ANNEX 8.4 Other media (non core media)

Introduction

This annex reports briefly what is found in the documents that have been used in the Other Media chapter, and provides more detailed references to the material therein. As is mentioned in the chapter this is a summary of the information provided by a few well-established long-term monitoring programmes, it is not an extensive review of primary litterature by the authors of the chapter.

Mediterranean:

2017 Mediterranean Quality Status Report

EO9: Common indicator 17. Concentration of key harmful contaminants measured in the relevant matrix (EO9, related to biota, sediment, seawater)

Reporter: UNEP/MAP/MED POL
Geographical scale of the assessment: Regional, Mediterranean Sea
Contributing countries: Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Malta, Montenegro, Morocco, Slovenia, Spain, Tunisia, Turkey.

The status and impact of the chemical contamination in the marine environment is the result of the human activities (drivers and pressures) that take place all around the coastal and marine areas of the Mediterranean Sea and cause imbalance to ecosystems from their natural steady-state conditions. The sources of contaminants can be of natural origin (e.g. heavy metals) or synthetic man-made chemicals (e.g. pesticides). Primarily, harmful contaminants enter the marine ecosystem through different routes, such as atmospheric deposition or inputs from land-based (and sea-based) sources. For example, in the Mediterranean coasts, from small recreational marinas up to major commercial ports, which number thousands, have created a number of different pressures in terms of chemical pollution. At present, there are still old threats and new pressures, although the trends and levels of the so-called legacy pollutants (e.g. heavy metals, persistent organic pollutants and pesticides), have decreased significantly in the most impacted areas in the Mediterranean Sea after the implementation of environmental measures (e.g. leaded-fuels ban, mercury regulations, anti-fouling paints ban), as observed in the Western Mediterranean Sea (UNEP/MAP/MEDPOL, 2011a). The major MED POL contaminant group (i.e. heavy metals), were considered for this assessment, as there is a significant number of quality assured datasets available from Mediterranean countries. On the other hand, despite the implementation of the MED POL monitoring for chlorinated compounds during almost two decades, the availability of new data with sufficient spatial geographical coverage and quality assured impedes to further assess their occurrence in the Mediterranean Sea region, beyond known sources and hotspots in coastal areas. On the other hand, most of the recent datasets show non-detectable levels, mainly in biota matrices, which is in accordance with the earlier decreasing levels and trends observed in previous MAP reports (UNEP/MAP/MED POL 2011a, 2011b, 2012). However, there are still point and diffuse pollution sources releasing both priority and emerging chemical contaminants (e.g. pharmaceuticals, personal care products, flame retardants) in the Mediterranean Sea. The land-based sources (LBS) of contaminants impacting the coastal environment enter both via treated (or non-treated) wastewater discharges and represent a major input, whilst in terms of diffuse pollution sources, land based run-off and atmospheric deposition (wet/dry deposition and diffusive transport) are the two major contributors to the coastal areas. The sea-based sources themselves are also accounted (i.e. direct inputs from maritime and industrial activities, such as shipping, fishing, oil refining oil and gas exploration and exploitation) which could be permanent chronic sources of pollution in the marine environment, including the potential for acute pollution events.

Heavy metals (Cadmium, Mercury and Lead), petroleum hydrocarbons and persistent organic pollutants (POPs) -from the national coastal monitoring networks reported to the MEDPOL Database- were initially evaluated. However, petroleum hydrocarbons and POPs show a data scarcity, a lack of regional coverage and mostly non-detected concentrations, and therefore, this assessment focus on heavy metals (Hg, Pb and Cd) at a regional scale.

Persistent Organic Pollutants (POPs) and Non-halogenated compounds.

Persistent organic pollutants (POPs) include certain legacy chlorinated pesticides and industrial chemicals, such as the so called polychlorinated biphenyls (PCBs), most of which have already been prohibited at global scale under the Stockholm Convention. These chemical substances are resistant to environmental degradation processes, and therefore persistent and prone to long-range transport. In the marine environment, the bioaccumulation and biomagnification in organisms have been largely investigated, as well as their implications for human health. The scarcity of recent POPs quality assured datasets in the MED POL Database and the fact that most of these show non-detectable levels, mainly in biota matrices, is in accordance with the earlier lowering levels and trends observed in previous reports (UNEP/MAP/MED POL 2011a, 2011b, 2012) and no further updates could be performed at present

Knowledge gaps

- The improvements in the limited spatial coverage, temporal consistency and quality assurance for monitoring activities hinder to some extent the regional and sub-regional assessments, as previously observed (UNEP/MAP/MED POL, 2011a and 2011b). The availability of sufficient synchronized datasets for a state assessment should be improved. To this regard, the evaluation performed have further shown the necessity to explore the new criteria at sub-regional scale for the determination of background concentrations of those chemicals occurring naturally, such a Pb in sediments. However, there are important gaps in the selection and measure of emerging contaminants, an issue that may be addressed by monitoring programmes. There is also a need to know the level of contaminants in deep-sea environments, and the dynamic of inputs, streams and distribution of contaminants, to be able to link sources, input entrances and environmental status. Two recent reports (UNEP/MAP MED POL, 2016a and 2016b) have reviewed and proposed updated background assessment criteria (BACs) for the Mediterranean Sea. These reports were built in line with the 2011 reports (UNEP/MAP MED POL, 2011a and 2011b).
- The current spatial assessment covered different periods according the most recent data available, despite the number of datasets did not increased significantly the potential for the evaluation of temporal trends. At present, the major studies are performed in coastal populations of marine bivalves (such as Mytilus galloprovincialis), fish (such as Mullus barbatus) and sediments. Bioaccumulation on large predator fish stocks may represent a concern that still needs to be properly addressed by ad hoc monitoring activities. Sediment sieving and normalization factors also require proper standardization to improve the comparability of monitoring data in sediments.

EU - MSFD

REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL assessing Member States' monitoring programmes under the Marine Strategy Framework Directive {SWD(2017) 1 final}

The twenty Member States reported over 200 monitoring programmes, including nearly 1 000 sub-programmes.

Contaminants in waters (Descriptor 8), eutrophication (Descriptor 5) and commercial fish (Descriptor 3) are better covered (13 %, 11 % and 9 % respectively of the monitoring efforts).

Five Member States reported their monitoring programmes were in place for most categories of descriptors as of 2014. Four Member States had no monitoring programmes in place in 2014. Overall, the monitoring programmes were only partially adequate by July 2014, the date at which they should have been created and implemented in accordance with Article 5(2)(a)(iv) of the MSFD. As a consequence, Member States will have significant gaps in the data available for assessing progress towards good environmental status and environmental targets as required for the 2018 assessment. According to Member States' reports, the situation is expected to improve progressively over time: by 2018, nine Member States are expected to have a full (or nearly full) coverage of the descriptor categories and by 2020 a total of fifteen Member States will have their programmes in place. Overall, Member States have for the most part identified 2020 as the point by which most of their monitoring programmes will be fully in place. This is reassuring only insofar as it means that MSFD monitoring is expected to be fully operational by that date.

Twelve Member States are expected to have monitoring activities in place to measure the environmental targets they have defined. Ireland plans to cover all targets but will only do so after 2020, by when good environmental status should have already been achieved.

The shortcomings identified in the 2014 Commission report in terms of lack of consistency and comparability in applying Decision 2010/477/EU amongst Member States is confirmed in this assessment. Therefore only an indicative comparative assessment was possible in the context of this report.

Most Member States have identified gaps in their programmes and are aware of the key areas that need further work. Gaps have generally been noted in monitoring methodologies and methodological standards (e.g. for seabed habitats and water column habitats and contaminants).

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, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council - Annex II

Annex X to Directive 2000/60/EC is replaced by the following:
‘ANNEX X

LIST OF PRIORITY SUBSTANCES IN THE FIELD OF WATER POLICY

Number	CAS number [1]	EU number [2]	Name of priority substance [3]	Identified as priority hazardous substance
(1)	15972-60-8	240-110-8	Alachlor	
(2)	120-12-7	204-371-1	Anthracene	X
(3)	1912-24-9	217-617-8	Atrazine	
(4)	71-43-2	200-753-7	Benzene	
(5)	not applicable	not applicable	Brominated diphenylether [4]	X [5]
	32534-81-9	not applicable	Pentabromodiphenylether (congener numbers 28, 47, 99, 100, 153 and 154)	
(6)	7440-43-9	231-152-8	Cadmium and its compounds	X
(7)	85535-84-8	287-476-5	Chloroalkanes, C_{10-13} [4]	X
(8)	470-90-6	207-432-0	Chlorfenvinphos	
(9)	2921-88-2	220-864-4	Chlorpyrifos (Chlorpyrifos-ethyl)	
(10)	107-06-2	203-458-1	1,2-dichloroethane	
(11)	75-09-2	200-838-9	Dichloromethane	
(12)	117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	
(13)	330-54-1	206-354-4	Diuron	
(14)	115-29-7	204-079-4	Endosulfan	X
(15)	206-44-0	205-912-4	Fluoranthene [6]	
(16)	118-74-1	204-273-9	Hexachlorobenzene	X
(17)	87-68-3	201-765-5	Hexachlorobutadiene	X
(18)	608-73-1	210-158-9	Hexachlorocyclohexane	X
(19)	34123-59-6	251-835-4	Isoproturon	
(20)	7439-92-1	231-100-4	Lead and its compounds	

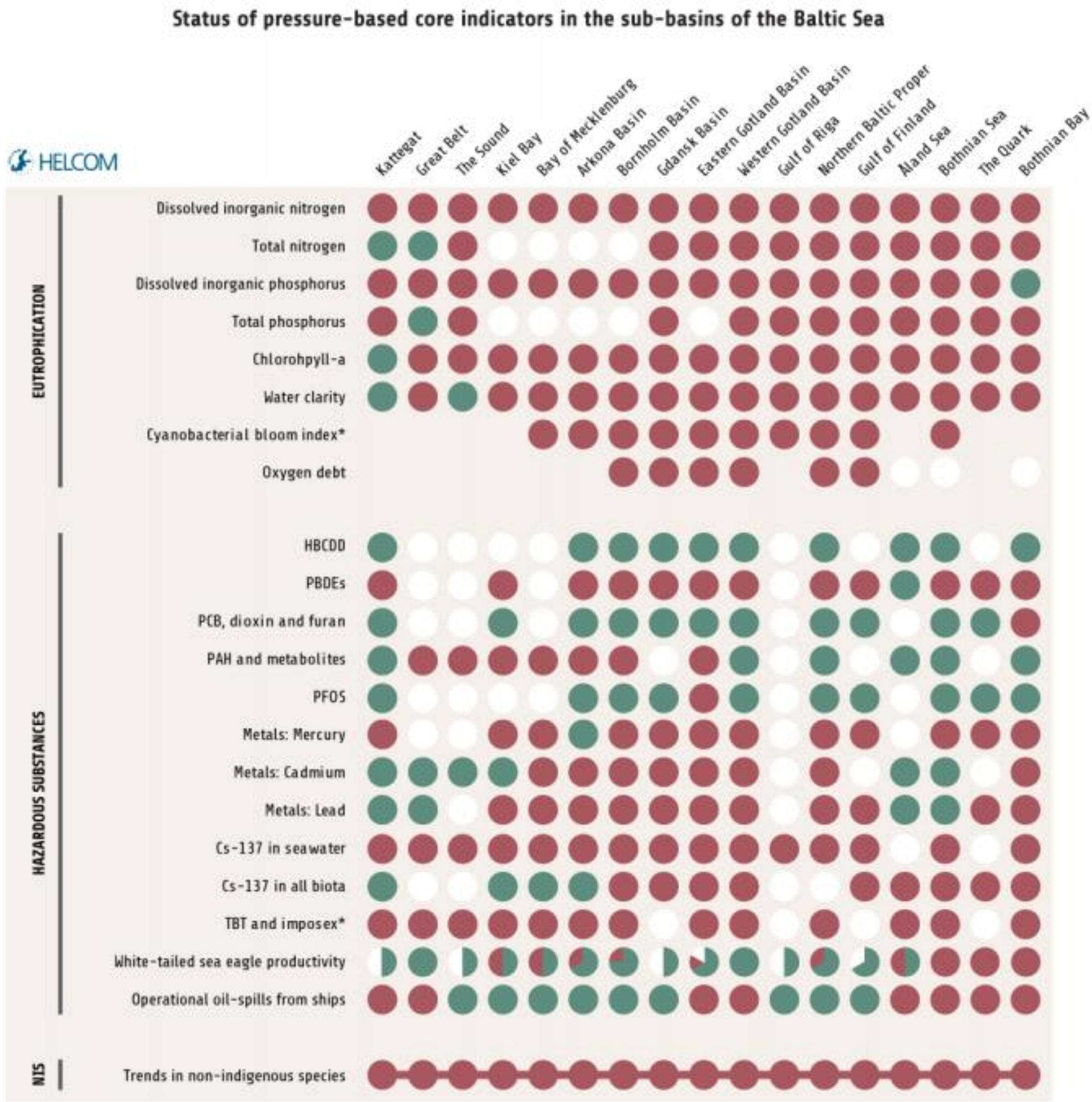
(21)	7439-97-6	231-106-7	Mercury and its compounds	X
(22)	91-20-3	202-049-5	Naphthalene	
(23)	7440-02-0	231-111-14	Nickel and its compounds	
(24)	25154-52-3	246-672-0	Nonylphenol	X
	104-40-5	203-199-4	(4-nonylphenol)	X
(25)	1806-26-4	217-302-5	Octylphenol	
	140-66-9	not applicable	(4-(1,1′,3,3′-tetramethylbutyl)-phenol)	
(26)	608-93-5	210-172-5	Pentachlorobenzene	X
(27)	87-86-5	231-152-8	Pentachlorophenol	
(28)	not applicable	not applicable	Polyaromatic hydrocarbons	X
	50-32-8	200-028-5	(Benzo(a)pyrene)	X
	205-99-2	205-911-9	(Benzo(b)fluoranthene)	X
	191-24-2	205-883-8	(Benzo(g,h,i)perylene)	X
	207-08-9	205-916-6	(Benzo(k)fluoranthene)	X
	193-39-5	205-893-2	(Indeno(1,2,3-cd)pyrene)	X
(29)	122-34-9	204-535-2	Simazine	
(30)	not applicable	not applicable	Tributyltin compounds	X
	36643-28-4	not applicable	(Tributyltin-cation)	X
(31)	12002-48-1	234-413-4	Trichlorobenzenes	
(32)	67-66-3	200-663-8	Trichloromethane (chloroform)	
(33)	1582-09-8	216-428-8	Trifluralin	

HELCOM

State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016 (2018)

(New indicator specific reports were released in 2020 for PBDE (HELCOM, 2020a), PCB and Dioxin (HELCOM, 2020b) and PFOS and other PFASs (HELCOM, 2020c), too late for a detailed inclusion, however, the results up to 2018 that are in line with the ones up to 2016, summarized in the chapter Other media (5.2.4 and below)).

Levels of contaminants are elevated and continue to give cause for concern. However, the number of improving trends outweighs the number of deteriorating trends in the monitored hazardous substances. The integrated contamination status is mainly influenced by polybrominated flame retardants and mercury, together with cesium, deposited after the accident at the Chernobyl nuclear power plant in 1986. Levels of radionuclides are now at acceptable levels in some sub-basins and can be expected to be so in all of the Baltic Sea by 2020. Acute pollution events from oils spills have decreased.



* *Included as test*

Figure ES3.
Status of pressure-based core indicators for eutrophication, hazardous substances and non-indigenous species by sub-basin. Green circles indicate good status, red circles indicate not good status, and white circles indicate that the core indicator is applicable or relevant to the sub-basin, but has not been assessed. Empty points indicate that the indicator is not applicable or relevant. For coastal indicators, pie charts show proportion of coastal assessment units per sub-basin in good status (green), not good status (red) and not assessed (white).

Figure 1.1.
The Baltic Sea is surrounded by nine countries, covers an area of around 420,000 km^2, and has a drainage area around four times its surface area. Due to its strong salinity gradient, and hence biological features, the area is sub-divided into 17 sub-basins based on topography and hydrology. These sub-basins are also referred to in the assessments made in this report.

Some hundreds of substances are regularly monitored. A subset of these are represented in the core indicators included in this assessment.

Polybrominated diphenyl ethers (PBDEs) have mainly been used as flame retardants in plastic materials and polyurethane foams, and enter the Baltic Sea through waste-water treatment plants and diffuse sources. The use of these flame retardants has been banned in most products since 2004 in Europe.

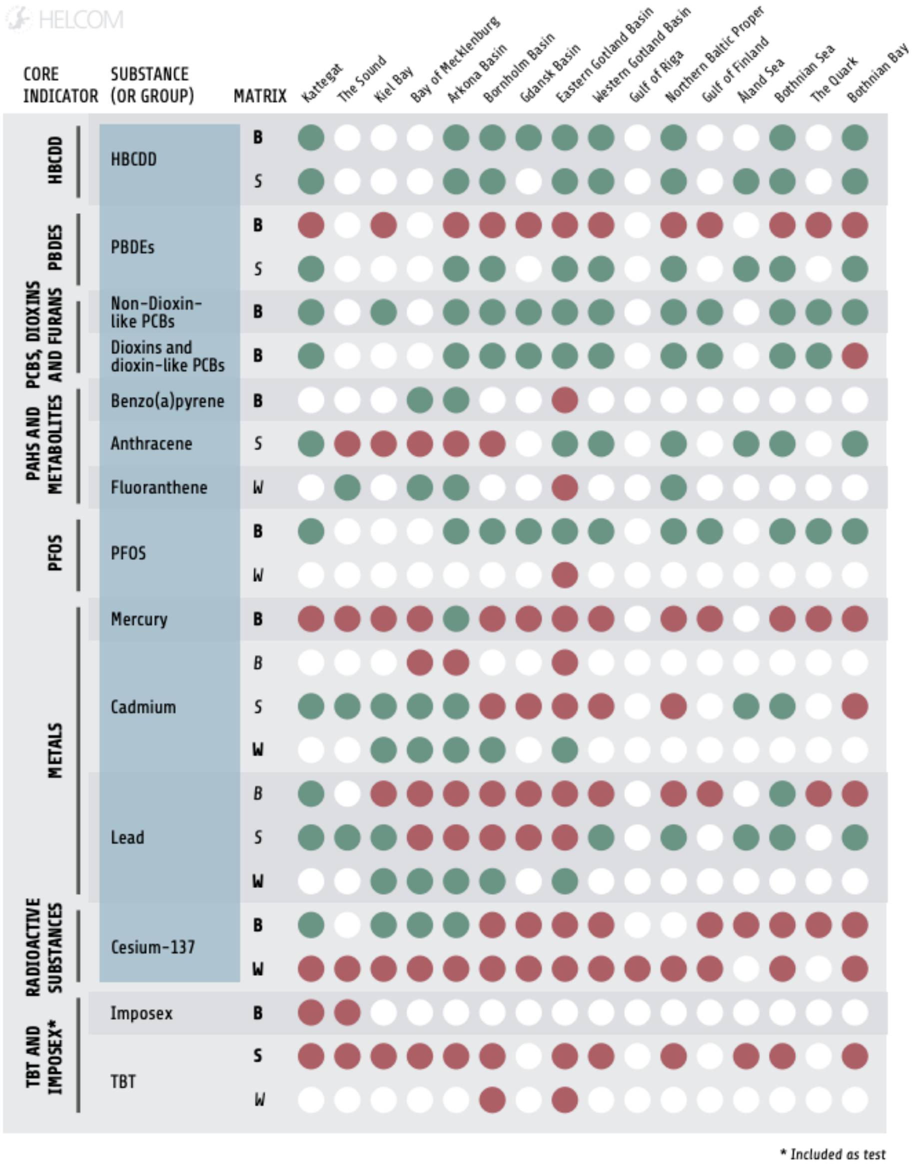


Figure 4.2.3.
Detailed results for the hazardous substances assessment in the open sea assessment units, by core indicators and substances. Red denotes that the substance fails the threshold value, and green denotes that threshold value is achieved. White cells are shown for units not assessed due to a lack of data. The core indicators have primary and secondary substances and threshold values. Primary substances and the matrix in which the primary threshold is set are shown in bold. Secondary substances and threshold values are shown in italics. Abbreviations used for matrices: B=biota; S=Sediment, W=Water, for substances (or groups): BCDD = hexabromocyclododecane, PBDE = polybrominated diphenyl ethers, PAHs = polyaromatic hydrocarbons, PCBs = polychlorinated biphenyls, PFOS = perfluorooctane sulphonate, TBT = tributyltin. The twelve substances (or groups) used in the integrated assessment are marked with pale blue shading.

The overall contamination status has not changed markedly since the previous holistic assessment (HELCOM 2010), showing that contamination from hazardous substances still gives cause for concern throughout the Baltic Sea area. Based on an analysis at core indicator level, the situation seems, however, not to be deteriorating. Out of 559 data series analyzed with respect to trends over time, close to half (236) showed downward trends, 311 showed no detectable trend, and only 12 showed upward trends (Figure 4.2.4).

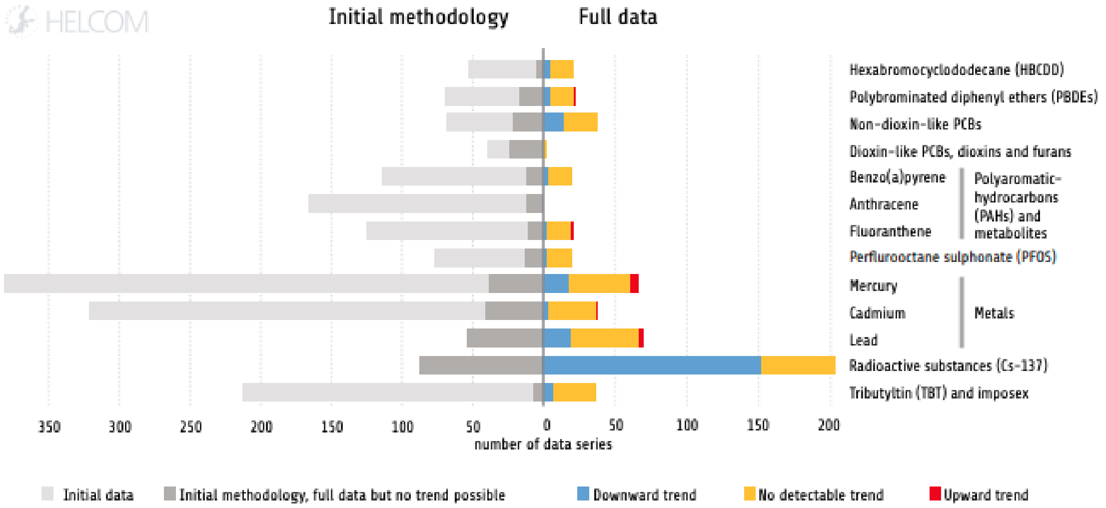


Figure 4.2.4.
Trends in indicator substances or substance groups shown as counts of data series based on the type of assessment methodology applied. The available data for which the trends are calculated differ between substances and stations, covering roughly the following years for each substance; polybrominated diphenyl ethers (PBDE): 1999–2016; mercury: 1979–2016; cadmium: 1985–2016; lead: 1979–2016; hexabromocyclododecane (HBCDD): 1999–2016; perfluorooctane sulphonate (PFOS): 2005–2016; benzo(a)pyrene: 1997–2016; anthracene: 1990–2016; non-dioxine-like polychlorinated biphenyls (PCB): 1978–2016; fluoranthene: 1997–2016, Cesium-137: 2011–2016, and for Tributyltin (TBT) and imposex: 1998–2016.

Due to the methodological differences between assessment periods, it is not possible to make a direct comparison between the current (2011-2016) and the previous holistic assessment. For example, there has been a development of regionally agreed threshold values, different substances or substance groups are sampled, and there is a substantial increase in the monitoring data included in the assessment. Changes can, however, be seen with respect to selected aspects. For example, polychlorinated biphenyls (commonly known as PCBs) and dioxins were identified amongst the substances having highest contamination ratios in the previous assessment (HELCOM 2010), but PCBs, dioxins and furans do to not appear to be a major driver of the integrated assessment status in 2011-2016.

