protect freshwater and marine ecosystems from potential adverse effects of chemicals, as well as adverse effects on human health via drinking water and food from aquatic environments. QSs are derived for different protection goals. The most stringent of the QSs for the different protection goals is the base for the EQS (2013/39/EU).

In the case of the PBDEs, the EQS is based on the value derived for human health. The EQS is used as a threshold value although it is debated as being very low, and has not been endorsed by the European Food Safety Authority (EFSA). Thus it is not clear if the value is in accordance with the food safety risk assessments.

The EC Guidance Document No. 32 on biota monitoring (the implementation of EQS_{biota}) under the Water Framework Directive (EC 2014) was derived for harmonization purposes. This guidance document recommends that for lipid soluble, biomagnifying compounds such as PBDEs the fish assessed for EQS compliance should be at a trophic level of 4.5 for marine environments with a whole body lipid content of 5%. For practical reasons, the guidance opens up for adjustments of results from ongoing monitoring to meet this standard by the use of trophic magnification factors and trophic level. The EU directive on Environmental Quality Standards (2008/105/EC), Article 3, states that also long-term temporal trends should be assessed for substances that accumulate in sediment and/or biota.

In cases where it is not possible to evaluate the environmental status using biota-monitoring, a secondary threshold value based on concentration in sediment can be used as a complement. The threshold value for sediment is 4.5 µg kg^{-1} dry weight (dw). This value has been suggested by the working group on priority substances for the protection of the benthic community.

Assessment Protocol

Assessment methodology for contaminants in biota, sediment and water

PBDEs are considered a relevant substance group to evaluate throughout the entire Baltic Sea area. In addition to the atmospheric dispersion, PBDEs are introduced to the marine environment from waste and waste water treatment plants and storm-water run-off. Concentrations may be higher in the coastal areas compared to the off-shore areas, and therefore the indicator is evaluated on HELCOM assessment scale 4.

The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

Relevance of the Indicator

Hazardous substances assessment

The status of hazardous substances is assessed using several core indicators. Each indicator focuses on one important aspect of the complex issue. In addition to providing an indicator-based evaluation of the concentration of polybrominated diphenyl ethers (PBDE), this indicator will also contribute to the overall hazardous substances assessment along with the other hazardous substances core indicators.

Policy relevance

The polybrominated diphenyl ethers (PBDEs) have mainly been used as flame retardants in plastic materials and polyurethane foams. PBDEs are diphenyl ethers with different degrees of bromination varying from 2 to 10. PentaBDEs refer to the congeners 82–127, 47 and 99 being the most abundant, octaBDEs refer to the congeners 194–205 and decaBDEs mainly refers to the congener 209.

PBDEs are on the HELCOM BSAP priority list and in the Stockholm Convention Annex A (Elimination). The use of substance groups pentaBDE and octaBDE is banned in the EU since 2004 (Commission regulation EC 552/2009). PentaBDE and octaBDE are not allowed to be placed on the market as substances, in mixtures or in articles in higher concentration than 0.1 % by weight. The substance group decaBDE that is restricted but not completely banned, is currently found in biota and is able to degrade into lower brominated congeners. The European Food Safety Authority (EFSA) has encouraged countries to also monitor decaBDE.

The substance groups pentaBDE and octaBDE have been prioritised through two consecutive prioritisation procedures under the WFD: pentaBDE were prioritised following COMMPS (Combined Monitoring-based and Modelling-based Priority Setting scheme) procedure in 2001, while octaBDE was prioritised in the context of the second European Commission proposal for a new list of priority substances, for the reason that they are PBT (Persistent, Bioaccumulative and Toxic) and vPvB (very Persistent and very Bioaccumulative) substances.

The use of PBDEs in electrical and electronic products (E&Es) was restricted even earlier than 2004 by the Directive 2002/95/EC (RoHS). From June 30, 2008, this directive covers also decaBDE. This implies that the only permitted use of PBDEs in Europe is now the application of decaBDE in products other than E&Es. As a result of this new regulation, the majority of the previous use of decaBDE in the EU is now prohibited (corresponding to ca 80 percent of the total EU use in 2001). It is, however, still possible for industries to apply for exemptions for certain applications under the procedure laid out in article 5 of the RoHS Directive.

PentaBDE is now included in Annex A (Elimination) in the Stockholm Convention and should no longer be on the EU market as well as hexaBDE and heptaBDE contained in octaBDE.