In addition, a number of substances that were assessed in the initial holistic assessment (HELCOM 2010), such as hexachlorocyclohexane (HCH, lindane) and dichlorodiphenyltrichloroethane (DDT) and its metabolites are no longer considered as of significant concern. Substances that appear to have decreased in concern, however, still warrant careful future checking and monitoring, to ensure that concentrations remain low and that alternative or secondary sources do not result in degraded environmental status. For example, hexachlorobenzene has recently been recorded at increasing levels in air at some European monitoring stations and concentrations in sediment have been found to increase in at Swedish offshore sampling stations (EMEP 2017, Apler and Josefsson 2016).

Polybrominated diphenyl ethers. Polybrominated diphenyl ethers (PBDEs) are toxic and persistent substances which bioaccumulate in the marine food web. The sum of six PBDE congeners are compared to the threshold value. The threshold value for biota is an environmental quality standard set to protect both the marine ecosystem, and humans consuming fish, from adverse effects. It is currently due for scientific re-assessment. Polybrominated diphenyl ethers fail the threshold value for biota in all areas where they are monitored (Core indicator report: HELCOM 2018t, Figure 4.2.5). For sediments, the threshold value is achieved. For example, the green area in the indicator summary map around the Åland Sea reflects an assessment based on the secondary threshold value in sediments, while there is a lack of data from biota in that area. The use of polybrominated diphenyl ethers as flame retardant has been banned in most products in Europe since 2004. Therefore, decreasing concentrations are expected in the future. Out of the twenty-two stations where trends were assessed, downward trends were identified in five stations (both coastal and offshore). One station showed an upward trend.

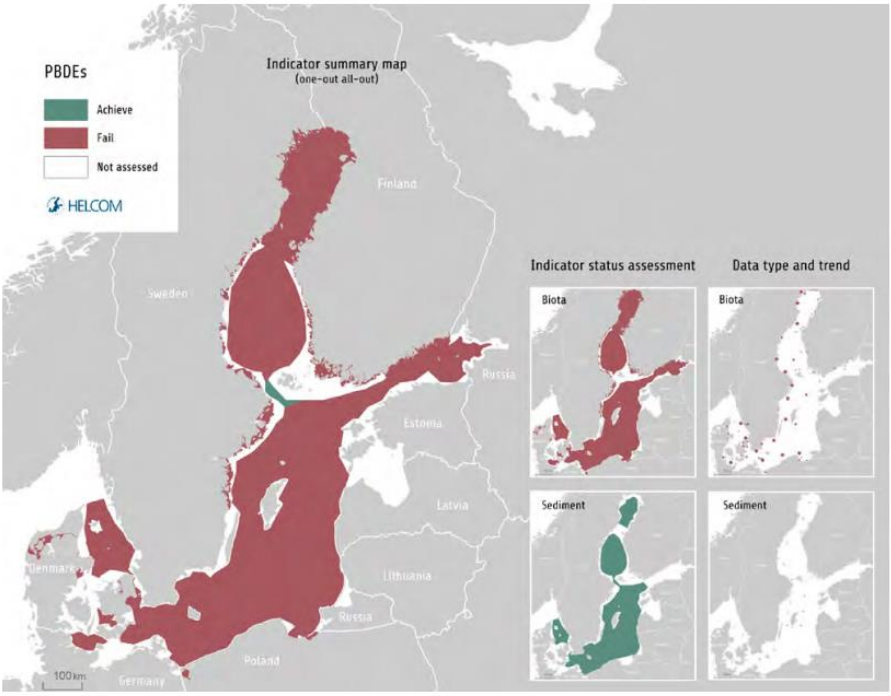


Figure 4.2.5.
Status assessment for polybrominated diphenyl ethers (PBDEs). The summary map (main map) shows the status assessed by the one-out-all-out approach, meaning that the matrix-threshold combination with the worst status is shown for each assessment unit. Status based on the primary threshold in biota (top inset row) and secondary threshold in sediment (bottom inset row) is also shown. Status in biota is evaluated in herring, cod, flounder, dab, eelpout and perch. Red colour indicates that PBDEs fail the threshold value and green colour indicates that the measured PBDEs concentrations are below the threshold value (achieve the threshold). Symbols on map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectible trends. For more details, see HELCOM (2018t).

Perfuorooctane sulphonate. Perfuorooctane sulphonate (PFOS) is considered a global environmental contaminant. It is a persistent, bioaccumulating and toxic compound with possible effects on the reproductive, developmental and immune systems in organisms, as well as on their lipid metabolism. The substance has been produced since the 1950s and was used in the production of fuoropolymers, and also to provide grease, oil and water resistance to materials such as textiles, carpets, paper and coatings. Perfuorooctane sulphonate has also been widely used in firefighting foams. Concentrations of perfluorooctane sulphonate are below the threshold value in biota in all the monitored areas (Core indicator report: HELCOM 2018w). However, concentrations in seawater exceed the threshold value (EQS for water) where measured, which is reflected in the red area in summary map (Figure 4.2.6). There are a few downward trends in biota but no general trends are detected. Perfuorooctane sulphonate has been banned in the EU since 2008 for most of its used categories, but it has been replaced with other similar substances (per- and polyfuoroalkyl substances; PFAS) which have widespread use. Most PFAS are highly persistent and bioaccumulating, and other PFAS (in addition to perfuorooctane sulphonate) are also a cause for concern. Some per- and polyfuoroalkyl substances (PFAS) are listed on the EU candidate list on ‘Substances of very high concern’ under the REACH regulation (ECHA 2017). Inclusion of additional PFAS as core indicators should be considered in the future to keep track of their use and occurrence in the Baltic Sea region.

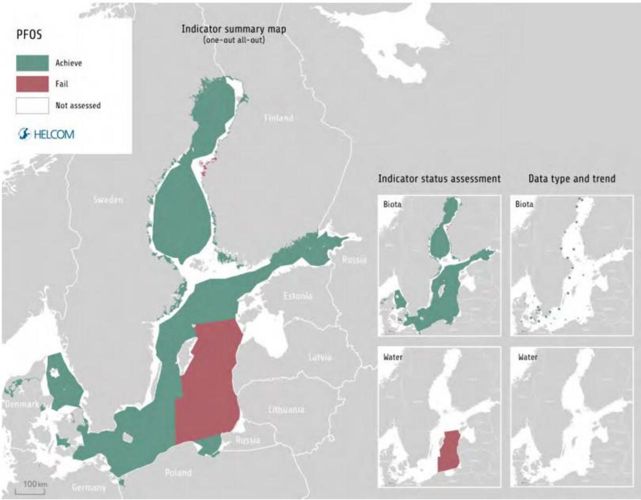


Figure 4.2.6.
Status assessment for perfluorooctane sulphonate (PFOS). The one-out-all-out approach is used to summarise all matrix-threshold combinations (main map), with the primary threshold in biota (top inset row), secondary threshold in water (bottom inset row). Biota analyses is carried out in herring, cod, flounder, dab, eelpout and perch. Symbols on map define data type and trend with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends. For more details, see the Core indicator report: HELCOM (2018w).

Table 2. HELCOM hazardous substances indicator details and threshold values. Indicators are divided into those entering the integrated assessment and those used to support the overall assessment provided in this report. Indicator name is provided and where multiple substances or substance groups are assessed within the same indicator then these divisions are presented and the codes used in the report are also provided. The matrix (biota, water or sediment) in which samples are collected is defined and the threshold type (primary or secondary). Indicators using multiple matrix types and threshold types incorporate the various threshold-matrix combinations to give widest spatial coverage and all assessed aspects are presented in the indicator reports, and outlined in Chapter 5 of this report. Details related to normalisation or filtration procedures are provided and the threshold values and origin. Abbreviations used: CORG = organic carbon concentration, Al = Aluminium, AA = Annual average, BAC = Background Assessment Cconcentrations, DW = dry weight EcoQO= Ecological Quality Objectives, EQS = Environmental quality standard, QS= Quality standard, TEQ=Toxic Equivalent, WW = wet weight.

Indicator	Substance or substance group (code)	Matrix (threshold type)	Details	Threshold value
Hexabromocyclo-dodecane (HBCDD)	**HBCDD** (HBCD)	Biota (primary)	5% lipid normalisation	EQS – 167 µg/kg WW human health[1]
		Sediment (secondary)	5% CORG normalisation	QS from EQS dossier 170 µg/kg DW[2]
Polybrominated diphenyl ethers (PBDEs)	**PBDEs** (SBD6)	Biota (primary)	5% lipid normalisation	EQS – 0.0085 µg/kg WW human health[3]
		Sediment	5% CORG normalisation	QS from EQS dossier 310 µg/kg DW benthic community protective[3]
Polychlorinated biphenyls (PCBs), dioxins and furans	**Dioxin-like PCBs, dioxins and furans** (SDX)	Biota (primary)	5% lipid normalisation	EQS – 0.0065 TEQ/kg WW human health[1]
	Non dioxin-like PCBs (SCB6)	Biota (primary)	5% lipid normalisation	EC - 75 µg/kg WW foodstuff[5, 9]
Polyaromatic hydrocarbons (PAHs) and their metabolites	**Benzo(a)pyrene** (BAP)	Biota (primary)		EQS – 5 µg/kg WW human health[1]
	Fluoranthene (FLU)	Biota (secondary)		EQS – 30 µg/kg WW human health[1]
	Anthracene (ANT)	Sediment (secondary)	5% CORG normalisation	QS from EQS dossier 24 µg/kg DW[4]
Perfluorooctane sulphonate (PFOS)	**PFOS** (PFOS)	Biota (primary)	Conversion from liver to muscle	EQS – 9.1 µg/kg WW human health[1]
		Water (secondary)	Unfiltered ideally	EQS AA – 0.00013 µg/l[1]
Metals	**Cadmium** (CD)	Water (primary)	Filtered or unfiltered*	EQS AA - 0.2 µg/l[6]
		Biota (secondary)		BAC 960 µg/kg DW mussels*
		Sediment (secondary)	5% Al normalisation	QS from EQS dossier 2.3 mg/kg DW[7]
	Lead (PB)	Water (primary)	Filtered or unfiltered*	EQS AA – 1.3 µg/l[1]
		Biota (secondary)		BAC 26 µg/kg WW fish liver*
				BAC 1300 µg/kg DW mussels*
		Sediment (secondary)	5% Al normalisation	QS from EQS dossier 120 mg/kg DW[8]
	Mercury (HG)	Biota (primary)		EQS – 20 µg/kg WW secondary poisoning[9]
Radioactive substances: Cesium-137 in fish and surface water	**Cesium-137** (CS-137)	Biota (primary)		2.5 Bq/kg herring[10] 2.9 Bq/kg flounder[10]
		Water (primary)		15 Bq/m^3 seawater[10]

The overall contamination status has not changed markedly since the previous holistic assessment (HELCOM 2010b), showing that contamination from hazardous substances still gives cause for concern throughout the Baltic Sea area. Based on an analysis at core indicator level, the situation seems, however, not to be deteriorating. Out of 559 data series analyzed with respect to trends over time, close to half (236) showed downward trends, 311 showed no detectable trend, and only 12 showed upward trends (Figure 10). Due to the methodological differences between assessment periods, it is not possible to make a direct comparison between the current (2011-2016) and the previous holistic assessment. For example, there has been a development of regionally agreed threshold values, different substances or substance groups are sampled, and there is a substantial increase in the monitoring data included in the assessment. The method developments represent improvements to ensure that future assessments, particularly assessments of measures or progress towards threshold values, will be continuously more viable, and to follow the societal development in how hazardous substances are used and managed. Developments in recent years have also enabled a more extensive monitoring, so that the spatial and temporal sampling coverage of the current substances or substance groups is on a generally much greater scale, indicated by the several thousand data series included in this assessment (discussed in detail below) compared to less than 150 data series used in the previous assessment. Over time, longer assessment periods will also allow larger numbers of data series to have statistical trends assigned in the future, and offer greater insights into the behaviour and trends of hazardous substances. Changes can, however, be seen with respect to selected aspects. For example, polychlorinated biphenyls (commonly known as PCBs) and dioxins were identified amongst the substances having highest contamination ratios in the previous assessment (HELCOM 2010b), but PCBs, dioxins and furans do to not appear to be a major driver of the integrated assessment status in 2011-2016 (Figure 8). Although 14 of 61 HELCOM scale 4 assessment units still fail the threshold value, the dominant status across the region indicates that the threshold value is achieved. Furthermore, of the 149 data series utilised in this indicator, 15 downward trends, 25 no detectable trends, and zero upward trends were recorded, the remaining data series being treated with the methodology for initial data.

However, mercury, polybrominated diphenyl ethers (PBDEs), and radioactive substances are the major drivers of the degraded status in the current integrated assessment.

In addition, a number of substances that were assessed in the initial holistic assessment (HELCOM 2010b), such as hexachlorocyclohexane (HCH, lindane) and dichlorodiphenyltrichloroethane (DDT) and its metabolites are no longer considered to be of significant concern. Substances that appear to have decreased in concern, however, still warrant careful future checking and monitoring, to ensure that concentrations remain low and that alternative or secondary sources do not result in degraded environmental status. For example, hexachlorobenzene has recently been recorded at increasing levels in air at some European monitoring stations and concentrations in sediment have been found to increase in at Swedish offshore sampling stations (EMEP 2017, Apler and Josefsson 2016)

The consideration of substances as no longer of concern, in conjunction with the promising number of downward trends recorded in this assessment, and observed ecosystem responses such as improved breeding success in the white-tailed sea eagle that has been attributed to reductions in DDT compounds, would suggest that policy and measures are facilitating steps towards improved status. Overall this would suggest that while hazardous substances in the Baltic Sea remain a major concern in all assessed areas, Those substances most distant from their threshold values and failing the threshold value (based on the whole regional scale) are PBDEs, mercury, cesium-137 and TBT13. This also highlights the specific behaviour (and environmental recovery due to banning) of substances or substance groups, for example HBCDD and PBDEs that show very different status in the current assessment. Although this may in part relate to the potentially highly precautionary threshold currently applied to PBDEs in biota it is important to understand the factors underlying the recorded trends when exploring reasons behind ecosystem recovery and when planning appropriate measures, and such aspects may warrant further exploration.

Altogether, 2,517 individual contaminant data series were assessed to produce the hazardous substances core indicator evaluations of this assessment. Of these data series, 559 of were classified as full data to which trends could be assigned and 1,958 were treated with the methodology for initial data. In all cases, as status assessment was made the underlying methodology differed. Out of the 559 data series, 236 downward trends, 311 series with no detectable trend, and only twelve upward trends were detected.

Hexabromocyclododecane (HBCDD)

Hexabromocyclododecane (HBCDD) is a persistent, bioaccumulating and toxic substance with possible impacts on the reproductive and developmental system. It is a brominated flame retardant which is used in insulation material for the construction industry and as textile coating to improve the fire resistance of materials. HBCDD is placed on the Stockholm Convention list of chemicals for which measures are required to eliminate their use and production, and for the use of which specific exemption permits are required. Levels of HBCDD are below the threshold value in biota, which is set to protect the marine ecosystem and humans consuming fish, from adverse effects (Core indicator report; HELCOM 2018b Figure 11) and are below the QS threshold value for sediments, indicating that overall this substance achieves the threshold (One-out-all-out combination of all matrix-threshold values per assessment unit). The monitoring of HBCDD concentrations in biota mainly show no detectable trends and in some cases even downward trends.

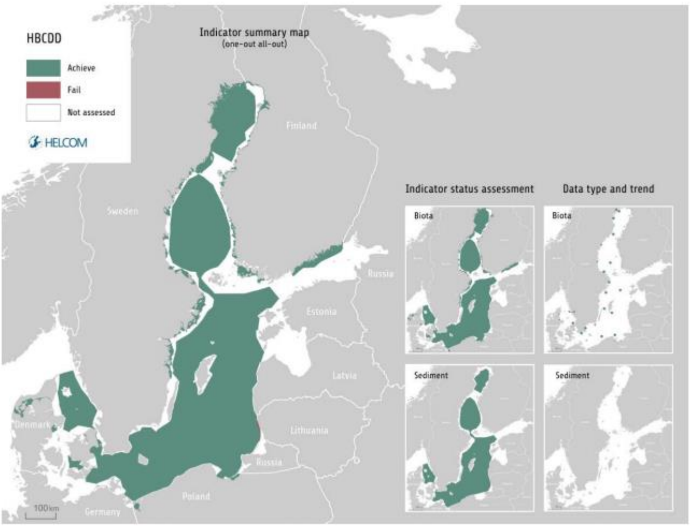


Figure 11. Status assessment for hexabromocyclododecane (HBCDD). The one-out-all-out approach is used to summarise all matrix-threshold combinations (main map), with the primary threshold in biota (top inset row) and secondary threshold in sediment (bottom inset row) also shown. Status is evaluated in biota based on HBCDD concentrations in herring, cod, flounder, dab, eelpout and perch. Green colour indicates that the measured HBCDD concentrations are below the threshold value (achieve the threshold). Symbols on map define data type and trend (see section 3.5) with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends.

Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are toxic and persistent substances which bioaccumulate in the marine food web. The sum of six PBDE congeners are compared to the threshold value. The threshold value for biota is an environmental quality standard set to protect both the marine ecosystem, and humans consuming fish, from adverse effects. It is currently due for scientific re-assessment. Polybrominated diphenyl ethers fail the threshold value for biota in all areas where they are monitored (Core indicator report; HELCOM 2018c, Figure 12). For sediments, the threshold value is achieved. For example the green area in the indicator summary map around the Åland Sea reflects an assessment based on the secondary threshold value in sediments, while there is a lack of data from biota in that area.

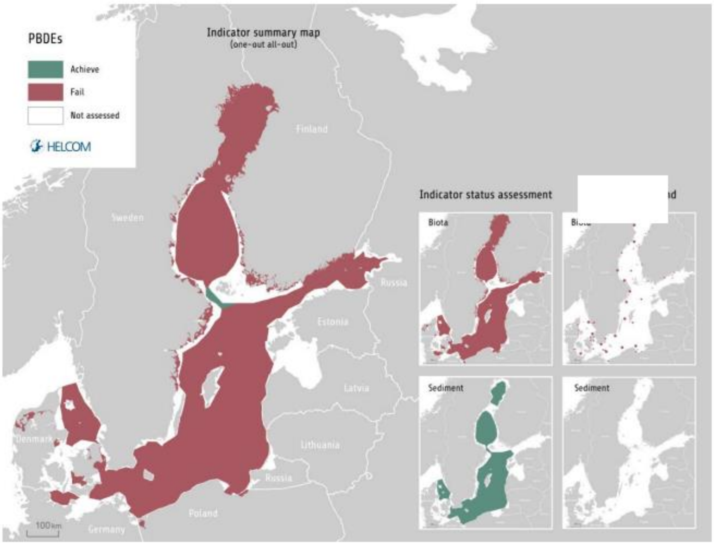


Figure 12. Status assessment for polybrominated diphenyl ethers (PBDEs). The summary map (main map) shows the status assessed by the one-out-all-out approach, meaning that the matrix-threshold combination with the worst status is shown for each assessment unit. Status based on the primary threshold in biota (top inset row) and secondary threshold in sediment (bottom inset row) is also shown. Status in biota is evaluated in herring, cod, flounder, dab, eelpout and perch. Red colour indicates that PBDEs fail the threshold value and green colour indicates that the measured PBDEs concentrations are below the threshold value (achieve the threshold). Symbols on map define data type and trend (see section 3.5) with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectible trends. For more details, see HELCOM (2018c).

PCBs, Dioxins, and Furans

Polychlorinated biphenyls (PCBs) are persistent, toxic substances and bio-accumulate in the marine food web. The substances have been used in a wide variety of applications and manufacturing processes, especially as plasticizers, insulators and flame-retardants. Polychlorinated biphenyls enter the marine environment due to inappropriate handling of waste material or leakage from transformers, condensers and hydraulic systems. Dioxins (PCDD/Fs) were never produced intentionally, but they are minor impurities in several chlorinated chemicals (e.g., PCBs, chlorophenols, hexachlorophene, etc.) and are formed in several industrial processes, mainly from combustion processes.

Non-dioxin-like PCBs were assessed in relation to a threshold value that is based on food safety, showing values above the threshold value in some areas (Core indicator report; HELCOM 2018d, Figure 13). Over time concentrations of nondioxin-like PCBs showed no detectable trends or downward trends (Figure 13). Dioxins, furans and dioxin-like PCBs, were assessed against an EQS based on levels in foodstuffs (WHO TEQ). Similar to non-dioxin-like PCBs, some areas had concentrations above the threshold value. Even though the dioxin concentrations are below the EQS in many areas, diotrxins are still considered to be one of the most problematic pollutants in the Baltic Sea for the marine environment.

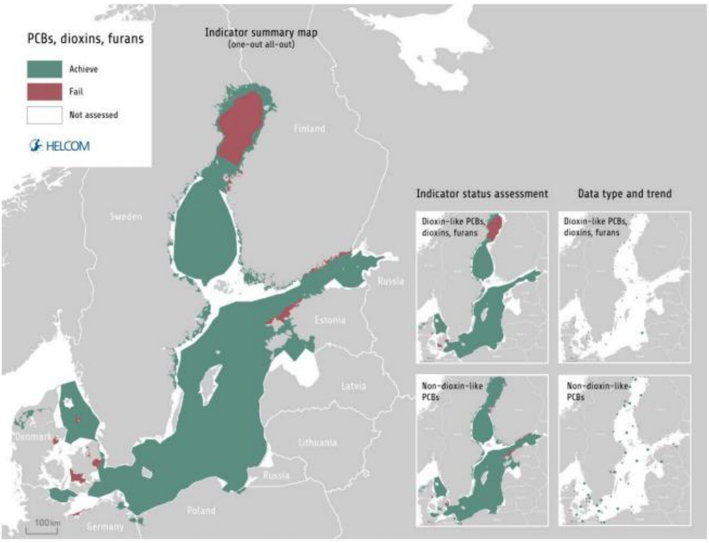


Figure 13. Status assessment for dioxin-like polychlorinated biphenyls (PCBs), dioxins and furans, and non-dioxin-like PCBs. The one-out-all-out approach is used to summarise all matrix-threshold combinations (main map), with the primary threshold in biota for dioxin-like polychlorinated biphenyls (PCBs), dioxins and furans (top inset row) and primary threshold in biota for non-dioxin-like PCBs (bottom inset row) shown. Status is evaluated in biota based on concentrations in herring, cod, flounder, dab, eelpout and perch. Red colour indicates that the threshold value is failed (i.e. concentrations are higher) and green colour indicates that the measured concentrations are below the threshold value (achieve the threshold). Symbols on map define data type and trend (see section 3.5) with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends.

Perfluorooctane sulphonate (PFOS)

Perfluorooctane sulphonate (PFOS) is considered a global environmental contaminant. It is a persistent, bioaccumulating and toxic compound with possible effects on the reproductive, developmental and immune systems in organisms, as well as on their lipid metabolism. The substance has been produced since the 1950s and was used in the production of fluoropolymers, and also to provide grease, oil and water resistance to materials such as textiles, carpets, paper and coatings. Perfluorooctane sulphonate has also been widely used in firefighting foams.

Concentrations of perfluorooctane sulphonate are below the threshold value in biota in all the monitored areas (Core indicator report; HELCOM 2018f). However, concentrations in seawater exceed the threshold value (EQS for water) where measured, which is reflected in the red area in summary map (Figure 15). There are a few downward trends in biota but no general trends are detected (Figures 15).

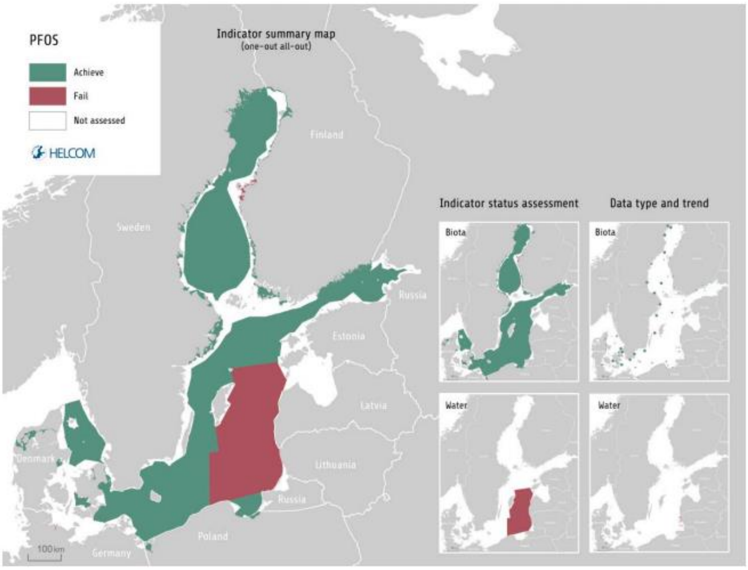


Figure 15. Status assessment for perfluorooctane sulphonate (PFOS). The one-out-all-out approach is used to summarise all matrix-threshold combinations (main map), with the primary threshold in biota (top inset row), secondary threshold in water (bottom inset row). Biota analyses is carried out in herring, cod, flounder, dab, eelpout and perch. Symbols on map define data type and trend (see section 3.5) with downward triangles indicating decreasing concentrations, upward triangles indicating increasing concentrations and circles indicating no detectable trends. For more details, see the Core indicator report; HELCOM 2018f).

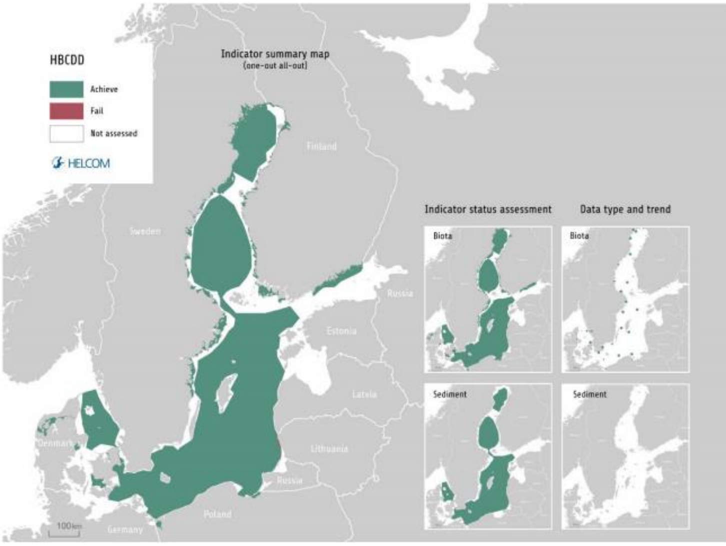
Annex 5. Summary of data series used in each indicator

	Status assessment - full data with trends assessed			Status assessment – treated as initial data, trend not possible			
Substance or substance group	**Downward trend**	**No detectable trend**	**Upward trend**	***Full data but no trend***	***Initial data***	**Number of trend assessments**	**Total number of data series**
Hexabromocyclododecane (HBCDD)	5	16	0	5	47	21	73
Polybrominated diphenyl ethers (PBDEs)	5	16	1	16	53	22	91
Non-dioxin-like PCBs	15	23	0	21	48	38	107
Dioxin-like PCBs, dixins and furans	0	2	0	24	16	2	42
Benzo(a)pyrene	4	16	0	12	102	20	134
Fluoranthene	3	16	2	10	115	21	146
Anthracene	0	0	0	11	154	0	165
Perfluorooctane sulphonate (PFOS)	3	17	0	13	64	20	97
Mercury	18	43	5	38	207	66	311
Cadmium	4	33	1	40	281	38	359
Lead	19	48	3	54	327	70	451
Radioactive substances (Cs-137)	152	52	0	87	0	204	291
Tributyltin (TBT) and imposex	8	29	0	7	206	37	250
TOTALS	**236**	**311**	**12**	**338**	**1620**	**559**	**2517**

HELCOM INDICATORS – HELCOM core indicator report, July 2018

Hexabromocyclododecane (HBCDD)

This core indicator evaluates the status of the marine environment based on concentrations of hexabromocyclododecane (HBCDD) in Baltic Sea fish and sediments. Good status is achieved when the concentrations of HBCDD are below the specific threshold values. The current evaluation is based on data up to 2016, and the status is assessed for the period 2011-2016.

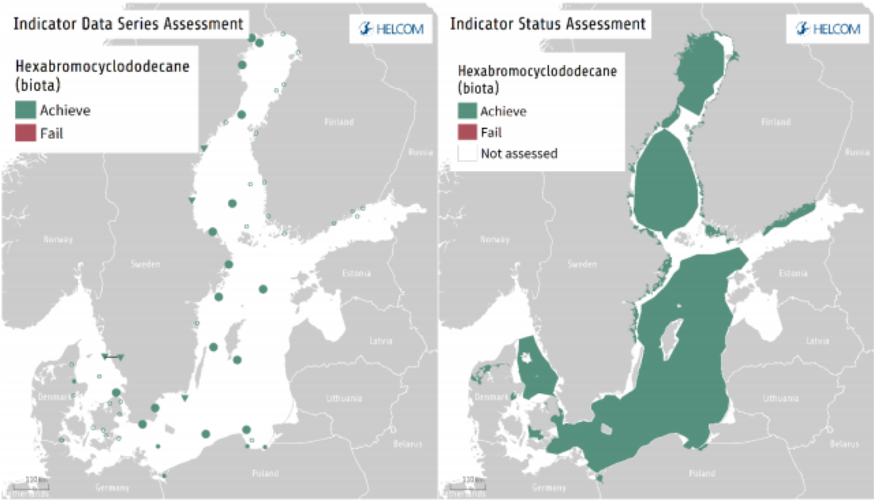


Key message figure 1. Status assessment results based on evaluation of the indicator 'hexabromocyclododecane (HBCDD)'. The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). One-Out-All-Out (OOAO) method (main figure), in biota (upper inset) and in sediment (lower inset). The left map show the assessment of the primary matrix biota, the right map the secondary. **Click here to access interactive maps at the HELCOM Map and Data Service:** **HBCDD**.

Time series of HBCDD levels in biota showed increasing concentrations since the 1980s in the Baltic Proper and Bothnian Sea. However, since the 2000s no increases have been observed and decreasing HBCDD concentrations are seen in fish from the west coast and southern coast of Sweden since the late 1990s. The confidence of the indicator evaluation results is considered to be high. It should also be noted, however, that the majority of the stations are selected as reference stations while potential local problems with HBCDD may occur in areas not included in the current monitoring programmes. The indicator is applicable in the waters of all the countries bordering the Baltic Sea.

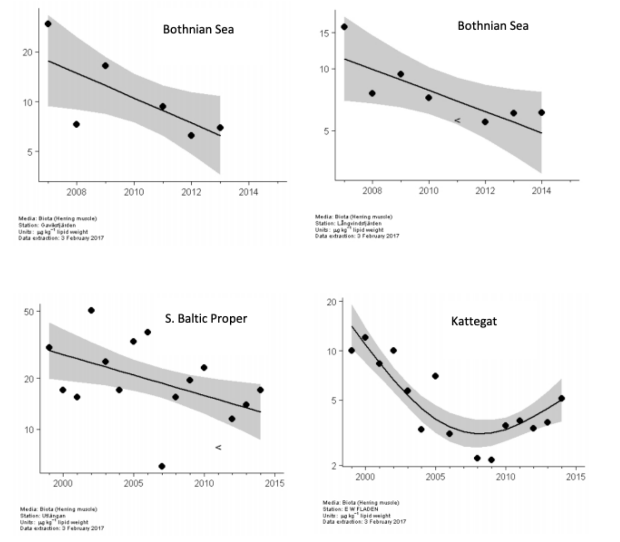
HBCDD is a persistent, bioaccumulative and toxic compound with possible impacts on the reproductive and developmental system. The main use of HBCDD is in insulation material in the building industry or as coating for textiles to improve the fire resistance of the materials. Measurements of HBCDD provide information of the contaminant load in the Baltic Sea and the presence of HBCDD in biological samples also reflects the bioavailable part of the contaminant pool. Predators (particularly top predators) and humans are exposed to the contaminant through consumption of the species assessed in this indicator.

Mean concentration of HBCDD in fish from all monitored stations were well below the threshold value (Results figure 2). The lowest values of HBCDD are observed in assessment unit SEA-001 (Kattegat open sea subbasin) with the upper 95% confidence interval of 0.35 ng/g ww in fish and the highest concentrations in assessment unit in SEA-017 (Bothnian Bay open sea subbasin) with upper confidence values of 3.4 ng/g ww in fish. These values are adjusted to a mean lipid content of 5%. The threshold value is about 50 times higher than the maximum upper confidence value detected.



Results figure 2. Spatial variation of the HBCDD sampling stations in biota (herring, cod, perch, eelpout and European flounder) (left) and status assessment by assessment unit in biota (right). Green colour indicates that the upper 95 % confidence interval for HBCDD concentrations are below the threshold value (i.e. good status). Small open circles indicate a status assessment based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. **Click here to access interactive maps at the HELCOM Map and Data Service: HBCDD.**

Long term data from biota monitoring stations show increasing HBCDD concentrations from the 1970s and 1980s to the 2000s (Bignert et al. 2017). Cod from south-eastern Gotland show a high increase with concentration values four times higher in the 2000s than in the 1980s. Since the end of the 1990s, decreasing levels are seen at the Swedish west coast station Fladen for both herring and cod, and the same trend is also detected for herring from Utlängan in the southern Baltic Proper, and in herring from two stations in the Bothnian Sea (Results figure 3 and Bignert et al. 2017).

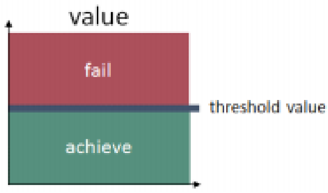


Results figure 3. Temporal trend of HBCDD concentration (ng/g wet weight) in herring muscle from the Bothnian Sea, the south Baltic Proper and in Kattegat (HQS – threshold level, grey colour- confidence level 95% range (see Assessment protocol).

The overall confidence of the assessment is high.

Good status in biota is achieved if the concentration of hexabromocyclododecane (HBCCD) is below the threshold value of 167 µg kg-1 fish wet weight (Thresholds figure 1). The threshold value is an environmental quality standard (EQS), derived at EU level as a substance included on the priority list under Directive 2008/105/EC regarding priority substances in the field of water policy (EQSD)

(European Commission 2008a). Good status in accordance with the MSFD is defined as 'concentrations of contaminants at levels not giving rise to pollution effects'.



Thresholds figure 1. Good status is achieved if the concentration of HBCCD is below the threshold value of 167 µg kg^{-1} fish wet weight. The threshold value is an environmental quality standard (EQS) derived at EU level as a substance included on the priority list under the Directive on Environmental Quality Standards.

The technical HBCDD products consist of three stereoisomers, α-, β- and γ-HBCDD, but the QS and EQS values are derived for the sum of these three stereoisomers

The technical product consists of three stereoisomers, 70–95 % γ-HBCDD and 3–30% of α- and β-HBCDD, proportions depending on the manufacturer and the production method used. However, HBCDD is known to undergo thermal rearrangement, i.e. a shift in the relative amount of each stereoisomer can be seen if HBCDD, or a material containing HBCDD, is heated above 140°C. This has for instance been shown by Peled et al. (1995) and Heeb et al. (2010). The result of the transformation is that a relative increase of α-HBCDD and a relative decrease of γ-HBCDD could be observed. The transformation rate is dependent on time and temperature. HBCDD in this core indicator refers to the sum of the three diastereoisomers unless otherwise stated.

Estimated emissions within the EU from HBCDD production and handling, associated with micronizing (fine grade grinding) of HBCDD is about 3 kg per year. The estimated release of particles during usage of EPS and XPS has been estimated to 100 g per tonne EPS and 5 g per tonne XPS. This amounts to an estimated release of approximately 560 kg HBCDD per year (of which 530 kg and 30 kg are from the use of EPS and XPS, respectively, assuming a use of 3% HBCDD in both EPS and XPS). This can be compared to a total estimated release of around 3000 kg per year in the EU, including all known sources (ECHA, 2009).

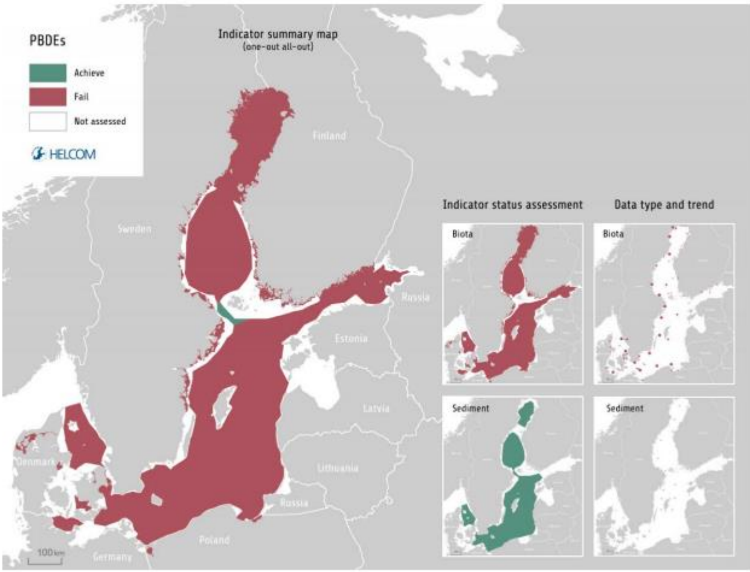
Environmental monitoring of hexabromocyclododecane (HBCDD) in biota is currently not coordinated in the HELCOM community, implying that national guidelines are applied in the sampling as documented in the monitoring concepts table in the HELCOM Monitoring Manual under the sub-programme: Contaminants in biota. So far, there are no technical guidelines related to HBCDD monitoring in biota in the HELCOM Monitoring Manual and there is a need to develop such common monitoring guidelines.

Presently, only Denmark, Poland and Sweden have permanent monitoring of HBCDD in biota. Germany monitors HBCDD in biota on a project basis, national water monitoring is under development and sediment monitoring is in a planning phase. Finland and Lithuania have results from a few years and are planning to include the substance in their national monitoring programmes. Estonia will include HBCDD analysis (sediment and biota) in coastal areas from 2017. Latvia has only screening data and there is no information from Russia.

HELCOM INDICATORS – HELCOM core indicator report, July 2018

Polybrominated diphenyl ethers (PBDEs)

The available data and evaluations show that the concentration of polybrominated diphenyl ethers (PBDEs) is high in biota (though less so in sediments) throughout the Baltic Sea. The status of the sum of PBDE congeners (28, 47, 99, 100, 153 and 154) in fish, during the period 2011 to 2016, shows that the threshold is exceeded at every monitoring site in the Baltic Sea, resulting in all fish monitoring areas being classified as ‘not good status’ (Key message figure 1). The core indicator threshold value is the EU Environmental Quality Standard (EQS) of 0.0085 µg kg-1 wet weight (ww) in fish. The threshold is considered to be very precautionary and is due for review by the EU Chemicals Working Group.

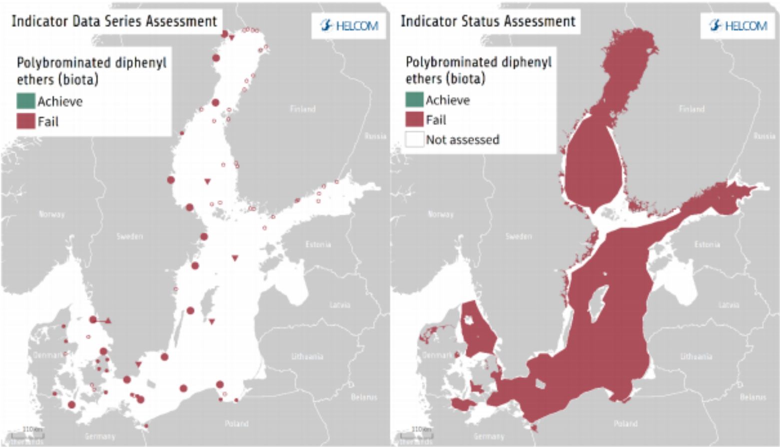


Key message figure 1. Status assessment results based on the evaluation of the indicator Polybrominated diphenyl ethers (PBDEs). Status assessments are provided as a summary using the One-Out-All-Out approach (main figure), for biota (upper inset), and for sediment (lower inset). The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: PBDEs.**

Concentrations of single PBDE congeners are declining, but the availability of long time series is limited in the Baltic Sea and concentrated to 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.

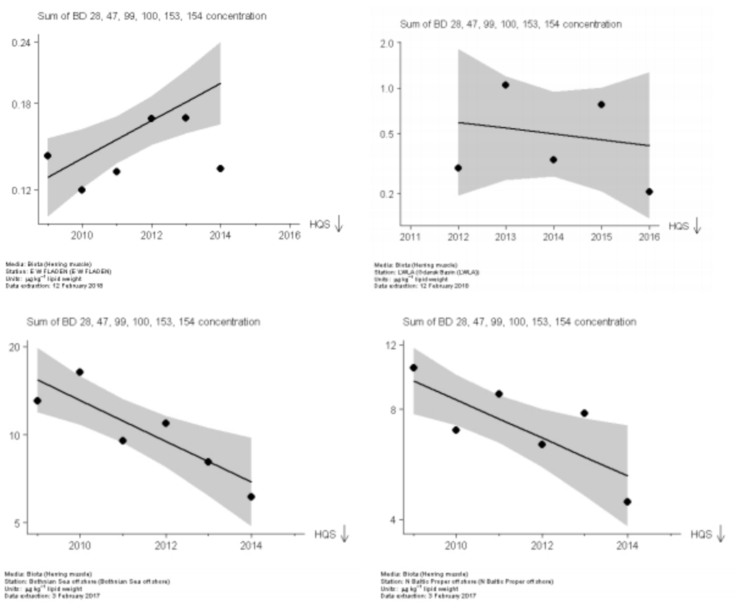
Polybrominated diphenyl ethers (PBDEs) are toxic and persistent substances that bioaccumulate in the marine foodweb. Increasing concentrations of PBDEs were detected in the environment in past decades as their use as commercial flame retardants increased. The use of most PBDE products have been banned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

Overall the status of polybrominated diphenyl ethers (PBDEs) fail the threshold value. Data is available across a wide spatial area and shows that the concentrations of PBDEs are above the threshold value in biota throughout the Baltic Sea.



Results figure 2. PBDE biota measurements per station in the Baltic Sea (right) and resulting status assessment (left). Red colour indicates that the upper 95 % confidence interval for PBDE concentrations are above the threshold value. Small open circles indicate a status assessment based on only 1-2 years of data, small filled circles indicate that there is not enough data to assess a statistical trend, large filled symbols indicate statistical trends assigned with circles indicating no detectable trend in concentration during the whole monitoring period and the filled arrows indicating significant upward or downward trend in concentration during the monitoring period. **Click here to access interactive maps at the HELCOM Map and Data Service:** PBDEs.

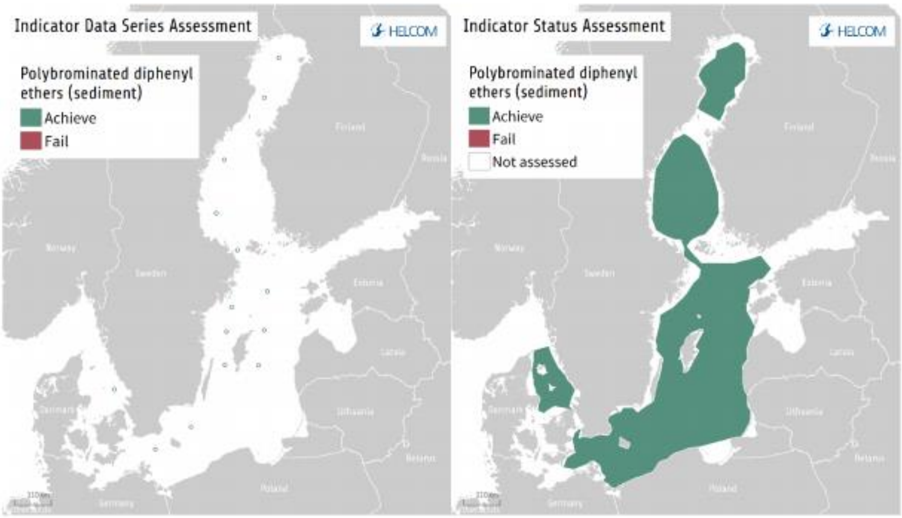
The threshold value of 0.0085 µg/kg ww defined by the Environmental Quality Standard (EQS) is exceeded everywhere, but there are regional/local differences in concentration. Mean values for the monitoring stations range from 0.03 to 0.82 ng/g ww in fish muscle (0.098 to 3 ng/g ww per scale 4 HELCOM assessment unit). 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. 2017). PBDEs seem to be declining in open sea areas, but the variation both between and within sites is larger in coastal areas (Result figure 2 and 3). The monitoring has gaps in Estonian, Latvian and Russian waters. In other areas, e.g. Finland, the monitoring period is too short to evaluate the levels with high confidence. Concentrations of several PBDEs in the marine environment are declining (Bignert et al. 2017). Concentrations of PBDE show decreasing trend in herring muscle from 5 monitoring stations in the Baltic Sea (results figure 2), but in coastal areas the trend is less clear (Results figure 3).



Results figure 3. Temporal trends of PBDEs concentration (ng/g wet weight – 5% lipid normalized) in herring muscle from stations Fladen Kattegat, Gdansk Basin, Bothnian Sea and north Baltic Proper, (grey colour- confidence level 95% range (see Assessment protocol)).

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

Concentrations of PBDEs has also been measured in sediments. The threshold value for sediment is 310 µg kg-1 dry weight (dw). This threshold value is high compared to the threshold value in biota. When these results are assessed against the QS for sediment all assessment units with data show a good status (Results figure 4).



Results figure 4. Assessment per station in the Baltic Sea (left) and status assessment results (right) based on the evaluation of the indicator Polybrominated diphenyl ethers (PBDEs) in sediments. Green colour indicates that the upper 95 % confidence interval for PBDE concentrations are below the threshold value. Small open circles indicate a status assessment based on only 1-2 years of data. The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: PBDEs.**

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.

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.

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.

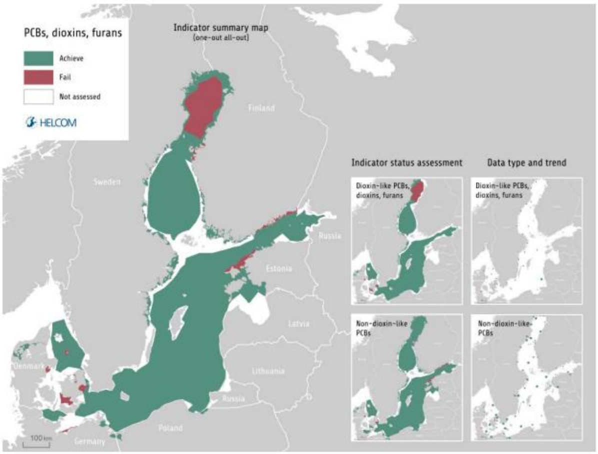
DecaBDE (BDE 209) is the dominant congener from sources (e.g. WWTPs) and in the Baltic Sea sediments; it can also be found in Baltic Sea fish, although tetraBDE is the most dominant congener in biota. Levels of decaBDE may be increasing because its use is only partly restricted. However, because of the 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.

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.

HELCOM INDICATORS – HELCOM core indicator report, July 2018

Polychlorinated biphenyls (PCBs), dioxins, and furans

This core indicator evaluates the status of the marine environment based on concentrations of dioxin and dioxin like compounds in Baltic Sea fish, crustacean and molluscs as well as on concentrations of non-dioxin like PCB in Baltic Sea fish. Good status is achieved when the concentrations of PCBs, dioxins and furans are below the threshold values. The current evaluation is based on data up to 2016 to evaluate the assessment period 2011-2016.