Role of PBDEs in the ecosystem

General properties

PBDEs with smaller molecules are more toxic and bioaccumulative than larger ones. The biotic and abiotic debromination of highly brominated BDEs, such as decaBDE, to these smaller forms is a possibility and justifies that monitoring is based on a broad set of congeners. All PBDEs are hydrophobic or very hydrophobic substances, that are very likely to adsorb on particulate matter and not likely to volatilize from the water phase. The higher the bromination degree, the lower the water solubility. Therefore decaBDE is found only in low concentrations in fish, in contrast to lower-brominated BDEs which are more commonly found in marine organisms. PBDEs have the potential to photodegrade in the environment.

The occurrence of PBDEs is widespread in the Baltic marine environment. It is probable that current legislative measures (penta- and octaBDE banned in the EU since 2004) have already decreased penta- and octaBDE levels in the Baltic Sea.

According to EU-RAR (2000), concentrations increased with the age of the fish and were higher in seals than in fish in the Baltic Sea, indicating bioaccumulation and biomagnification.

DecaBDE (BDE 209) is the dominant congener from sources (e.g. WWTPs) and in the Baltic Sea sediments; it can also be found in Baltic Sea fish, although tetraBDE is the most dominant congener in biota. Levels of decaBDE may be increasing because its use is only partly restricted. However, because of the environmental problems of decaBDE and anticipating regulatory measures, the European industry has taken voluntary action to reduce releases of decaBDE. This would be expected to lead – over time – to decreasing concentrations.

Main impacts on the environment and human health

PBDEs are categorized as endocrine disrupters (Category 2) for animals and humans. This means that the substances have the potential to disrupt endocrine functions, such as hormone regulation in the organisms. PBDEs have been shown to have endocrine-disrupting effects, in particular, on estrogen and thyroid hormone levels and functioning. It has been shown to disturb development of the nervous system.

Human pressures linked to the indicator

	General	MSFD Annex III, Table 2a
Strong link		Substances, litter and energy - Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events
Weak link		

PBDEs mainly spread to the Baltic Sea via the atmosphere, rivers and waste water treatment plants (WWTPs). PBDEs are mainly discharged from landfills and waste sorting sites or emitted via atmosphere to the environment. The substances accumulate on waste sites as a result of production and use of flame-protected materials. More information on the occurrence of penta-, octa- and deca-BDE discharges is needed from the whole Baltic Sea area also including from WWTPs.

Monitoring Requirements

Monitoring methodology

HELCOM monitoring of relevance to the indicator is documented in the on-line HELCOM Monitoring Manual in the sub-programme: Contaminants in biota. Monitoring guidelines on the determination of persistent organic compounds in biota are currently documented in the HELCOM COMBINE manual. The guidelines are to be updated and included in the HELCOM monitoring manual in the future.

The concentration of PBDEs in environmental monitoring is to be determined in an appropriate biota matrix that includes muscle of herring, perch, cod and eelpout. The basis for determination of the concentration is the lipid or wet weight with lipid content (%) in fish.

Current monitoring

The monitoring activities relevant to the indicator that are currently carried out by HELCOM Contracting Parties are described in the HELCOM Monitoring Manual

Sub-programme: Contaminants in biota monitoring concepts table

Denmark, Finland, Germany, Lithuania, Poland and Sweden presently monitor PBDEs in fish. Lithuania, and Sweden monitor PBDEs in sediments. Germany prepares for monitoring in sediment. Estonia and Latvia have screening or research data. No information is available from Russia.

When time series have started to accumulate data from the new monitoring stations in Finland, Lithuania and Poland, the monitoring of temporal trends of PBDEs will be considered adequate in the Baltic Sea. The current time series stations use highly mobile sample species (herring, cod and flounder) which makes the network of time series stations geographically representative. The adequacy of the current network could be further tested through power analysis.

Description of optimal monitoring

Data and updating

Access and use

The data and resulting data products (tables, figures and maps) available on the indicator web page can be used freely given that the source is cited. The indicator should be cited as following:

HELCOM (2017) Polybrominated diphenyl ethers (PBDE). HELCOM core indicator report. Online. [Date Viewed], [Web link].

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Metadata

Result: Polybrominated diphenyl ethers (PBDE)

Data: Polybrominated diphenyl ethers (PBDE) biota data

Data are extracted from the HELCOM COMBINE database, hosted by ICES. The data is based on regular monitoring activities carried out by Contracting Parties of HELCOM.

Most data sets cover only short time series which prevent temporal analyses. With the available data, status maps can be produced adequately for most parts of the western Baltic Sea, covering data up to 2015.

Data from several existing stations and some new stations of the Baltic Sea shall be uploaded in the ICES database in 2017.

Contributors and references

Contributors

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HELCOM Expert Network on Hazardous Substances

Archive

This version of the HELCOM core indicator report was published in July 2017:

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