Key message figure 1. Status assessment results based evaluation of the indicator 'PCBs, dioxins and furans'. One-Out-All-Out (OOAO) method (main figure), dioxin-like PCBs, dioxins and furans in biota (upper insert) and non-dioxin-like PCBs in biota (lower insert). The assessment is carried out using Scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service:** PCBs, dioxin and furan.

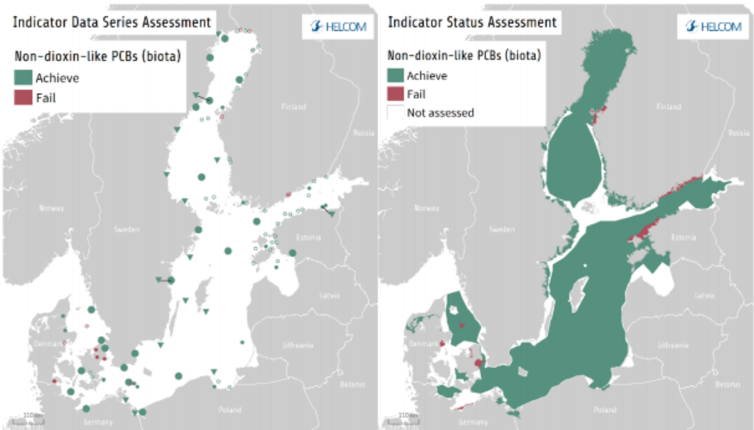
Good status was achieved in the majority of coastal and open sea areas. PCBs as well as dioxins and furans were responsible when the overall good status was not achieved. However, there are areas where dioxins and furans data are absent, or of low abundance and often short time series (i.e. initial data) and thus extended monitoring is required to enable an improved status evaluation in the entire Baltic Sea. A good example of this is the fail status in the One-Out-All-Out (OOAO) method map (Key figure message 1) that is driven by the status of dioxin-like PCBs, dioxins and furans, the assessment if which is based on limited data availability and a precautionary 'initial' data handling approach (see assessment protocol and Results figure 2. Time series of PCB levels in biota show decreasing concentrations at some stations, e.g. in the Bornholm Basin, the Eastern Gotland Basin and the Bothnian Bay. However, most of the stations show no significant trends. The confidence of the indicator assessment is moderate. The indicator is applicable in the waters of all countries bordering the Baltic Sea.

PCBs are synthetic chemicals which do not occur naturally in the environment. Due to their properties, PCBs have been used in a wide variety of applications and manufacturing processes, especially as plasticizers, insulators and flame-retardants. They are widely distributed in the environment through, for example, inappropriate handling of waste material or leakage from transformers, condensers and hydraulic systems. Long-term effects of PCBs include increased risk of cancer, infections, reduced cognitive function accompanied by adverse behavioural effects, as well as giving birth to infants of lower than normal birth weight (Carpenter 1998, Carpenter 2006). There are also indications that PCBs are associated with reproductive disorders in marine top predators.
Dioxins (PCDD/Fs) were never produced intentionally, but they are minor impurities in several chlorinated chemicals (e.g., PCBs, chlorophenols, hexachlorophene, etc.) and are formed in several

industrial processes and from most combustion processes, such as municipal waste incineration and small-scale burning under poorly controlled conditions. The most relevant toxic effects of PCDD/Fs are developmental toxicity, carcinogenity and immunotoxicity.

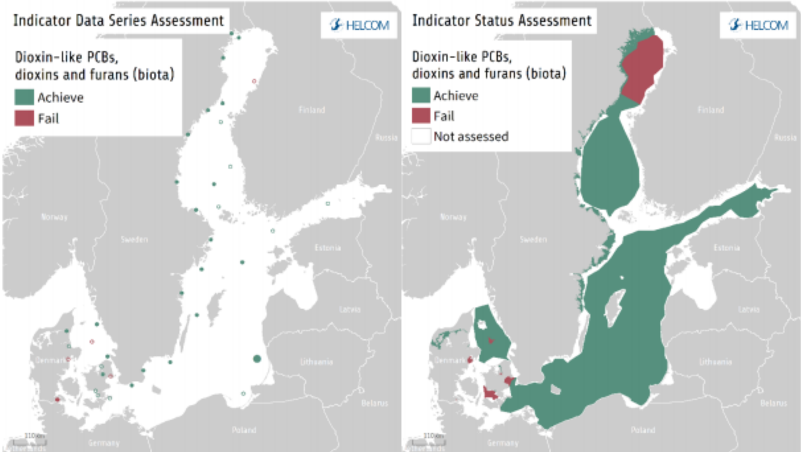
Good status was achieved in terms of concentrations of non-dioxin like PCB (Sum of 6 CB: 28, 52, 101, 138, 153 and 180, see Good Environmental status table 1) in fish in most evaluated assessment units during the period 2011-2016, as the average concentrations were below the threshold value of 75 µg/kg wet weight (ww) in fish muscle (or 75 ng/g ww) (Results figure 1). At some stations, especially along the coast in the Bothnian Bay (< 3 years data), the Arkona Basin, Gulf of Finland (< 3 years data), Kattegat and in the Quark (< 3 years data), good status was not achieved. The concentrations of PCB showed no trend or were based on too few years of monitoring to do a trend assessment.

The results are based on PCB concentrations in different fish species, but also different matrices, i.e. muscle and liver (Results figure 1). To reduce the variability between different matrices, the threshold value is adapted to differences in lipid content of different matrices.



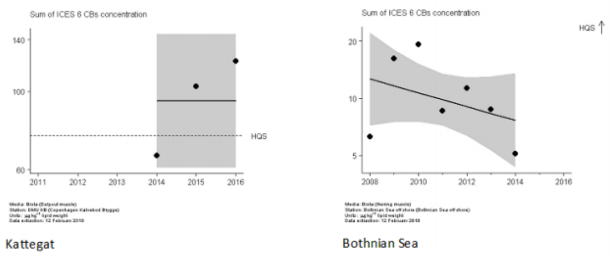
Results figure 1. Spatial variation of the non-dioxin like PCBs (Sum of 6 PCB) sampling stations in biota (flounder, common dab, herring, cod, European perch, European sprat and eelpout) (left) and status assessment in biota (right). Green colour indicates that the upper 95 % confidence interval for non-dioxin like PCBs concentration is below the threshold value (i.e. good status). Small open circles indicate a status assessment based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. **Click here to access interactive maps at the HELCOM Map and Data Service:** PCBs, dioxin and furan.

Good status was achieved in terms of concentrations of dioxins and furans in fish in most of the evaluated assessment units during the period 2011-2016, as the average concentrations were below the threshold value of 0.0065 TEQ/kg ww (fish muscle, crustaceans or molluscs) (Results figure 2).
At some stations in the Bothnian Bay (< 3 years data), the Arkona Basin (< 3 years data), Great Belt and Kattegat (< 3 years data) good status was not achieved. The concentration of dioxins and furans showed no trend or were based on too few years of monitoring to do a trend assessment.
The results are based on dioxin and furan concentrations is acquired from different fish species (Results figure 2) and in some cases different matricies (liver and muscle), which lead to an extra variability in the results due to species/matricies differences. However, to reduce the variability between different species/matrices, the threshold value is adapted to differences in lipid content of different species/matrices.

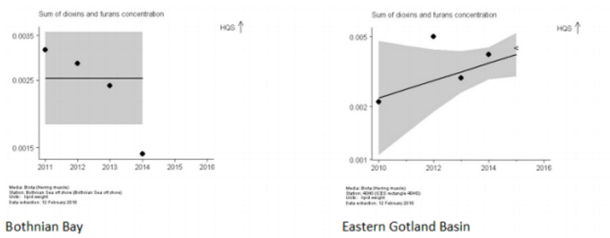


Results figure 2. Spatial variation of dioxin and furan sampling stations in biota (European perch, European sprat, flounder, herring and eelpout) (left) and status assessment by assessment unit (right). Green colour indicates that the upper 95 % confidence interval for non-dioxin like PCBs concentration is below the threshold value (i.e. good status). Small open circles indicate a status assessment based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. **Click here to access interactive maps at the HELCOM Map and Data Service:** [PCBs, dioxin and furan](#).

Non dioxin-like PCBs: The data from biota monitoring stations show decreasing or no significant trend for PCBs. Results figure 3 shows examples of different trends at stations in the Baltic Sea. Monitoring data for dioxins and furans are only available in ICES database since 2010, and in all cases these show no significant trend (Results figure 4 shows examples). Furthermore, some dioxin data are not sufficient for trend assessment to be made (i.e. less than 3 years of data) and are therefore only shown as status assessment data and treated with the precautionary 'initial' data approach (see assessment protocol).



Results figure 3. Temporal trend of the sum of 6 PCBs concentration (ng/g wet weight) in herring and eelpout muscle from the Kattegat and the Bothnian Sea (HQS – threshold level (Human-health Quality Standard), grey colour- confidence level 95% range (see Assessment protocol)).



Results figure 4. Temporal trend of the Sum of dioxins and furans concentration (ng/g wet weight) in herring muscle from the Bothnian Bay and the Eastern Gotland Basin (HQS – threshold level (Human-health Quality Standard), grey colour- confidence level 95% range (see Assessment protocol)).

The overall confidence of the assessment is moderate. The geographical resolution of the current dataset for the coverage of the whole Baltic Sea is high, mainly due to measurements of non-dioxin like PCBs, even so dioxin and furan data were assessed in Denmark, Sweden, Lithuania and Finland so far. No detailed geographical studies to investigate the variability in dioxin and furan concentrations across the whole region have yet been carried out. It should also be noted that the majority of the monitoring stations are selected as reference stations and potential local problems with

PCBs, dioxins and furans may occur in areas not included in the current monitoring programmes. The confidence of the threshold for the Sum of 6 PCBs is low as this value is derived from the food safety directive and no environmental quality standard is available. Thus, the overall confidence is moderate

Thresholds table 1. Threshold value for the core indicator 'PCBs, dioxins and furans'. The secondary threshold value for the dl-PCB CB-118 is not yet fully agreed in HELCOM and therefore not used in the assessment and marked *.

	Primary threshold value	reference	*Secondary threshold value**	*reference*
Dioxin and dioxin-like compounds	Sum of PCDDs, PCDFs, dl-PCBs 0.0065 TEQ/kg ww fish, crustaceans or molluscs	EQS biota human health 2013/39/EU	*CB-118 24 µg/kg lw fish liver or muscle*	*EAC*
Non-dioxin like PCBs	sum of congeners (28, 52, 101, 138, 153, 180) 75 µg/kg ww fish muscle	EC 1881/2006 and 1259/2011		

The threshold value for PCB is defined for the Sum of 6 congeners (non-dioxin like) (Good Environmental status Table 1). Other congeners included in current monitoring programmes can be included when suitable boundary values become available. For dioxins, the threshold value is defined as the EQS-value for human consumption. However, this EQS value stems from the foodstuff legislation and is derived taking into consideration information beyond the environmental parameters, such as typical levels of contaminants in different foodstuff. The aim of the target value is to identify and prevent contaminated foodstuff from being placed on the market. Thus, the foodstuff threshold values do not cover all combinations of matrices and contaminants relevant for an environmental assessment of the marine environment. Because of this, a full equivalence between EQSs based on foodstuff threshold values and EQS based on toxicological evaluations should not be expected.

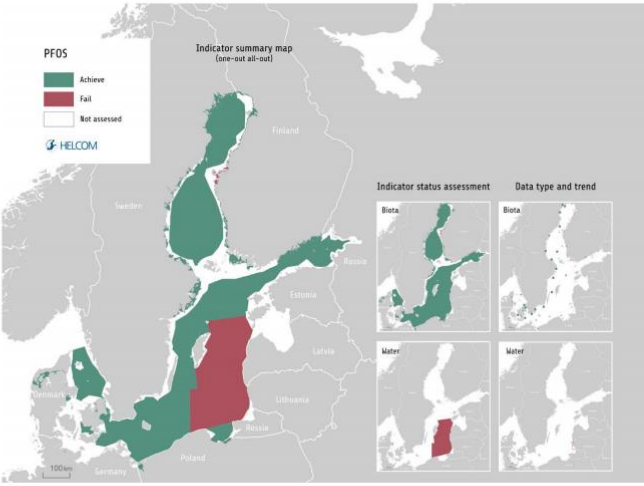
PCBs, dioxin and furan are considered relevant substances to evaluate in the entire Baltic Sea area. Concentrations may be higher in the coastal areas compared to the offshore areas, and therefore the indicator is evaluated on HELCOM assessment unit scale 4.

Numerous recent reports and papers have shown differences in PCDD/F and dl-PCB concentrations in Baltic herring, sprat and salmon between the Baltic Sea basins (e.g., Bignert et al. 2017; Karl et al. 2010). Higher concentrations have been detected in the northern basins where dioxin and dl-PCB levels in herring exceed established maximum limit concentrations for human consumption. Regional variation within a sub-basin has been found in the Swedish coastal region of the Bothnian Sea (Bignert et al. 2007), where the concentrations are higher than in other Swedish areas (Bignert et al. 2017). Since the atmospheric deposition pattern (lowest in the north) is different compared to the patterns detected in the concentrations in fish (generally highest in the north), other factors or sources than atmospheric deposition are thus likely to be involved. The reasons remain unclear, but higher historical PCDD/F discharges from point sources in the northern basins have been suggested. In general, the contribution from the dl-PCBs to the TEQ is substantial and seems to increase the further south in the Baltic region the samples are collected.

HELCOM INDICATORS – HELCOM core indicator report, July 2018

Perfluorooctane sulphonate (PFOS)

This core indicator evaluates the status of the marine environment based on concentrations of perfluorooctane sulphonate (PFOS) in Baltic Sea fish and in a few assessment unit using the secondary matrix seawater. Good status is achieved when the concentrations of PFOS are below the threshold values. The current evaluation considers the assessment period 2011-2016.



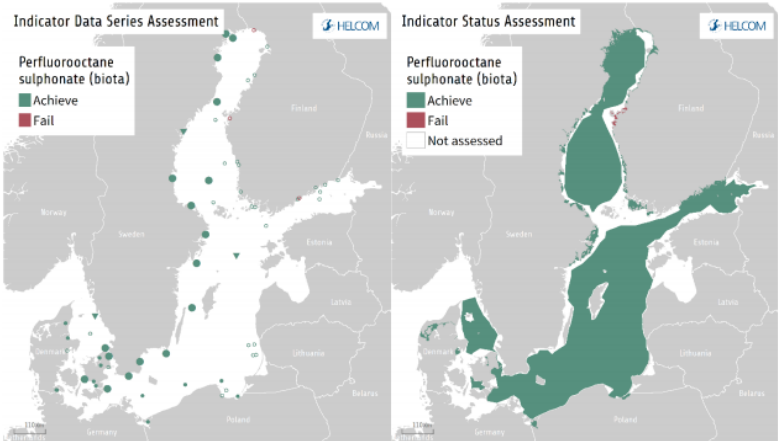
Key message figure 1. Status assessment results based on evaluation of the indicator 'perfluorooctane sulphonate (PFOS)'. One-Out-All-Out (OOAO) method (main figure), in biota (upper inset) and in seawater (lower inset). The assessment is carried out using scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: PFOS.**

Concentrations of PFOS are below the threshold value in biota in almost all the monitored areas. However, the concentrations in seawater exceed the threshold value (EQS for water) where measured. This is the reason for the large red area in summary indicator map. Good status is achieved for all evaluated areas, except for L4-area FIN-006 (Merenkurkun sisäsaaristo), using the primary threshold in matrix biota for the assessment period 2011-2016. Data is available from Denmark, Finland, Poland and Sweden but there are still areas where data are absent, for example, Gulf of Riga and the Estonian coast of the Gulf of Finland. A lot of the monitoring stations are also only based on one or few years of monitoring data, therefore, extended monitoring would be required to enable a complete status evaluation throughout the Baltic Sea.
Time series of PFOS levels in biota show increasing concentrations since the 1970s and 1980s in the Baltic Proper and the Bothnian Sea. However, in the most recent ten-year period decreasing concentrations of PFOS are observed in the Baltic Sea.
The confidence of the indicator evaluation results is considered to be high for those areas for which data are available. The indicator is applicable in the waters of all the countries bordering the Baltic Sea.

PFOS is a persistent, bioaccumulative and toxic compound with possible effects on the immune, reproductive and developmental systems as well as lipid metabolism in organisms. It is considered a global environmental contaminant. PFOS has been produced since the 1950s, and has been used for production of fluoropolymers and used commercially to provide grease, oil and water resistance to materials such as textiles, carpets, paper and coatings in general. PFOS has also been used widely in firefighting foams. Measurements of PFOS concentrations provide information on the contaminant load of the Baltic Sea, the presence of PFOS in biological samples also reflects the bioavailable part of the contaminant. Predators (particularly top predators) and humans are exposed to the contaminant through consumption of the species assessed in this indicator.

All scale 4 assessment units evaluated for the primary matrix biota achieved good status during the period 2011-2016, except for unit FIN-006 (Merenkurkun sisäsaaristo). It should be noted that those assessment units failing the threshold were generally dominated by few and short data series (i.e. ‘initial’ data, see assessment protocol) for this current assessment. This means that the upper confidence concentration of PFOS in sampled fish were below the threshold value (Key message figure 1 and Results figure 1). The primary threshold value is set to 9.1 µg/kg wet weight in fish muscle (or 9.1 ng/g ww) with the protection goal of human health.

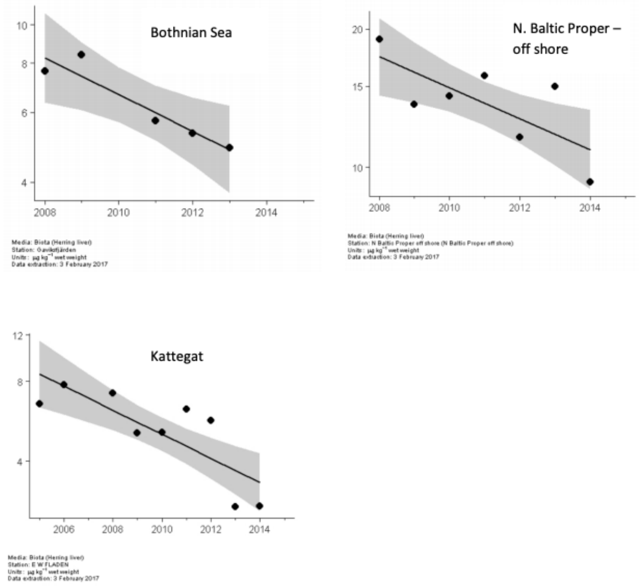
There are currently areas in the Baltic Sea that are not covered by any PFOS monitoring (Results figure 2). The Estonian coastline of Gulf of Finland and the Gulf of Riga lack reported PFOS concentrations. There are also areas where the results are only based on measurements of 1-2 years (‘initial’ data: open circles in Results figure 2.). Thus increased monitoring is needed to enable a status evaluation for the entire Baltic Sea. The lowest mean concentration in the aggregated assessment (0.32 ng/g ww muscle) is observed in area SEA001 (the Kattegat open sea subbasin) and the highest concentration in area FIN-006 (Merenkurkun sisäsaaristo) with estimated upper confidence interval of 13 ng/g ww muscle (1.4 times the threshold value) (Results figure 1).



Results figure 2: Spatial distribution of PFOS monitoring stations for biota (herring, cod, perch, eelpout and European flounder are represented) (left) and status assessment by assessment unit in biota (right). Green colour indicates that the upper 95 % confidence interval for PFOS concentration is below the threshold value (i.e. good status). Small open circles indicate a status assessment based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. **Click here to access interactive maps at the HELCOM Map and Data Service: PFOS.**

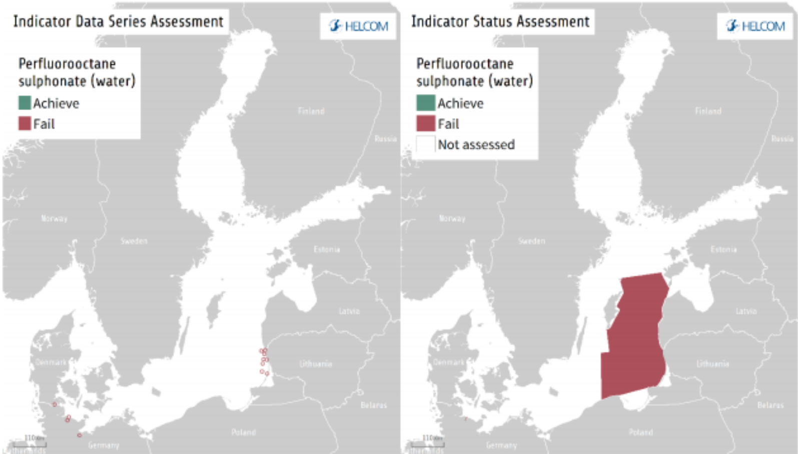
It is important to be aware that the results used for this core indicator are mainly (but not completely) based on fish from stations considered as reference stations with no local pollution. There are most likely local areas within the Baltic Sea where the pollution load of PFOS is higher than presented in the evaluation outcome of this indicator.

Increasing PFOS concentrations have been shown in biota time series starting in the 1970s and 1980s (Bignert et al. 2017). However, some downward trends are seen in herring from the Bothnian Sea, the offshore station in the Northern Baltic Proper and in Kattegat in the more recent time period (Results figures 2 and 3) in the current assessment.



Results figure 3: Temporal trend of PFOS concentration (µg/kg wet weight) in herring liver from the Bothnian Sea, the off shore station in the Northern Baltic Proper and in Kattegat (HQS – threshold level, grey colour- confidence level 95% range (see Assessment protocol)).

Concentrations of PFOS have also been monitored in surface water by some countries (Denmark, Germany and Lithuania). When these results are assessed for the QS(secondary poisoning)set in water, all assessment units fail the threshold value (Results figure 4 and 5). The water QS is derived from biota QS and the difference in PFOS status between biota and water are most likely due to uncertainties in translation of biota QS into water QS. The translation involves assumptions of bioconcentration factors and biomagnification factors with a precautionary approach and may lead to a stricter QS value in water.



Results figure 4: Spatial distribution of PFOS monitoring stations for the secondary threshold evaluation in seawater (left) and status assessment by assessment unit in seawater (right). Green colour indicates that the upper 95 % confidence interval for PFOS concentration is below the threshold value (i.e. good status). Small open circles indicate a status assessment based on only 1-2 years of data (initial data), small filled circles indicate that data is not suitable to assess a trend (treated with initial methodology), large filled circles that no detectable concentration trends can be identified during the whole monitoring period (full data), and the filled arrow indicate that there is a statistically defined upward or downward trend during the monitoring period. The assessment is carried out using scale 4 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **Click here to access interactive maps at the HELCOM Map and Data Service: PFOS.**

The geographical resolution for the coverage of the whole Baltic Sea is low. No detailed geographical studies to investigate the variability have yet been carried out. The conversion of PFOS concentrations in liver to muscle values introduces uncertainties into the status evaluation. In addition, the trophic level of the fish used for monitoring (predominantly herring, which has a trophic level of approximately 3 in the Baltic Sea) is lower than recommended for the threshold value, thus leading to possible underestimations in relation to the threshold value.
With the uncertainties and low geographical coverage taken into account, but with values considerably lower than the threshold value, the confidence in the evaluation of the aggregated assessment units is considered to be high.

Good status is achieved when the concentration of perfluorooctane sulphonate (PFOS) in fish muscle is below 9.1 µg/ kg fish wet weight. The threshold value is an environmental quality standard (EQS), derived at EU level as a substance included on the list of priority substances under the Water Framework Directive (European Commission 2000, 2013). Good environmental status within the MSFD is defined as 'concentrations of contaminants at levels not giving rise to pollution effects'.

An alternative, secondary threshold value at 0.00013 µg/l is set for water. It is derived within the EQS process by using a bioconcentration factor and biomagnification factor for PFOS and represents the corresponding water concentration to the selected QS biota, secondary poisoning (PFOS EQS dossier, 2011). The secondary threshold value should only be used when it is not possible to evaluate an area using the primary biota-based threshold value.

The production and use of perfluorooctane sulfonate (PFOS) has been regulated in some countries (e.g., US, Canada, and the EU), but large-scale PFOS production continues in other parts of the world, e.g. China. PFOS has been produced and used since the 1950s, but due to findings of detectable concentrations in human blood in the general population and negative health effects on living organisms, PFOS was phased out in 2002 by its main producer 3M.

Marine mammals have considerably higher contamination levels of PFOS compared to marine and freshwater fish, and were found to be the most contaminated by PFOS of all Nordic biota studied (HELCOM 2010). Several hundreds to one thousand μg kg−1 ww of PFOS have been found in the livers of grey seals (in the southern Baltic Proper and Bothnian Sea; Nordic Council of Ministers 2004), harbour seals (Great Belt and the Sound; Nordic Council of Ministers 2004) as well as ringed seals (Bothnian Bay; Kannan et al. 2002). In the eggs of common guillemots (Western Gotland Basin), PFOS concentrations were greater than 1,000 μg kg−1 ww (Holmström et al. 2005). An OSPAR risk assessment (OSPAR 2005) on the marine environment concluded that the major area of concern for PFOS is the secondary poisoning of top predators, such as seals and predatory birds.

The evaluations in this core indicator are made based on concentrations mainly measured in fish, usually from reference areas with no specific local pollution load. The case studies and measurements from marine mammals in the Baltic Sea, highlight that PFOS may pose more severe contamination risks to the Baltic Sea than the current indicator evaluation would suggest.

Only a few measurements of PFAS in the Baltic Sea surface water exist (Nordic Council of Ministers 2004; Theobald et al. 2007; Lilja et al. 2009) and they were mostly performed in potentially affected coastal areas. PFOA and PFOS dominated the water samples. Concentrations of PFOA were determined in the range 0.57- 0.68 ng l−1 (Little Belt, Kiel Bight, Mecklenburg Bight, Arkona Basin) up to 4–7 ng l−1 (Little Belt, the Sound, coast of Poland, Gulf of Finland). PFOS was found at levels of 0.34-0.90 ng l−1 for all locations mentioned, with the exception of single measurements of 2.9 ng l−1 (coast of Poland) and 22 ng l−1 close to Helsinki (Gulf of Finland). Farther away from the coast, in the Arkona Basin, PFOA and PFOS levels were 0.35-0.40 ng l−1 .

Limited data exist for PFAS concentrations in Baltic Sea sediments (Nordic Council of Ministers 2004; SEPA 2006; NERI 2007; Theobald et al. 2007). PFOS and/or PFOA were occasionally detected, but consistently at levels below 1 μg kg−1 dw or ww. The highest levels reported so far have been from the Gulf of Finland close to Helsinki (PFOS 0.9 μg kg−1 ww), close to Stockholm (PFOS 0.6 μg kg−1 ww) and along the coast of Poland (PFOS and PFOA both around 0.6 μg kg−1 dw). Along the German Baltic Sea coast, concentrations of PFOS in sediments were in the order of 0.02-0.67 μg kg-1 dw and those of PFOA 0.09-0.68 μg kg-1 dw (Theobald et al. 2007).

The most important route of exposure of PFOS for humans is uptake from food (especially fish), drinking water and exposure to indoor dust (FOI 2013).

PFOS is both intentionally produced as well as an unintended transformation product of related anthropogenic chemicals. PFOS is still produced in several countries, such as China. Some PFAS have been manufactured for more than five decades. They are applied in industrial processes (e.g., production of fluoropolymers) and in commercial products such as water- and stain-proofing agents and fire-fighting foams, electric and electronic parts, photo imaging, hydraulic fluids and textiles (Paul et al. 2009).

The American company 3M, was the main producer of PFOS and its related substances until 2002. They started the production of perfluorochemicals already in 1949. The production of PFOS increased between 1966 and 1990 and peaked between 1990 and 2000. In 2003, China started a large scale production of PFOS. Between 2003 and 2008 China was both the main global producer and user of PFOS substances. However, also Japan and Germany produced PFOS during the same time period, but after 2007 no PFOS production occurs in Germany (Carloni 2009).

The major transport ways of PFOS to the Baltic Sea has been shown to be rivers (77%) but also atmospheric deposition (20%). Waste water treatment plants on the other hand were shown to have a negligible contribution (less than 2%) (Filipovic et al. 2013). The sources of PFOS to the atmosphere are still not clear, but a major contributor is believed to be transformation of precursor compounds (FOSA (Perfluorooctane sulfonamide) and FOSE (Perfluorooctane sulfonamidoethanol)) that have been emitted from production facilities and fluorochemical products (Armitage et al. 2009). Seventy-eight percent of the total PFOS in the Baltic Sea was estimated to be stored in the water column (Filipovic et al. 2013).

PFAS can be introduced into the environment both from point sources (e.g. landfills, manufacturing plants, application of firefighting foam containing PFOS) and non-point sources such as atmospheric deposition and degradation of precursors (Ahrens & Bundschuh 2014). High amounts of PFOS have been found in both sludge and groundwater close to military air base sites and airports where firefighting foam has been used to prevent fires (FOI 2013; Arias et al. 2015). Furthermore high levels of PFAS, including PFOS, have been found close to industries producing fluortelomers (Wang et al. 2014; Shan et al. 2014).

Environmental monitoring of perfluorooctane sulphonate (PFOS) in biota is currently not coordinated in the HELCOM community, but general information about monitoring in the region is documented in the HELCOM Monitoring Manual under the sub-programme: Contaminants in biota. So far, there are no technical guidelines related to PFOS monitoring in biota in the HELCOM Monitoring Manual and there is a need to develop such common monitoring guidelines.

Denmark, Finland, Germany and Sweden monitor PFOS concentrations in their national monitoring programmes. During the period 2014-2019, Poland will include PFOS analysis in fish muscle to their national monitoring. Germany monitors PFOS in biota from 2018 and in water from 2017. Lithuania monitors PFOS in water, sediments and biota every 3 years since 2015. Estonia will include PFOS analyses in coastal waters (water, sediment and biota) from 2017. The substance is not included in the monitoring programmes in Latvia. No information is available from Russia. A few measurements in water and fish (flounder and herring) were taken from Estonia, Latvia, Lithuania and Poland during the HELCOM SCREEN project (2009). Finland has screening data from several fish species for human consumption along the coast line (Koponen et al. 2015).

AMAP

AMAP Assessment 2015: Temporal trends in persistent organic pollutants in the Arctic

Monitoring undertaken to contribute to the AMAP Trends and Effects Monitoring Programme includes studies that aim to establish long-term trends which can be used (i) to assess the effectiveness of national and international control strategies, (ii) to assess long-range transport of POPs to the Arctic, and (iii) to identify new priority chemicals which may be of concern in the region.

Long-term (multi-annual) changes in levels of POPs in Arctic environmental media and biota are determined by a number of factors, including:

- changes in primary emissions/releases of these chemicals (or their precursors), related to production and uses in industrial applications, agriculture, consumer products, and other uses; and from waste streams associated with such uses
- changes in re-emissions of chemicals that have accumulated in environmental media such as surface soils and surface waters (including possible influences of climate change)
- changes in environmental transport pathways, and processes that affect these, both in abiotic systems (e.g. winds and ocean currents) and in biological systems (ecosystem and food web structure, etc.).

The influence of these factors is also likely to depend on whether contamination is associated with local sources or (long-range transport) from remote sources.

The AMAP Trends and Effects Monitoring Programme is a harmonized program for monitoring the trends and effects of contaminants and climate change across the circumArctic region. It includes sub-programs concerned with monitoring atmospheric, marine, terrestrial and freshwater media, and human tissues (in connection with monitoring effects of contaminants on human health). The AMAP monitoring program is based largely on ongoing national monitoring and research activities that comprise AMAP national implementation plans of the eight Arctic countries. AMAP coordinates these activities and works to ensure harmonization, and to promote quality assurance activities, and compiles results for use in circumArctic assessment activities. The AMAP program is also coordinated with other international programs such as the UNECE European Monitoring and Evaluation Programme (EMEP) and OSPAR's Joint Assessment and Monitoring Programme (JAMP). The AMAP program therefore represents a significant component in the implementation of the GMP in the Arctic.

AMAP's previous POPs temporal trend assessment (AMAP, 2010) included a treatment of time-series in air (Hung et al., 2010) and biota (Rigét et al., 2010) up to 2006/7. Many of these time-series are extended to 2011/12 in the present assessment and these additional years provide a more (statistically) solid foundation for evaluating temporal trends of POPs in Arctic air and biota. See Annex 1 for a discussion of the power of the AMAP biota trends monitoring program for trend detection.

A large number of time-series datasets were considered in this assessment – over 2000 for contaminants in biota and more than 150 for contaminants in air. With so many datasets it is not practical to examine each in the level of detail that would be required to rigorously address all potential confounding factors and supplementary information. The main objective of this assessment has therefore been to apply robust statistical methodologies consistently to all available time-series – to gain a general overview of trends for certain compound groups across the wide range of datasets available, and across the entire geographical region. On this basis, a form of metaanalysis is performed, looking at the consistency (or otherwise) of the apparent trends. In addition, information from more detailed data interpretations produced by those responsible for individual (national) trend studies has also been compiled, and where possible used to qualify the results of the robust trend evaluations.

It should be noted that trend statistics produced in the metaanalysis conducted in this assessment and those produced in other work may differ, depending for example on the statistical methods applied, although these differences are generally small. What is gained from a more careful consideration of individual time-series is, however, better insight into possible reasons for trends, which may be associated with local conditions and/or circumstances pertaining to the specific monitoring studies.

Time-series datasets considered – POPs monitoring in biota

For biota, time-series are available from seven countries for a total of 75 location-species-tissue combinations. These include locations in Alaskan marine areas; Arctic Canada; East Greenland (Ittoqqortoormiit area) and West Greenland (Disko Island area and Isortoq), subsequently referred to as eastern and western Greenland; marine areas around Iceland, the Faroe Islands and northern Norway; and lakes in Sweden. No relevant biota timeseries datasets are currently available for the Arctic areas of Russia or Finland. Figure 2.1 shows locations where long time-series monitoring of POPs in Arctic biota are conducted

Figure 2.1 Locations where long time-series monitoring of POPs in Arctic air and biota are conducted. For biota, the species monitored are also indicated.

For the purposes of this assessment, AMAP biota monitoring datasets were selected that included at least six years of data. For 'legacy' POPs, priority was also given to timeseries that included data from both before and after 2000. The average length of the time-series considered is around 12 years; the longest available time-series has 42 years of data and some time-series include samples collected as early as 1975. Previous AMAP temporal trend assessments (e.g. Rigét et al., 2010) have included terrestrial and marine species. The current assessment includes only marine and freshwater species as no new data were available for the terrestrial components.

Icelandic and Norwegian datasets include data reported to AMAP/OSPAR and archived at the AMAP marine TDC at the International Council for the Exploration of the Sea (ICES) in Denmark. Other AMAP data were collected from lead scientists responsible for relevant temporal trend monitoring studies in Canada, Denmark/ Greenland/ Faroe Islands, Sweden and the United States.

Statistical methods applied

Time-series datasets for POPs in biota samples were analyzed using a robust regression approach (based on Nicholson et al., 1998) testing for both linear and non-linear trend components, using the PIA computer application developed by Anders Bignert and co-workers (Bignert, 2013; see also Annex 1).

Statistical analyses were applied to individual time-series for 65 compounds/compound groups (see Tables 3.1 and 3.2). In all, some 2481 statistical analyses were performed. Of these, a significant number (310) were excluded because the time-series concerned were considered unsuitable for statistical analyses (for example, they included a large proportion of 'less than' values). A selection was also made where alternative runs were performed using different available covariates. Results for some 1809 datasets were eventually summarized and evaluated, comprising time-series that start before 2000 (1074 datasets) as well as time-series that begin in or after 2000, or have years prior to 2000 excluded (735 time-series), see Figure 3.1. The largest number of trend results for a single contaminant was 61 (for CB153 time-series covering the entire period).

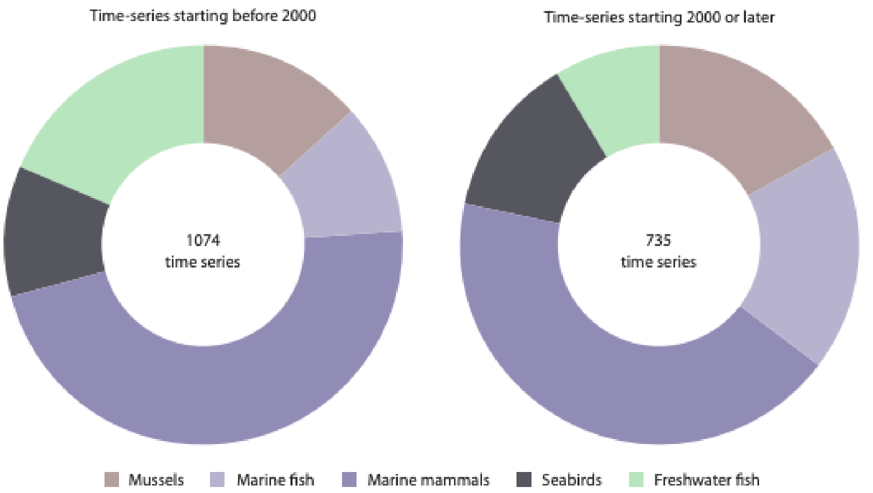


Figure 3.1 Overview of available biota time-series shown by animal group.

Table 3.1 Number of time-series starting before 2000 by compound/compound group and country.

Compound / Compound Group	Canada	Faroe Islands	Greenland	Iceland	Norway	Sweden	USA	Total
Dieldrin	19		3					22
cis-Chlordane	4	3	3	5			4	19
trans-Chlordane	4	3		3			4	14
cis-Nonachlor	4	3	3				4	14
trans-Nonachlor	8	3	8	11			5	35
Oxychlordane	4	3	8		1		4	20
ΣCHL	18	3	5				5	31
o,p'-DDD		2					4	6
o,p'-DDE		2					4	6
o,p'-DDT		2					3	5
p,p'-DDD	4	3		5	3		4	19
p,p'-DDE	20	3	8	12	11	2	4	60
p,p'-DDT	4	3			1		4	12
ΣDDT	21	3	8	10	10		5	57
HEPOX	4		3				5	12
HCB	19	3	8	10	7	2	5	54
α-HCH	20		8	9	2	2	5	46
β-HCH	16	3	7	2			5	33
γ-HCH	16		4	2	3	2	4	31
Mirex	8	3					5	16
Pentachlorbenzene	9						4	13
CB28	4	3	1		10			18
CB31	4		1					5
CB28/31							4	4
CB52	4	3	7		10		4	28
CB99		3			1			4
CB101	4	3	8		10		4	29
CB105	4	3	2		10		4	23
CB118	4	3	2		11	2	4	26
CB128		3						3
CB138	4	3	8		11		4	30
CB153	20	3	8	12	11	2	5	61
CB156	2	3	1		10		4	20
CB158							1	1
CB170		3			1			4
CB180	4	3	8		11		4	30
CB183		3						3
CB187		3						3
CB209					10		1	11
ΣPCB_{10}	20	2	8	10	11		5	56
Toxaphene Parlar 26		3	4	9			1	17
Toxaphene Parlar 32							1	1
Toxaphene Parlar 50		3	4	9			1	17
Toxaphene Parlar 62		1					1	2
BDE47	14	1	6			1	4	26
BDE49							1	1
BDE99	9	1	5				4	19
BDE100							2	2
BDE153						1	1	2
BDE154							1	1
BDE155							1	1
HBCDD	3		5				1	9
PFCs							3	3
PFDA	3	1	3				3	10
PFDoA	3		3				3	9
PFHxS							4	4
PFNA	3	1	3				4	11
PFOA			3					3
PFOS	6	1	6			2	4	19
PFOSA	1		3				4	8
PFTA							3	3
PFTrA			3				4	7
PFUnA	3	1	3				4	11
OCS	8		3					11
Total	**329**	**102**	**184**	**109**	**155**	**16**	**186**	**1081**

Table 3.2 Number of time-series starting in 2000 or later by compound/compound group and country.

Compound / Compound Group	Canada	Faroe Islands	Greenland	Iceland	Norway	Sweden	USA	Total
Dieldrin	10		3					13
cis-Chlordane	2	3	3	10				18
trans-Chlordane	2	3		2				7
cis-Nonachlor	2	3	3					8
trans-Nonachlor	4	4	7	11				26
Oxychlordane	2	3	7	2				14
ΣCHL	10	5	4				1	20
o,p'-DDD		1						1
o,p'-DDT		1						1
p,p'-DDD	2			8	2			12
p,p'-DDE	12	5	7	13	10	2	1	50
p,p'-DDT	2	2			1			5
ΣDDT	11	3	7	12	8		1	42
HEPOX	3		2				1	6
HCB	10	5	7	11	7	2	1	43
α-HCH	12		7	11	3		1	34
β-HCH	11	3	7	2			1	24
γ-HCH	7		4	6	4		1	22
Mirex	5	4					1	10
Pentachlorbenzene	7				1			8
CB28	2	3			2			7
CB31	2		1					3
CB52	2	3	7		3			15
CB99		3						3
CB101	2	5	7		5			19
CB105	2	4	2		3			11
CB118	2	5	2		6	1		16
CB128		4						4
CB138	2	3	7		8			20
CB153	12	5	7	13	10	2	1	50
CB156	1	3			1			5
CB163		3						3
CB170		3						3
CB180	2	5	7		3			17
CB183		3						3
CB187		3						3
ΣPCB_{10}	12	5	7	11	11		1	47
Toxaphene Parlar 26		4	4	12				20
Toxaphene Parlar 50		5	4	13				22
Toxaphene Parlar 62		1						1
BDE47	13		6			1	2	22
BDE99	10		5				2	17
BDE153						1		1
HBCDD			1					1
PFDA	2		3					5
PFDoA	2		3					5
PFNA	2		3					5
PFOA			3					3
PFOS	3		3			2		8
PFOSA			3					3
PFTrA			3					3
PFUnA	2		3					5
OCS	5		3		1		2	11
Total	**194**	**115**	**162**	**137**	**89**	**11**	**17**	**725**

The PIA statistical application (Bignert, 2013) provides a robust method for investigating trends in time-series data represented by annual index values (Nicholson et al., 1998). The method employed tests for the presence of (log-)linear trends, and nonlinear trend components (for example an increase followed by a subsequent decrease) in the time-series (at a significance level of 5%). Median concentrations were used as the annual index values to minimize the influence of outliers and less-thandetection-limit values. The method also evaluates the number of years required to detect an annual change of 5% with a power of 80% for the particular time-series.

Datasets were handled in a manner similar to previous evaluations (Rigét et al., 2010), taking account of data originators' recommendations for sub-setting animal groups and including covariates. Many time-series were run in different configurations (for example, with and without covariate adjustment) to investigate the influence of factors such as age, sex, and lipid content on the observed trends.

Time-series with a large number of values reported as lessthan-detection-limit were examined to consider the pattern of these (for example whether they were concentrated at the end of a time-series exhibiting decreasing trends). Time-series where more than 50% of values were reported as less-thandetection-limit in three or more years and thereby have annual median values of less-than-detection-limit for these years, were generally considered inappropriate for trend analyses, unless these years were concentrated at the start or end of the timeseries. 'Less-than' qualified values were replaced by half the reported detection limit.

Biota trend results were classified as shown in Table 3.3.

Table 3.3 Classification of biota trend results.

Class	Comment
Increasing trend	A statistically significant increasing log-linear trend
Increasing trend with non-linear trend component	Both the increasing log-linear and non-linear trend components are statistically significant
Decreasing trend	A statistically significant decreasing log-linear trend
Decreasing trend with non-linear trend component	Both the decreasing log-linear and non-linear trend components are statistically significant
Non-linear trend component	A statistically significant non-linear (fluctuating) trend with no clear increasing or decreasing tendency
No trend	The time-series did not exhibit a statistically significant trend
Not evaluated	The time-series was unsuitable for trend analysis (for example, it contained too many 'less-than-detection-limit' values)

Temporal trend analyses results

Aldrin, endrin, and dieldrin

Twenty-two dieldrin time-series starting before 2000 were assessed; 19 (including freshwater fish, seabird eggs, and marine mammals) were from Arctic Canada, and three (marine mammals) from eastern Greenland. Ten showed significant decreasing trends or decreasing trends with a non-linear trend component; three increasing trends (all <1% per year) were identified, but none were statistically significant. The mean annual decrease for time-series starting before 2000 was 3.0%. For the post-2000 period, only one (ringed seal Pusa hispida, Canada) of 13 available time-series showed a significant decreasing trend, and the mean annual decrease was close to zero indicating little if any decrease in levels since 2000.

The observed rate of dieldrin decrease in biota (a mean of 3% per year) also reflects very slow declines consistent with the air observations of barely discernible changes over the period since 1993 (a 3% annual change is equivalent to a first order half-life of 23 years). The indications are therefore that Arctic (aldrin and) dieldrin contamination has slowly decreased following bans introduced in the period before 2000. Levels of dieldrin currently observed in Arctic biota are relatively low (means of annual medians since 2010 of about 30–40 ng/g lipid weight (lw) in blubber of Canadian ringed seal populations, about 430 ng/g lw in beluga Delphinapterus leucas blubber from Canada, and 150–300 ng/g lw in eastern Greenland polar bear Ursus maritimus adipose tissue) and either stable or changing only slowly, again consistent with a pattern of general equilibration between residual historical accumulation of ‘drins’ in different (Arctic) environmental media and declining entry of dieldrin into Arctic marine food webs

Chlordanes and nonachlors

Long time-series were assessed for ΣCHL (sum of cischlordane, trans-chlordane, cis-nonachlor, trans-nonachlor and oxychlordane) as well as for individual compounds. The largest numbers of time-series starting before 2000 were for ΣCHL (31), trans-nonachlor (35) and oxychlordane (20). Close to half of the ΣCHL, trans-nonachlor and oxychlordane time-series showed decreasing trends or decreasing trends with a non-linear trend component (Fig. 4.6). This was also the case for cis-chlordane and trans-chlordane (not shown in the graphic). Although one transnonachlor time-series did show a significant increasing trend, this particular species-location combination (blue mussel Mytilus edulis, from Hvalstod in Hvalfjörður southwestern Iceland) was located near a whale processing site, which is considered a local source of contamination that may be responsible for increasing trends in several POPs at this site (see the Icelandic national report, Annex 3). The trends for chlordane compounds from all sites ranged between annual decreases of 3.6% for transnonachlor and 9.7% for trans-chlordane.

As for most organochlorines, the proportion of significantly decreasing trends in biota is less and the proportion of no trend time-series is greater when considering time-series starting after 2000. The annual decrease since 2000 ranged from 0.6% for trans-nonachlor to 6.8% for trans-chlordane.

Oxychlordane is the primary metabolite of chlordane and is very persistent (Bondy et al., 2000); seabirds and marine mammals are able to metabolize cis- and trans-chlordane (Fisk et al., 2001). Hence, the ratio between oxychlordane and ΣCHL in some species may provide a rough indication of the age of chlordane residues in the environment. Figure 4.7 shows temporal trends in the ratio of oxychlordane to ΣCHL in three (selected) long time-series. Differences between the ratio in the three species (generally increasing in the order beluga < ringed seal < polar bear) reflect the relative metabolic potential among these species. All three time-series show an increase in the ratio over time; however, this increase is only significant for ringed seal (log linear regression of annual medians, $p<0.01$).This indicates that levels of the metabolite oxychlordane increased relative to some of its precursors, for example, trans-nonachlor and trans-chlordane (Tashiro and Matsumura, 1978).

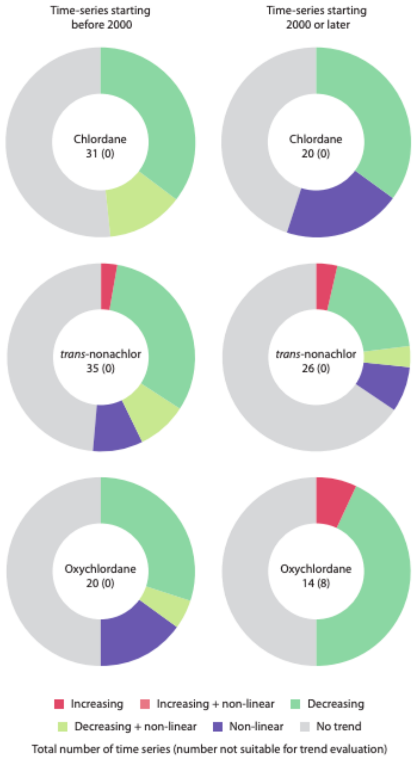


Figure 4.6 Overview of trend results for ΣCHL, *trans*-nonachlor and oxychlordane for time-series starting before 2000 and after 2000.

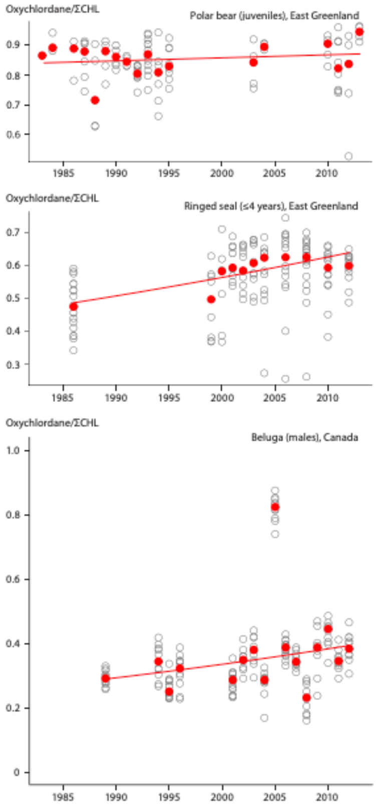


Figure 4.7 Trends in the ratio of oxychlordane to ΣCHL in selected Arctic long time-series.

Trends in biota are consistent with those in air with approximately similar rates of decrease, indicating that Arctic chlordane contamination has decreased following the bans introduced in western industrialized countries since the 1980s.

The highest recent (post-2010) ΣCHL levels are found in pilot whale (Globicephala melas) blubber from the Faroe Islands (1500–2200 ng/g lw) and polar bear adipose tissue from eastern Greenland (1700–2100 ng/g lw). In Canadian and Greenlandic ringed seal populations, recent annual medians were 100–300 ng/g lw in blubber. These can be compared with the highest annual medians in the entire time-series of about 7500 ng/g lw (pilot whale), 4000 ng/g lw (polar bear), and 750 ng/g lw (ringed seal).

Similar to the ‘drins’, trends in levels of chlordanes in Arctic air and biota appear to reflect the influence of bans and controls on these substances introduced in western industrialized countries, including most countries near the Arctic, as early as the 1970s. The slow declines observed in air, with t1/2 = >10 years (<6.9% per year) for all chlordane- and nonachlor-related isomers, are comparable to the annual decreases observed in biota. Levels in Arctic biota are therefore expected to continue to decrease, but only very slowly as chlordanes present in environmental media slowly degrade.

DDTs

Time-series of ΣDDT (sum of p,p’-DDE, p,p’-DDD, and p,p’-DDT) and individual o,p’ and p,p’ isomers in biota were analyzed, including 165 time-series starting before 2000 and 111 starting 2000 or later, most of these for ΣDDT (71%) and p,p’-DDE (82%). Many time-series of p,p’-DDD in mussels and some marine fish could not be evaluated owing to several years with medians below the detection limit. 46% of ΣDDT time-series showed a significant decreasing trend, while this was only the case in 32% of p,p-DDE time-series. One ΣDDT time-series (blue mussel from Hvalstod in Hvalfjörður southwestern Iceland) showed a significant increasing trend, but this particular site is near a whale processing station that is a possible source of local contamination (Sturludottir et al., 2013).

The mean annual decrease was 4.2% and 4.1% (t1/2 = 17 y) for ΣDDT and p,p'-DDE, respectively. For species-tissue-location combinations having time-series of both ΣDDT and p,p'-DDE, no significant difference in annual change was found (paired t-test, $p = 0.64$). p,p'-DDE is the major metabolite of DDT (Kelce et al., 1995). The ratio of p,p'-DDE to Σp,p'-DDTs may be a rough indicator of the age of DDT residues in the environment. Figure 4.10 shows the trends of this ratio in selected long timeseries. In all four time-series the ratio p,p'-DDE to Σp,p'-DDTs increases with time and was significant in polar bear, ringed seal and pilot whale (log-linear regression of annual medians, $p < 0.01$, $p < 0.01$ and $p = 0.03$, respectively), but not in beluga ($p = 0.12$). These results are consistent with an absence of 'fresh' sources of DDT to the Arctic environment. This is also supported by the 12 p,p'-DDT time-series with a mean annual decrease of 9.1% (t1/2 = 7.6 y), the largest mean rate of decrease of all DDT isomers considered, and a similar rate of decline to that observed in air at Zeppelin.

The proportion of post-2000 ΣDDT time-series showing a significant decreasing trend was much lower than for the timeseries starting before 2000 (Fig. 4.11), as was also the case for PCBs (see Sect. 4.9). In the post-2000 time-series, mean annual decreases were 2.4% and 3.6% (t1/2 = 29 and 19 y) for ΣDDT and p,p'-DDE , respectively (which is larger than the decreases observed for PCBs).

Seventeen time-series of o,p'-DDE, o,p'-DDD, and o,p'-DDT were available for pilot whales from the Faroe Islands and beluga and northern fur seal (Callorhinus ursinus) from the United States. Female and juvenile beluga from East Chukchi / Bering Sea and northern fur seals from St. Pauls Island / Bering Sea showed significant non-linear trends with levels relatively constant, followed by a sharp decrease in most recent samples.

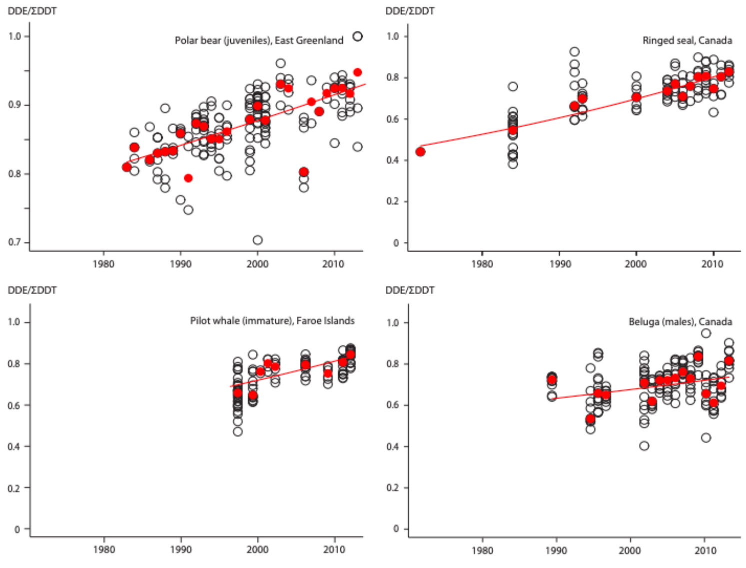


Figure 4.10 Trends in the ratio DDE to Σp,p'-DDTs in selected long time-series.

Figure 4.11 Overview of trend results for ΣDDT and *p,p'*-DDE for time-series starting before and after year 2000.

As a result of national action, levels of DDT and DDE were already strongly declining in biota in western Europe and North America by the mid-1990s (AMAP, 1998). The few available time-series for Arctic biota that extend back to 1970s show that, by 2000, DDE levels had decreased from around 1 to <0.04 ng/g lw in pike (Esox lucius) muscle at Storvindeln in northern Sweden (Fig. 4.12), by a factor of about 5 in seabird eggs at Prince Leopold Island (Canadian Arctic Archipelago), and by a factor of about 3-4 in ringed seal blubber (Canadian Arctic Archipelago) and polar bear adipose tissue (Hudson Bay) (AMAP, 2004).

For the time-series starting before 2000, more time-series with a positive annual change were found in the eastern part of the Arctic than in the western part (Fig. 4.13). Most blue mussel time-series from Iceland and Norway had increasing trends although the trend was significant in only one case.

The highest levels of ΣDDT observed in recent years are found in pilot whales from the Faroe Islands with annual medians since 2010 of 5500–8300 ng/g lw, and in beluga from Canada with annual medians of 1000–4000 ng/g lw. Levels in seabird eggs are also still relatively high in recent years when expressed on a lipid weight basis (annual medians of 400–1300 ng/g lw). In polar bears, which have the highest levels of many POPs, recent levels of ΣDDT are lower, at around 200–300 ng/g lw. This probably reflects the ability of polar bears to metabolize the most persistent DDT compounds (Bernhoft et al., 1997).

Although national and global restrictions have resulted in continuing decreases in levels of DDTs in Arctic ecosystems, biota and humans (AMAP, 2014), the major decline occurred before 2000. This was also the case for air where decreases in concentration were no longer apparent for most DDT isomers after 2000 at sites other than Zeppelin. However, long-range transport continues to be a source of DDTs to the Arctic, for instance, temperature can only account for about 27% of DDT variability in air at the Villum Research Station meaning that long-range sources cannot be excluded. p,p'-DDE concentrations were not correlated with temperature, indicating a predominance of long-range transport rather than re-emission (Bossi et al., 2013).

Concerns still exist regarding the potential for fresh releases of DDTs from contaminated Arctic areas, in addition to long-range transport from continuing-use areas. The Arctic Contaminant Action Program (ACAP) was established to follow-up on the findings of previous AMAP assessments. In 2001, ACAP initiated a project on Environmentally Sound Management of Stocks of Obsolete

Pesticides in the Russian Federation to compile information and promote environmentally sound management of obsolete pesticide stockpiles in Russian territories in or close to the Arctic. Stocks of about 6800 tonnes of obsolete pesticides (including DDTs, toxaphene and hexachlorocyclohexanes), were identified during the project inventory activities in ten northern regions of the Russian Federation (Altai Krai, Arkhangelsk Region, Komi Republic, Magadan Region, Omsk Region, Tyumen Region, Altai Republic, Republic of Sakha (Yakutia), Tomsk Region, and Krasnoyarsk Krai). Many of the stockpiles were poorly stored. To reduce exposure of humans and the environment, most stocks were repackaged and transported to interim storage facilities to await environmentally sound destruction. Total stocks of obsolete pesticides in the Russian Federation have been estimated at 40,000 tonnes, mostly originating from the Soviet era (ACAP, 2013).

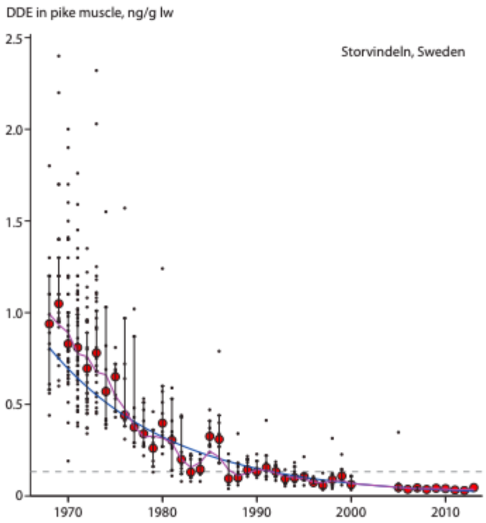


Figure 4.12 Trend in DDE concentrations in pike from Storvindeln (Sweden).

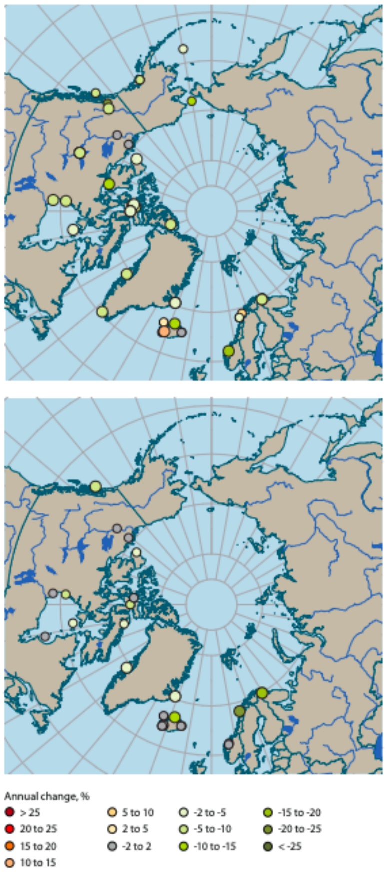


Figure 4.13 Geographical distribution of annual changes in ΣDDT in all time-series (upper) and in time-series starting at or after 2000 (lower) (larger symbols represent trends that are statistically significant or where statistical power was 'adequate').

Heptachlor and heptachlor epoxide

Three time-series of heptachlor (seabirds and northern fur seals from the United States) were available, but in all years most values were below detection limits.

Twelve heptachlor epoxide time-series starting before 2000 were evaluated. All time-series concerned concentrations in seabird eggs or marine mammal tissues. Of these, only two showed significant decreasing trends or decreasing trends with a non-linear trend component (annual decreases of 2–3%; t1/2 = 23–35 y), the rest showing no statistical trends. None of the six time-series for the post-2000 period showed significant trends other than one with a significant non-linear trend.

Heptachlor was mostly non-detectable in Arctic air and biota. The air and biota results point to the long environmental half-life of heptachlor epoxide (the degradation product of heptachlor) and so

Arctic contamination by these compounds is likely reflecting the slow and gradually diminishing influence of reemissions from past contamination and long-range transport.

The highest recent (since 2010) annual medians were in polar bears (180–240 ng/g lw), and were similar to the annual medians in the 1980s and 1990s (up to 260 ng/g lw). In eggs of thick-billed murre (Uria lomvia) from Canada, the mean annual medians in the 1975–1979 period, and after 2010 did not significantly differ, reflecting no decrease or only a very slow decrease in heptachlor epoxide.

Hexachlorobenzene

There were 54 and 43 time-series of HCB concentrations in biota starting before and after 2000, respectively. 35% of time-series from the North American and European Arctic starting before 2000 showed significant decreasing trends or a significant decreasing trend with a significant non-linear trend component. One time-series (black guillemot Cepphus grylle eggs from eastern Greenland) showed a significant increasing trend, and one time-series (adult male polar bears from eastern Greenland) showed an increasing trend with a significant nonlinear trend component. The mean annual decrease for these time-series was 2.6% (t1/2 = 27 y), which is lower than for most other organochlorine compounds (Fig. 4.17).

Six time-series starting after 2000 exhibited significant decreasing trends and three (from eastern Greenland) showed significant increasing trends. The remaining time-series showed no trend or had a significant non-linear trend component. The mean annual change for all time-series was 0.0% indicating that no decrease or a limited decrease has occurred since 2000.

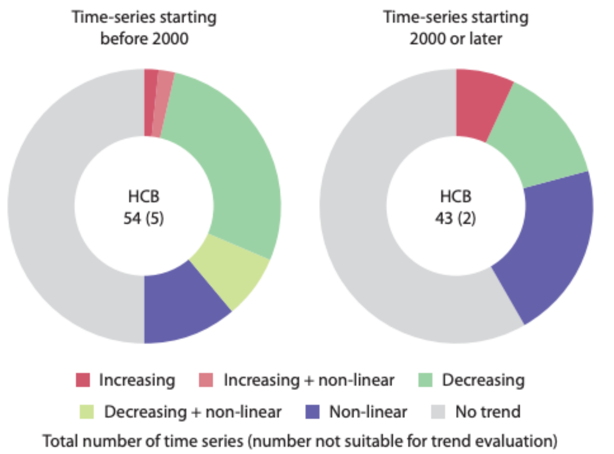


Figure 4.17 Overview of trend results for HCB in biota for time-series starting before and after 2000.

Despite the large proportion of decreasing time-series of HCB in biota observed across the North American and European Arctic over recent decades, the slow mean rate of the declines in biota and increasing trends in both air and biota at some sites since 2000 indicates that, unlike most other ‘legacy’ organochlorine pesticides, (primary and secondary) emissions and releases of HCB are still occurring. These are associated with by-production during manufacture of chlorinated compounds, the presence of HCB as an impurity in other pesticides, and its (industrial) combustion sources. Owing to its relatively high vapor pressure, the increase in HCB in air has also been associated with the decline in sea-ice cover and volatilization from environmental sinks in a warming Arctic (Hung et al., 2010). It is therefore possible that, despite its inclusion under the Stockholm Convention, HCB contamination, at least at some Arctic locations is increasing. The three biota time-series showing significant increasing trends since 2000 were from eastern Greenland, although one other eastern Greenland timeseries (ringed seal) showed a significant decreasing trend.

The highest recent annual medians (since 2010) were found in seabird eggs when expressed on a lipid weight basis (230–480 ng/g lw), pilot whales from the Faroe Islands (immature, 380 ng/g lw), and polar bears (90–300 ng/g lw).

Hexachlorocyclohexanes

In total, 110 α-HCH, β-HCH and γ-HCH time-series starting before 2000 were analyzed and 80 time-series starting after 2000 (Fig. 4.21). 80% of the α-HCH time-series starting before 2000 showed a significant decreasing trend or a significant decreasing trend with a significant non-linear trend component. For the time-series starting after 2000, the corresponding value was 53%. Mean annual decreases for time-series starting before 2000 were 8.9% (t1/2 = 7.8 y), which was the highest decrease among the chemicals investigated in this assessment. For time-series starting after 2000 the mean annual decrease was 9.9% (t1/2 = 7 y), which indicates that α-HCH has continued to decrease considerably since 2000 (See Table A6.3).

The β-HCH time-series were quite different to those for α-HCH. More than half (64%) the β-HCH time-series starting before 2000 showed no significant trend, or a significant non-linear trend. Both significant decreasing and increasing trends were found. Three time-series showed significant increasing trends and two showed significant increasing trends with a significant non-linear trend component (one seabird time-series and one marine mammals time-series), both from the Canadian Arctic. The mean annual decrease was 1.5% (t1/2 = >40 y) for time-series starting before 2000, which is the lowest decrease among organochlorines (see Fig. 5.1). For time-series starting after 2000, 83% showed no trend or a significant non-linear trend component. The difference between α-HCH and β-HCH could be due to different pathways to the Arctic caused by their different physical-chemical properties (Li and Macdonald, 2005). α-HCH and γ-HCH can be more readily metabolized (and so eliminated) than β-HCH, which is recalcitrant in most mammal species (and so biomagnifies) (Moisey et al., 2001). It should be noted that several β-HCH time-series could not be evaluated owing to more than two years with annual medians below detection limits, especially in the case of freshwater fish and blue mussels.

The γ-HCH time-series were similar to those for α-HCH, with 68% of time-series starting before 2000 showing a significant decreasing trend or a significant decreasing trend with a significant non-linear trend component. The corresponding value for the time-series starting after 2000 was 50%. Mean annual decreases were 7.6% (t1/2 = 9.1 y) and 6.2% (t1/2 = 11 y) for time-series starting before and after 2000, respectively; a smaller decrease than for α-HCH. It should be noted that several γ-HCH time-series could not be evaluated owing to more than two years with annual medians below detection limits.

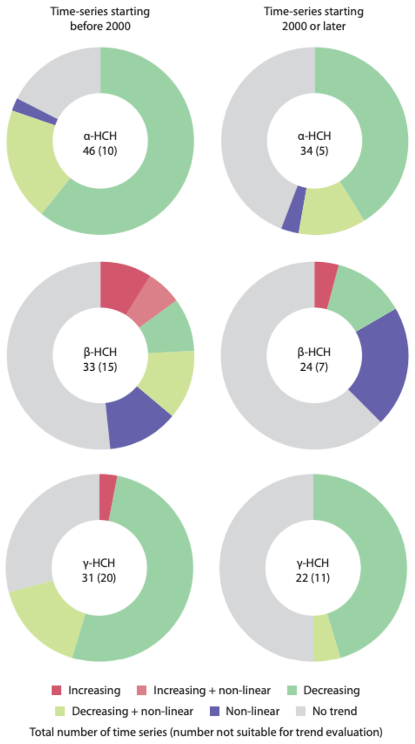


Figure 4.21 Overview of trend results for α-HCH, β-HCH and γ-HCH in biota for time-series starting before and after 2000.

Time-series for α-HCH and γ-HCH in air and biota showed decreasing trends. α-HCH is declining faster in air (t1/2 = ~5.3 y; 13% per year) than in biota (for time-series starting before 2000, t1/2 = 7.8 y; 8.9% per year). The half-life of γ-HCH in biota was almost twice that for air. These observations suggest a lag in decline between air and Arctic biota for those isomers subject to atmospheric transport.

Recent (since 2010) annual medians for α-HCH were relatively low, at less than 10–30 ng/g lw in beluga and polar bears; although recent levels of β-HCH in polar bears and beluga are up to 140–260 ng/g lw. γ-HCH levels were low and in several cases below the detection limit; the highest annual medians occurred in beluga from Canada (~18 ng/g lw).

For time-series starting before 2000, no relationships were found between the magnitude of annual change and longitude, for α-HCH, β-HCH or γ-HCH (Fig. 4.22). However, considering only the northern fur seal and five ringed seal populations, the two seal populations at the highest latitude exhibit lower annual decreases in α-HCH, and there is no obvious tendency with longitude (Fig. 4.23). The two seal populations at the highest latitudes also differ for β-HCH, showing increasing trends, while the other populations show decreasing trends. However, the length of these time-series differed, with two extending back to the early 1970s, two to the mid-1980s, and two to the mid-1990s, so no firm conclusions can be drawn as to why this deviation was observed.

Similar plots were prepared for trend results for freshwater fish and seabirds, but no clear patterns or differences were seen in annual changes for α-HCH and β-HCH by longitude or latitude.

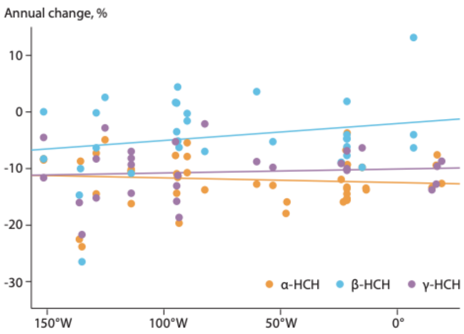


Figure 4.22 Percentage annual change for time-series starting before 2000 including all species for α-HCH, β-HCH and γ-HCH by longitude.

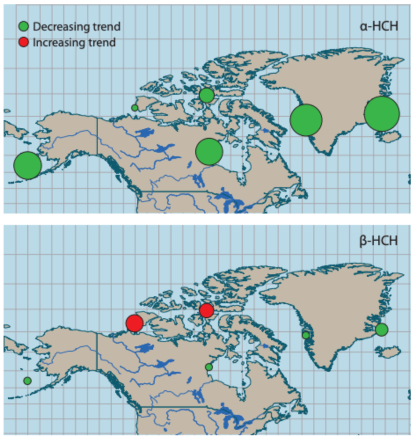


Figure 4.23 Annual decrease and annual increase in α-HCH and β-HCH in seal populations by longitude and latitude. The size of the circle represents the magnitude of the annual change.

Mirex
Sixteen time-series for mirex starting before 2000 were available. These were from the Faroe Islands, Canada and the United States and include marine mammals, seabirds and freshwater fish. Four showed significant decreasing trends (one with a significant non-linear trend component), while the others showed either a non-linear trend or no trend. Th e mean annual decrease for time-series starting before 2000 was 6.7% (t1/2 = 10 y). For the ten time-series starting after 2000 only one showed a significant decreasing trend, while the others showed either a non-linear trend or no trend. Th e mean annual decrease was lower at 1.9% (t1/2 = >30 y).

The highest recent (post-2010) levels of mirex in the timeseries considered were found in pilot whale from the Faroe Islands (annual medians of about 120 ng/g lw). In seabird eggs from Canada and the United States, recent levels are low (<0.01 – 1.5 ng/g lw). With a mean annual decrease in biota of 6.7%, mirex is among the compounds included in this assessment with the highest mean annual decrease (Fig 5.1). The relatively low annual decreases since 2000 also indicate that the main declines occurred in early years.

Pentachlorobenzene
Twelve time-series starting before 2000 were available for pentachlorobenzene, all from Canada or the United States. Many marine fish and blue mussel time-series (from Norway) could not be evaluated because of too many years with medians below the detection limit. Two time-series (one for freshwater fish and one for seabird eggs from Canada) showed significant decreasing trends or decreasing trends with a non-linear trend component. Th e others had significant non-linear trend components or no trend. Th e mean annual decreasing trend was 4.7% (t1/2 = 15 y). None of the six time-series starting after 2000 showed significant trends other than one (seabird eggs from Canada) which had a significant non-linear trend showing an increase in the initial period followed by a decrease in more recent years.

The highest recent (post-2010) (annual median) levels of pentachlorobenzene in the time-series considered were found in beluga from Canada (up to 40 ng/g lw). Recent levels are low in Canadian seabird eggs (<0.03 ng/g lw). Few time trend studies of pentachlorobenzene are available. In the Great Lakes region of Canada, outside the Arctic, a dramatic decrease since 1979 was found in eggs from colonies of herring gull (*Larus argentatus*) (Bailey et al., 2009).

Polychlorinated biphenyls
Time-series of ΣPCB10 concentrations (CB28, CB31, CB52, CB101, CB105, CB118, CB138, CB153, CB156, CB180) starting before 2000 and time-series of individual congeners were analyzed for a total of 358 time-series (see Annex 6, Table A6.2 and Fig. 4.25). Th is discussion focusses on time-series for ΣPCB10 and CB153. 38% of ΣPCB10 time-series and 34% of CB153 time-series showed a

significant decreasing trend, and 13% and 15%, respectively showed a significant decreasing trend with a significant non-linear trend component. One time-series (blue mussel in Mjoifjordur, Iceland) showed a significant increasing trend with a significant non-linear trend component for both ΣPCB10 and CB153. The mean annual decrease was 3.7% (t1/2 = 18) and 3.8% (t1/2 = 19 y) for ΣPCB10 and CB153, respectively.

To compare trends between congeners, 17 species-tissue-location combinations were selected as they all provide timeseries of eight PCB congeners (CB28, CB52, CB101, CB105, CB118, CB138, CB153, CB180) starting before 2000, covering all species groups. No significant difference in annual trend was found between congeners (ANOVA, p = 0.73).

For time-series starting after 2000, the proportions showing a significant decrease were 19% (t1/2 = 3.6 y) and 18% (t1/2 = 3.9 y) and the mean annual decreases were 1.5% (t1/2 = >40 y) and 2.5% (t1/2 = 28 y) for ΣPCB10 and CB153, respectively. This indicates that the main decreases in PCB levels occurred in earlier years, and that the decrease has slowed in recent years. Two blue mussel time-series from Iceland (from Hvalstod in Hvalfjordur and Mjoifjordur) and juvenile polar bears from eastern Greenland showed significant increasing trends for ΣPCB10. The polar bear time-series also showed an increasing trend for CB153, and one of the blue mussel CB153 time-series showed an increasing trend with a significant non-linear trend component.

Both air and biota time-series showed decreasing trends. They also both showed the decline to have slowed since 2000. Polar bears from Greenland and pilot whales from the Faroe Islands have the highest recent (since 2010) annual medians of 5000– 10000 ng/g lw, the highest values in adult males. In beluga from Canada and the United States, recent medians for ΣPCB10 were 280–1600 ng/g lw, and in ringed seals from Canada and Greenland were 100–500 ng/g lw.

A comparison of PCB trends across the circumpolar Arctic should be treated with caution as time-series from Arctic Russia were not available, with the exception of two years of air measurement from the Valkarkai station. Furthermore, monitoring species differed in the remaining areas. Time-series of PCBs in marine mammals were restricted to Greenland, Canada, the United States and the Faroe Islands with none from Iceland and Norway, while blue mussel and marine fish timeseries were restricted to Iceland and Norway. In polar bears from eastern Greenland, an unexpected increase is evident in concentrations of PCBs (and several other POPs) since 2000 (Fig. 4.26); this has been attributed to a shift in polar bear diet as a consequence of sea ice loss (McKinney et al., 2013; Rigét et al., 2016). Time-series with increasing trends of CB153 in biota were found in the region between eastern Greenland and Iceland (Fig. 4.27), most of these were associated with Icelandic blue mussel time-series, only one of which was significant. This concerned blue mussel at Mjoifjordur in Iceland, where the increasing trend has been attributed to a local source (Sturludottir et al., 2013). Sea-ice retreat and de-glaciation leading to increased re-emission from ice and oceans has also been suggested as a possible explanation for increasing air concentrations of CB52 and CB101 at Stórhöfði in Iceland (Hung et al., 2016).

Toxaphene

Seventeen toxaphene time-series starting before 2000 (Parlars 26 and 50) were available. Time-series were also available for Parlar 32 (one time-series) and Parlar 62 (two time-series). Five of the Parlar-26 and four of Parlar-50 time-series showed significant decreasing trends (two with a significant non-linear trend component), whereas three (two Parlar-26 and one Parlar-50 time-series) showed non-linear trends (Fig. 4.30). The rest showed no trends. The annual decrease of Parlar 26 was 6.0% (t1/2 = 12 y), but was considerably lower (0.8%; t1/2 = >80 y) for Parlar 50.

Twenty time-series of Parlar 26 starting after 2000 were available of which nine showed significant decreasing trends or decreasing trends with a significant non-linear trend component. In the case of Parlar 50, eight of 22 time-series showed significant decreasing trends. The others showed either non-linear trends or no trend. The mean annual decrease of Parlar 26 was 5.9% (t1/2 = 12 y), while Parlar 50 had a mean annual increase of 0.8% (t1/2 = >80 y).

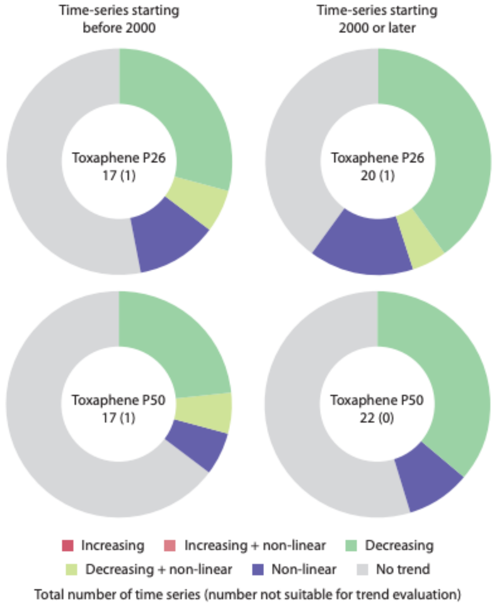


Figure 4.30 Overview of trend results for time-series of toxaphene Parlar 26 and Parlar 50 starting before and after 2000.

Air concentrations of toxaphene Parlar (26+50) have shown a decreasing trend since 2004 at Stórhöfði. In biota concentrations of Parlar 26 and Parlar 50 in biota also showed generally decreasing trends. The rate of decrease was greater for Parlar 26 than Parlar 50. Parlar 26 showed similar decreases in time-series starting after 2000 as those starting before 2000, while Parlar 50 switched from a slight decrease to a slight increase. Based on levels and congener composition in marine animals from Greenland, Vorkamp et al. (2015) suggested the biotransformation of nona- to octachlorinated toxaphene congeners (here represented by Parlar 50 and Parlar 26, respectively).

The highest recent (2010) annual medians of Parlar 26 and Parlar 50 were found in pilot whale blubber (about 800–1000 and 800–1400 ng/g lw, respectively). In black guillemot eggs, recent medians were about 200 and 300 ng/g lw respectively, and in ringed seal blubber from same location were 2–3 ng/g lw for both Parlar 26 and Parlar 50. For ringed seal, toxaphene levels were generally higher in seals from Canada and Alaska than from Greenland, Svalbard and the western part of Russia (Vorkamp et al., 2015). This likely reflects that the highest use of toxaphene was in the United States (Voldner and Li, 1995). The difference in mean annual change between Parlar 26 (a decrease of about 6% or t1/2 = 12 y) and Parlar 50 (a decrease of about 1% or t1/2 = 69 y) was mainly due to the Icelandic blue mussel time-series with a mean annual decrease in Parlar 26 of 8.5% (t1/2 = 8.2 y) and an increase in Parlar 50 of 3.5% (a doubling of concentration in 20 years).

Technical endosulfan and its isomers
No updated time-series of endosulfan and its isomers in biota were available for this assessment.

Polybrominated diphenyl ethers
Time-series of several PBDE congeners in biota starting before 2000 were available (BDE47, BDE49, BDE99, BDE100, BDE153, BDE154 and BDE155), however most concerned BDE47 (26 time-series) and BDE99 (19 time-series) and so these are the ones discussed here. For BDE47, nine time-series showed a significant increasing trend or a significant increasing trend with a significant non-linear trend component; for BDE99, this was the case for two time-series. One time-series (adult ringed seals from eastern Greenland) showed decreasing trends for both BDE47 and BDE99. The non-linear trend component was significant in eight BDE47 time-series and the typical pattern was an increase followed by a decrease in recent years (Figs. 4.33 and 5.2).

For time-series starting after 2000, no BDE47 time-series showed increasing trends and an increase was found in only one case for BDE99 (ringed seal from Canada). Decreasing trends were found for four BDE47 time-series and three BDE99 time-series. This indicates that the concentrations of these congeners in biota have peaked and are now mainly decreasing.

Mean annual medians (since 2010) of BDE47 were highest in pilot whales from the Faroe Islands (180 ng/g lw), followed by polar bears from eastern Greenland (25–35 ng/g lw) and beluga from Alaska (15 ng/g lw). Levels of BDE99 were lower, with recent annual medians of 35 ng/g lw in pilot whale and 1–3 ng/g lw in polar bears.

A parabolic trend, with an increase up to around 2000 followed by a decrease is found in several biota time-series. Similar trend patterns have also been observed in Leach's storm-petrel (Oceanodroma leucorhoa) from the Pacific coast of Canada (Miller et al., 2014). That a similar pattern is not found in the air time-series is not inconsistent given that these time-series only extend back to around 2000. In the period since 2000, air time-series show more constant or decreasing trends, which is also observed in a number of biota time-series.

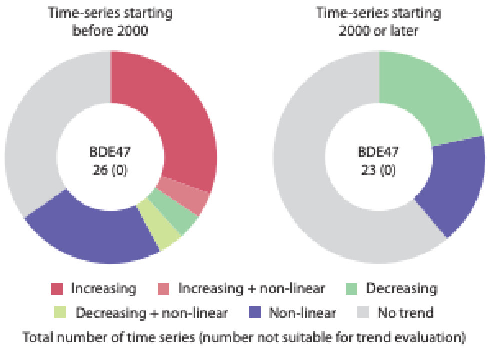


Figure 4.33 Overview of trend results for BDE47 time-series starting before and after 2000.

Hexabromocyclododecane

Seven time-series of α-HBCDD in marine mammals and seabird eggs were available (Fig. 4.36). Of these, five showed significant increasing trends. Two time-series showed a significant nonlinear trend or no trend. The mean annual increase of the seven time-series was 7.6% (t1/2 = 9.2 y).

In contrast, time-series starting after 2000 showed decreasing trends. The mean annual decrease of the three post-2000 timeseries was 3.6% (t1/2 = 19.2 y). One time-series starting after 2000 (thick-billed murre from Canada) showed a significant decreasing trend, while two time-series showed no trend.

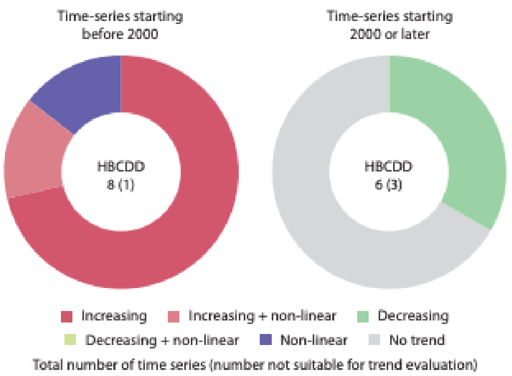


Figure 4.36 Overview of trend results for HBCDD time-series starting before and after 2000.

While α-HBCDD in air at Zeppelin showed decreasing trends with a relatively low t1/2 of 2.9 (corresponding to an annual decrease of 24%), the majority of biota time-series showed increasing trends. However, the air time-series at Zeppelin only extends back to mid-2006, while the biota time-series in several cases extend back to the mid-1980s. Increasing trends of α-HBCDD have also been found in beluga from Cook Island and the eastern Chukchi Sea (Alaska) covering the period from around 1990 to 2000 and 2005 (Hoguet et al., 2013).

The mean annual medians for the period 2000–2012 were highest in polar bears (25–40 ng/g lw). Levels were lower on seabird eggs (4–7 ng/g lw).

Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride
Time-series of the perfluorosulfonates (PFHxS, PFOS), the perfluorocarboxylates (PFOA, PFNA, PFDA, PFUnA, PFDoA, PFTrA, PFTA) and the perfluorosulfonamide (PFOSA) were available; including PFOS time-series from Alaska, Canada, Greenland, the Faroe Islands and Sweden. Most time-series concerned marine mammals, with a few for freshwater fish and seabird eggs. Only PFOS, PFNA, PFDA and PFUnA are discussed here because more than ten time-series for each were available. For PFOS, eight of 16 time-series showed a significant non-linear trend and one (juvenile polar bears from eastern Greenland) showed an increasing trend with a significant non-linear trend component. The others showed no trend. A common trend pattern was an increase until about the mid-2000s followed by a decrease, which was caught by the non-linear trend component (see Fig.4.39). For PFNA (6 of 11), PFDA (4 of 10) and PFUnA (6 of 11), several times-series showed significant increasing trends or significant increasing trends with a significant non-linear trend component (Fig. 4.40).

Eleven PFOS time-series starting after 2000 were available, all having significant non-linear trend components or showing no trend. For PFNA time-series, two of five showed significant increasing trends, the rest showed a significant non-linear component or no trend. All five time-series of PFDA and PFUnA showed a significant non-linear component or no trend.

No trends were observed in PFOS and PFOA in airborne particles at Zeppelin, while the PFOS precursors MeFOSE and EtFOSE showed no trend and a decreasing trend at Alert, respectively; reflecting the phase-out of PFOS-related production. A decrease in levels in response to this phase-out is also supported by trends in biota. Several of the PFOS timeseries in biota extend further back (to the early- or mid-1980s) than those for air, and many show an increase followed by a decrease with a significant peak around the mid-2000s. For northern fur seals from Alaska, however, perfluorinated alkyl acids (PFAAs) continued to increase over the period 1987 to 2007 (Kucklick et al., 2013). Trends in perfluorocarboxylates (PFNA, PFDA, PFUnA) differ from those for PFOS, with a relatively high proportion showing an increasing trend or an increasing trend with a non-linear trend component.

By far the highest levels of PFOS were found in polar bear liver from eastern Greenland. In the mid-2000s, when PFOS in these polar bears peaked, the annual median was almost 3060 ng/g ww. In recent years, the annual median has dropped to about 950 ng/g ww. Levels of PFNA and PFDA were also highest in polar bears, with mean recent (since 2010) annual medians of 130–170 and 45 ng/g ww, respectively. Recent levels of PFUnA in polar bears were 110–160 ng/g ww.

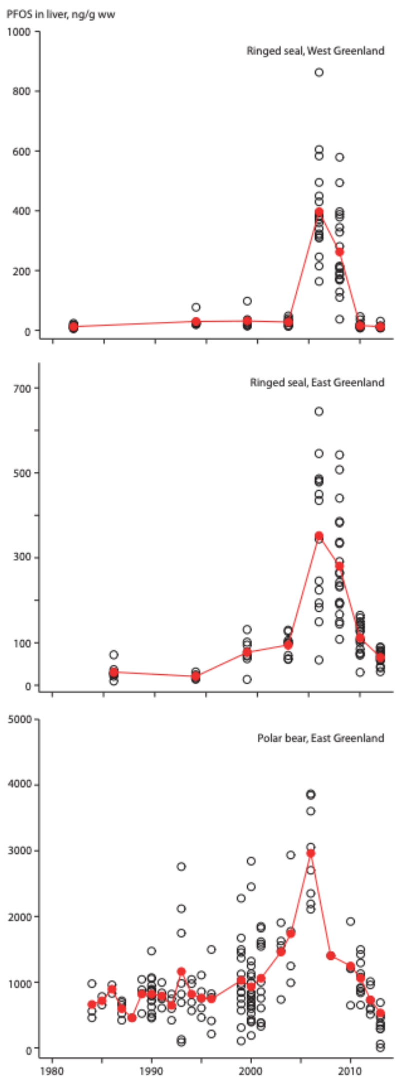


Figure 4.39 Trends of PFOS concentration in ringed seals from western and eastern Greenland and polar bears from eastern Greenland (updated from Rigét et al., 2013b).

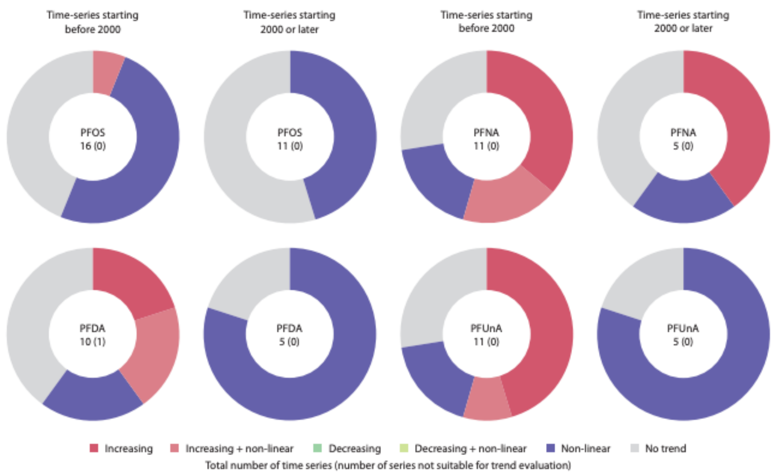


Figure 4.40 Overview of trend results for selected perfluorosulfonate and perfluorocarboxylate time-series starting before and after 2000.

Summary of trend results

Of the more than 1100 statistical runs considered on biota timeseries, about 25% were excluded, mainly due to the presence of a high proportion of 'less than' values. Of the non-excluded runs, about 12% of time-series are currently of adequate length to detect a 5% annual change with a statistical power of 80% for the current number of years; this highlights the need to maintain monitoring effort to obtain suffciently powerful timeseries for trend detection.

The results tabulated in Table A6.4 and summarised in Fig. 5.1 show the trends for the different chemical groups ranked from decreasing to increasing based on the mean trend for all biota time series. Also shown are the mean trends if all time series (not just those that are significant or 'adequate') are considered. The figure illustrates that the greatest annual declines (typically 5–10% per year) are observed for 'legacy' organochlorine pesticides, including toxaphenes, HCHs and DDTs. Chlordanes and industrial chemicals such as PCBs and HCB have also declined, but at slightly lower rates, and newer POPs including BDEs, PFOS/PFOA and HBCDD still exhibit increasing trends in many cases (although fewer time-series are currently available for these chemicals).

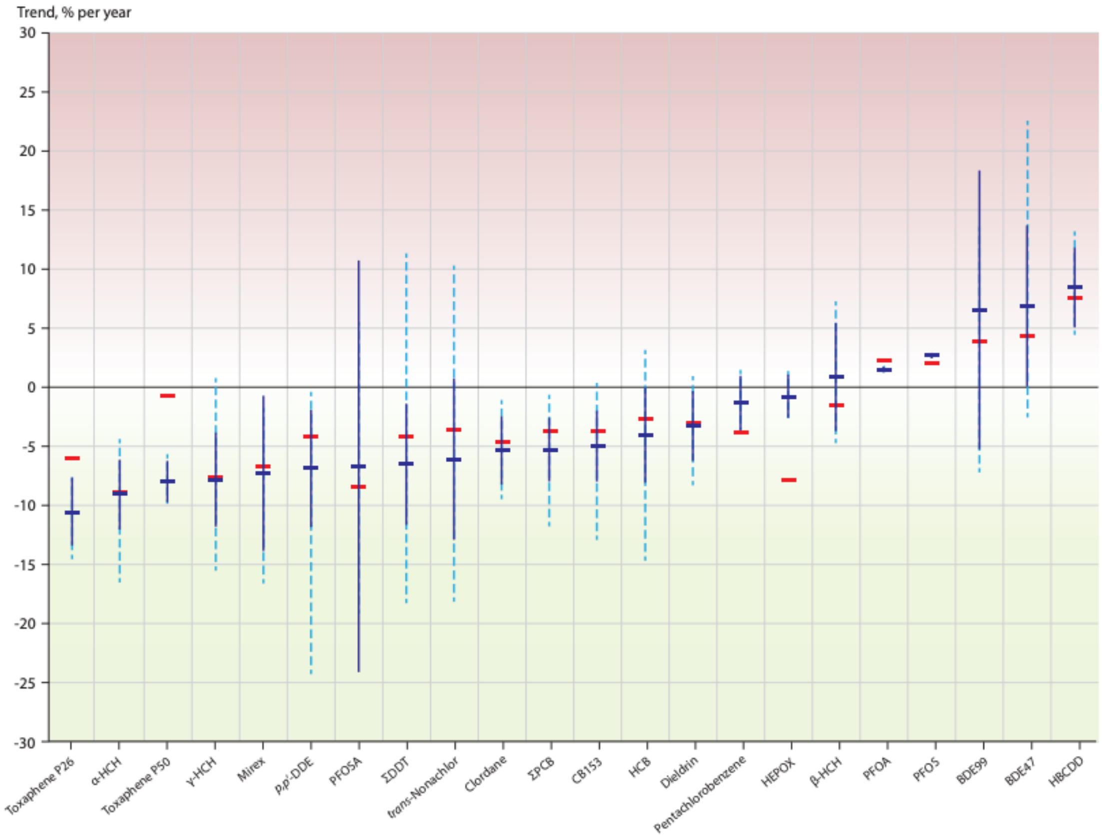


Figure 5.1 Summary of biota trends for different contaminants – results for time-series starting before 2000 where trend results were statistically significant and/or time-series were of 'adequate' power. The graphic shows the ranked mean ±SD (dark blue solid line), range (light blue dashed line); red marks indicate the mean for all runs.

Downward trends constitute the majority of statistically significant trends of (Stockholm Convention) POPs in Arctic air and biota that have been banned for extended periods (more than 20 to 30 years) in developed countries. For example, DDTs, HCHs, PCBs and chlordanes.

The downward trend in many of the time-series began decades before the Stockholm Convention entered into force. This probably reflects the impact of control measures introduced at the national level in the 1980s and 1990s, in Arctic countries and in non-Arctic countries in neighboring regions (see Fig. 5.3).

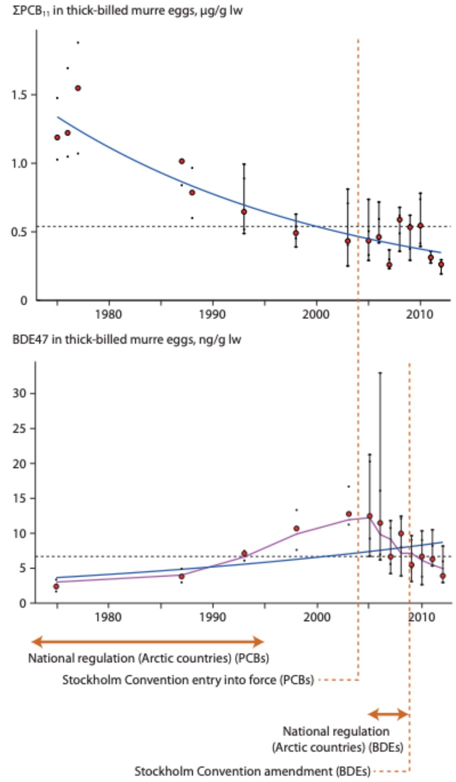


Figure 5.3 Examples of different patterns of change over time for 'legacy POPs' (as illustrated by ΣPCB_{11}) and 'new POPs' (as illustrated by BDE47) in thick-billed murre eggs collected at Prince Leopold Island (Canada).

The rate of decrease in Arctic air for Stockholm Convention POPs that have been subject to regulation for several decades is now slowing, indicating that concentrations are approaching steady state with other environmental media and that secondary sources now dominate. The rate of decrease for Stockholm Convention POPs in Arctic biota is also now slower when comparing time-series that started after 2000 with those that started before 2000.

'Newer' POPs that were subject to later regulation in several Arctic countries and have been added to the Stockholm Convention more recently (including the brominated flame retardants PBDEs and HBCDD, and polyfluorinated compounds such as PFOS), show a more mixed pattern of trends, in several cases showing trends increasing until the mid-1990s to 2000 and thereafter decreasing.

A few time-series for compounds/compound groups that have been subject to regulation for several decades, including trans-nonachlor, PCBs (ΣPCB10 and CB153), ΣDDT and HCB show increasing trends, however most of these occur at sites suspected to be influenced by local sources. This includes time-series of HCB and PCB congeners (CB52 and CB101) in air and HCB (in air and biota) in the eastern Greenland-Iceland-Svalbard region. Increasing trends in air have been attributed to enhanced re-emission from oceans and surfaces and melting ice/snow due to warming. A consistent increase in levels of PCBs and other POPs in polar bears from eastern Greenland in recent years, relative to levels in the mid-2000s seems to be related to a change in diet as a consequence of sea ice loss.

Some β-HCH time-series from the Canadian Arctic show significant increasing trends, while α-HCH is one of the compounds showing the greatest rate of decrease. The different trends are partly explained by different physicalchemical properties of the two isomers, with α-HCH being transported via air whereas β-HCH partitions to a greater extent into water and so is transported via ocean currents. Also, β-HCH is more persistent and has greater tendency to biomagnify in biota than α-HCH.

PBDEs: Increasing trends in biota time-series starting before 2000 are evident. Controls of hexa- and heptaBDE at both the national and international level were not widely introduced before the late

1990s. The increasing trends in biota are no longer apparent if the time-series for the period after 2000 are considered and, for BDE47 in particular, the proportion of decreasing trends increases (see the example in Fig. 4.33).

α-HBCDD levels in air have declined at Svalbard since 2006, while increasing trends are evident in biota time-series extending back to the 1980s. HBCDD was included on the Stockholm Convention Annex A list in 2013.

PFOS precursors showed no trends and decreasing trends in air measured since 2006 at Alert. In biota time-series extending back to the early or mid-1980s, PFOS levels peaked around the mid-2000s. The declines are thought to reflect the voluntary phase-out in 2000 by the US company 3M, of production of PFOS and PFOS-related products. However, particle phase PFOS and PFOA are not showing any decline in Arctic air at Zeppelin, and in biota the three perfluorocarboxylates included in this assessment (PFNA, PFDA, PFUnA) show increasing trends.

Trends in levels in biota (and also in air or human media) are often only interpreted as a response to changes in emission levels. Previous assessments of Arctic trend monitoring data have shown that interpreting trends in this over-simplistic manner is inappropriate. Changes in food-web structure, and in feeding habit and diet can strongly affect levels in biota (including humans), exemplified by the increasing trend of ΣPCB10 since 2000 in polar bears from eastern Greenland (Fig. 4.26). Trends in levels in air and biota can reflect changes in environmental processes – a number of which can be associated with climate change and variability. A detailed examination of trends in individual datasets is necessary for reliable trend interpretation. Nonetheless, consistency in results from a large number of trend studies, over a large geographical extent, and involving different matrices may provide an indication that global controls on emissions or global processes are responsible for at least some of the observed development. While not necessarily geographically or temporally coincident, there is also a degree of consistency in the trend results obtained from air and biota monitoring (Fig. 5.2) that lends support to the argument that 'other media' should be included in programs such as the Stockholm Convention Global Monitoring Programme that support work to evaluate the effectiveness of that Convention, in addition to the priority media (air and human biomedia).

Modelling results from studies associated with the EU-ArcRisk project (www.arcrisk.eu) indicate that for most 'legacy' POPs (i.e. POPs which were banned or considerably restricted several decades ago, and where contamination is essentially a legacy of past use) decreases associated with gradual degradation in the environment will continue to exceed any possible increases due to enhanced re-mobilization associated with climate change. Notwithstanding this, however, stockpiles of banned pesticides still exist in some countries which represent a potential source of future, at least local, contamination.

Results of the ArcRisk studies indicate the need to better characterize primary and secondary sources of POPs and improve models by including indirect effects, such as carbon cycling, catchment hydrology, land use, vegetation cover, etc. (Pacyna et al., 2015). Temperature increases are expected to increase volatilization of chemicals in open-use, including PCBs used as plasticizers in paints and sealants, and PBDEs used as flame retardants.

Longer time-series are generally more powerful for trend detection, emphasizing the need to continue existing timeseries and implement new time-series studies in areas not yet covered, and for new chemicals of emerging concern.

Annex 1. Observations on the power of the AMAP biota trends monitoring program and use of the PIA statistical application for trend detection.

How powerful is the time-series?

Statistical power is an important concept when examining temporal trends in monitoring data. The statistical power of a time-series should be sufficiently sensitive to detect a trend of a certain magnitude. When working with time-series with inadequate power, there is a risk of incorrectly suggesting that no change has occurred in a given period. In the case of a loglinear regression the power depends on the magnitude of the trend, the sample size collected each year, the number of years of sampling data and the between-year variability and choice of significance level (Fryer and Nicholson, 1993).

In the following, estimation of power will follow the method described by Fryer and Nicholson (1993). There will be two measures of power: (1) the number of years required to detect a log-linear trend of a 5% annual change with 80% power and a significance level α<0.05 with a one-sided test, and (2) the minimum average annual percentage change over a specified period that can be detected with 80% power, α<0.05 and a one-sided test. The two measures are essentially the same but provide different information.

Only 12% of the time-series starting before 2000 fulfill the statistical standard requirements (5% annual change, 80% power, 5% significance level) (Fig. A1.1, left). This number would of course increase if the statistical requirements were relaxed (increasing the annual change, decreasing the power, increasing the significance level). Especially in cases with increasing trends and the use of the rather conservative 5% significance level, this means that a test p-value should be below 0.05 before the zero hypotheses (H0) of no trend can be rejected. A more precautionary approach with regard to protection of the environment would be to use a significance level of 10% in order to give a warning for, for example, an increasing trend of a contaminant. In the case of the Greenlandic time-series, the number of time-series with 80% power to detect an annual change would increase from 29% to 43% if the significance level was increased from 5% to 10%.

The number of time-series started in or later than 2000 with a power of at least 80% falls to 4% as expected (Fig. A1.1, right). This underlines the fact that time-series must be rather long before sufficient power to detect trends is reached.

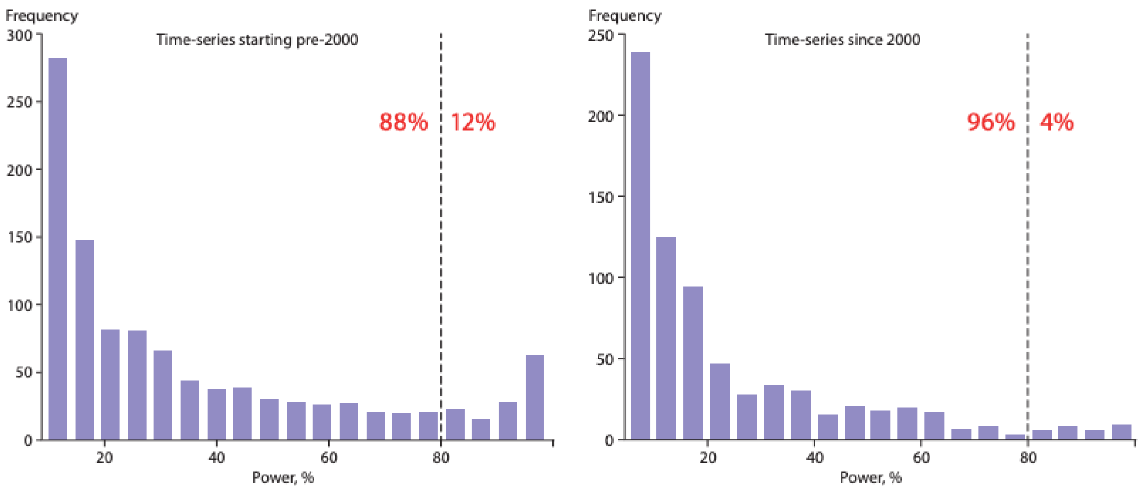


Figure A1.1 Frequency of the power of time-series to detect a 5% annual change with the current number of years with a significance level of 5%. Time-series starting before 2000 (left) and time-series starting after 2000 (right).

The last AMAP POP trend assessment (Rigét et al., 2010) reported that 8% of the time-series had 80% or more power. In this assessment the value increased to 13% for organochlorine time-series excluding the polybrominated diphenyl ethers (PBDEs) and perfluorinated alkylated substances (PFASs) time-series as they were not included in the previous AMAP assessment. Including the BDE and PFA time-series the percentage is 12%. It should be noted that the number of powerful OC time-series has increased from 24 in the previous assessment to 119 in the present assessment. The conclusions drawn in this assessment are therefore more solidly founded. Furthermore, if the number of time-series that showed a significant decreasing or increasing log-linear trend, but which did not necessarily meet the statistical requirements are also considered, the percentage and number increase to 44% and 478, respectively.

A consequence of the relatively low power and assuming that the sampling and analytical procedures have been optimized, is that the number of years of the time-series must be high. 53% of the time-series need more than 20 years to obtain 80% power to detect a 5% annual change with a significance level of 5% (Fig. A1.2).

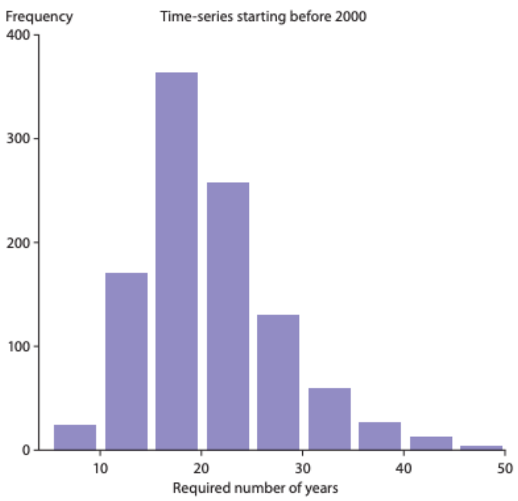


Figure A1.2 Frequency of the number of years required in a time-series to detect a 5% annual change with 80% power and a significance level of 5%.

Table A1.1 Mean and standard deviation of the statistical power and lowest detectable trend for a 10-year period for each medium. Time-series starting before 2000.

	Power	Lowest detectable trend
Freshwater fish	14 ± 11	33 ± 31
liver	12 ± 5	25 ± 12
muscle	15 ± 12	35 ± 35
Marine fish	16 ± 11	22 ± 10
liver	17 ± 13	21 ± 10
muscle	14 ± 7	23 ± 9
Marine mammals	22 ± 18	24 ± 28
adipose tissue	17 ± 9	23 ± 20
blubber	24 ± 20	23 ± 28
liver	14 ± 12	54 ± 56
muscle	19 ± 7	16 ± 6
Mussels	20 ± 19	19 ± 8
soft body	20 ± 19	19 ± 8
Seabirds	30 ± 23	21 ± 29
egg	32 ± 23	21 ± 30
liver	8	34
blood	17 ± 5	18 ± 9

The power and lowest detectable trend for a 10-year period are compared between media in Table A1.1. The highest power and among the lowest detectable trend are seen for seabird eggs. The reason for this is probably because seabird eggs are easier to sample consistently from year to year, both with regard to time of year and to problems with confounding factors such as age and sex. Low power is seen for fish liver and muscle and may be related to the rather low POP concentrations, where analytical uncertainties play a relatively greater role.

Comparison between test results of the log-linear regression and Mann-Kendall trend test
The PIA program gives the results of two different trend analyses; the log-linear regression and the Mann-Kendall trend test. The log-linear regression is a parametric test which assumes, besides a log-linear relationship that the errors are normally distributed. The Mann-Kendall trend test is a nonparametric test that measures the association between two variables. If a significance level of 5% is the basis for concluding whether a trend has occurred, the two tests sometimes lead to different conclusions

In all the time-series analyzed in this assessment that do not have a significant non-linear trend component, the two tests lead to different conclusions in 9% of the time-series. In 6% of the time-series, the Mann-Kendall p-values were above 5%, while the log-linear regression p-values were below 5% (Fig. A1.3). This can happen if one or more outliers are present at one end of a time-series (or at both ends in opposite directions). In 3% of the time-series, the Mann-Kendall p-values were below 5% while the log-linear regression p-values were above 5% (Fig. A1.3). This can happen in the presence of outliers especially in the middle of the time-series or when the trend is systematic from year-to-year but the magnitude of the trend is small.

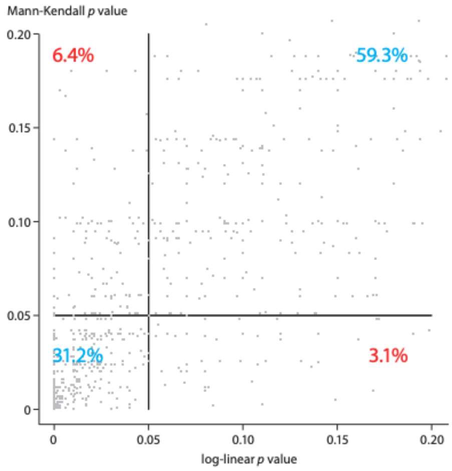


Figure A1.3 Plot of p-values from the log-linear regression test versus p-values of Mann-Kendall trend test. Time-series with a significant non-linear trend component are excluded.

Therefore, when a different result is achieved from each of the two tests, it is recommended to take a closer look at the timeseries data, for example the PIA trend plot, before any firm conclusions concerning the trend can be drawn.

Annex 6

Table A6.2 Summary of trend results (mean and range of annual change, %) for time-series starting before 2000.

	Dieldrin	*trans*-Nonachlor	ΣCHL	*p,p'*-DDE	ΣDDT	Heptachlor-epoxide	HCB	α-HCH	β-HCH	γ-HCH
Blue mussel		2.6 (-4.9 to 10.3)		-0.9 (-8.3 to 8.4)	1.1 (-10.9 to 11.3)		0.03 (-6.2 to 4.0)	-8.3 (-14.8 to -0.8)		-9.7
Arctic char	-6.0 (-8.3 to -3.8)	-8.3	-6.0 (-9.5 to -0.8)	-6.9 (-9.5 to -1.6)	-8.2 (-10.3 to -2.1)		-3.0 (-6.4 to 1.0)	-11.3 (-16.5 to -7.9)	1.7 (-3.3 to 6.4)	-9.9 (-15.5 to -5.7)
Burbot	-3.4 (-8.0 to 0.8)	-5.4	-5.4 (-6.7 to -4.1)	-1.4 (-3.7 to 1.0)	-3.4 (-5.7 to 0.5)		-2.4 (-5.0 to 0.5)	-10.7 (-13.1 to -7.5)	-3.4	-9.9 (-12.1 to -6.3)
Atlantic cod		-5.0 (-7.0 to -3.0)		-5.8 (-9.2 to -0.4)	-5.3 (-8.8 to -1.4)		-3.5 (-5.1 to -2.3)	-8.7 (-10.3 to -6.8)	-6.4 (-6.8 to -5.9)	-7.7 (-10.7 to -3.4)
European plaice				-14.6 (-15.6 to -13.5)	-11.1 (-15.5 to -6.6)		-13.8 (-14.7 to -12.9)			
Lake trout	-3.9 (-6.4 to -1.2)	-17.3 (-18.1 to -16.5)	-3.9 (-8.2 to 0.5)	-10.0 (-24.3 to -2.5)	-10.8 (-20.9 to -7.1)		-4.7 (-12.1 to 2.9)	-13.6 (-20.6 to -7.1)	-14.2 (-23.2 to -7.8)	-10.2 (-18.5 to -4.0)
Pike				-7.4			-2.9	-4.6		-6.6
Black guillemot		0.7	0.1	2.1	1.5		3.0	-10.2	4.7	-3.9
Black-legged kittiwake	-2.0	-0.5	-2.0	-5.8	-5.8	-1.1	-4.1	-2.5	2.6	
Common murre		-5.8	-5.9		-7.1	-1.5	-2.5	-5.7	-7.0	
Glaucous gull				1.5			-2.8			
Northern fulmar	-0.9	-1.0	-1.6	-4.4	-4.5	-0.7	-2.6	-7.7		
Thick-billed murre	-2.7 (-4.5 to -0.8)	-4.5 (-8.5 to -0.4)	-3.4 (-5.2 to -1.6)	-3.6 (-4.3 to -2.8)	-3.5 (-4.3 to -2.7)	-1.7 (-3.1 to -0.2)	-2.7 (-2.9 to -2.4)	-7.8 (-10.7 to -4.9)	-1.4 (-4.0 to 1.3)	0.8
Beluga	0.9	-7.3 (-18.5 to -1.4)	-7.6 (-19.9 to -1.0)	-3.9 (-8.9 to 0.1)	-4.9 (-10.3 to -0.7)	-27.6 (-39.3 to -16.0)	-5.4 (-13.9 to -0.2)	-3.5 (-5.5 to 1.2)	-1.2 (-5.3 to 2.9)	-6.8 (-11.5 to -1.6)
Northern fur seal		-3.2	-3.8	-4.2	-4.8	-1.2	-4.2	-8.6	-2.3	-7.3
Pilot whale		-6.0 (-6.6 to -5.3)	-4.9 (-8.1 to -0.3)	-4.8 (-15.7 to 4.6)	-6.9 (-18.3 to 2.1)		-0.6 (-3.5 to 5.1)		3.8 (-3.4 to 15.8)	
Polar bear	-1.3 (-2.5 to 0.6)	-2.4 (-3.0 to -1.6)	-1.2	-3.3 (-5.8 to -2.2)	-3.7 (-6.1 to -2.6)	-1.1 (-2.6 to 1.5)	1.4 (-1.4 to 5.4)	-11.4 (-12.5 to -8.5)	0.6 (-1.8 to 7.2)	
Ringed seal	-1.6 (-4.3 to -0.1)	-5.7 (-5.8 to -5.7)	-3.6 (-7.5 to 0.8)	-3.2 (-5.8 to -0.8)	-4.2 (-6.3 to -2.3)		-1.6 (-3.7 to 1.2)	-7.8 (-11.4 to -2.0)	-0.4 (-4.7 to 5.4)	-5.3 (-8.2 to 0.1)
All species	-3.0 (-8.3 to 0.9)	-3.6 (-18.5 to 10.3)	-4.6 (-19.9 to 0.8)	-4.1 (-24.3 to 8.4)	-4.2 (-20.9 to 11.3)	-7.8 (-39.3 to 1.5)	-2.6 (-14.7 to 5.4)	-8.9 (-20.6 to 1.2)	-1.5 (-23.2 to 15.8)	-7.6 (-18.5 to 0.8)

Cell shading: ≤-10% | -10 to -3% | >-3 to <3% | 3 to 10% | ≥10% annual change

Mirex	Pentachloro-benzene	CB153	ΣPCB_{10}	Toxaphene Parlar-26	Toxaphene Parlar-50	BDE47	BDE99	HBCDD	PFOA	PFOS	PFOSA
		-1.3 (-12.8 to 19.6)	-0.1 (-10.0 to 20.7)	-8.5 (-14.5 to -1.5)	3.5 (-2.7 to 7.4)						
		-6.2 (-9.5 to -3.2)	-7.0 (-10.7 to -3.0)	-7.7	-9.9	8.7 (2.1 to 22.5)	7.5 (3.6 to 13.5)			0.8	
-1.2	-3.8	-2.0 (-4.5 to 0.6)	-3.4 (-5.3 to -2.0)			7.4				-3.4	
		-5.4 (-9.3 to 0.3)	-7.4 (-10.6 to -4.2)								
		-9.9 (-11.3 to -8.4)	-9.1 (-11.7 to -6.5)								
-13.9 (-16.6 to -11.2)	-6.5 (-9.8 to -3.2)	-9.7 (-19.2 to -3.5)	-9.6 (-17.9 to -2.6)			-5.7 (-6.3 to -5.0)					
		-3.1									
		1.9	1.5	-2.1	-3.9						
-3.5	-2.1	-6.5	-6.8								
-7.3		-6.1	-5.9								
		-4.0						-4.1			
-1.7	-1.6	-3.8	-4.2			2.4	0.3				
-7.0 (-10.4 to -3.6)	-1.8 (-2.4 to -1.2)	-3.9 (-4.6 to -3.1)	-4.4 (-5.1 to -3.6)			-1.3 (-5.0 to 2.4)	-1.3 (-1.3 to -1.2)			-0.5	
-9.5 (-28.0 to -1.8)	-7.1 (-27.9 to 1.6)	-4.5 (-7.7 to -0.8)	-4.4 (-7.1 to -0.7)			8.4 (5.3 to 11.5)	11.9 (1.6 to 25.1)	10.1		3.1 (0.9 to 8.1)	-1.3 (-6.6 to 5.6)
-15.1	-3.4	-0.6		-7.9	-7.9	12.1	13.2	13.3		1.9	-7.0
0.4 (-3.7 to 5.1)		-2.8 (-5.7 to 1.8)	-2.5 (-5.3 to 0.4)	-2.4 (-5.3 to 1.8)	-3.0 (-5.3 to -0.1)	6.6	7.3			2.0	
	6.7	-0.9 (-2.3 to 1.3)	-1.2 (-2.8 to 1.0)			3.7 (0.8 to 9.3)	3.6 (0.5 to 5.8)	9.7 (6.6 to 14.5)	2.2 (-1.2 to 6.4)	-0.2 (-3.3 to 2.7)	-18.4 (-28.8 to -7.4)
		-3.1 (-5.9 to -0.3)	-3.5 (-5.7 to -1.2)	-0.3 (-1.4 to 0.9)	-7.1 (-8.4 to -5.7)	2.6 (-2.5 to 5.3)	-2.9 (-7.2 to 1.2)	4.5		6.7 (4.2 to 8.5)	
-6.7 (-28.0 to 5.1)	-3.8 (-27.9 to 6.7)	-3.8 (-19.2 to 19.6)	-3.7 (-17.9 to 20.7)	-6.0 (-14.5 to 1.8)	-0.8 (-9.9 to 7.4)	4.4 (-6.3 to 22.5)	3.8 (-7.2 to 25.1)	7.6 (-4.1 to 14.5)	2.2 (-1.2 to 6.4)	2.0 (-3.4 to 8.5)	-8.5 (-28.8 to 5.6)

Table A6.3 Summary of trend results (mean and range of annual change, %) for time-series starting in or after 2000.

	Dieldrin	*trans*-Nonachlor	ΣCHL	*p,p'*-DDE	ΣDDT	Heptachlor-expoxide	HCB	α-HCH	β-HCH	γ-HCH
Blue mussel		6.3 (-0.1 to 19.0)		-0.3 (-15.1 to 15.5)	0.6 (-14.0 to 16.5)		3.8 (-1.3 to 7.7)	-11.4 (-21.9 to -2.0)		-3.7 (-16.2 to 8.8)
Arctic char	3.2 (1.7 to 4.6)	-20.1	-10.8 (-24.3 to 2.8)	-2.1 (-20.3 to 12.5)	-2.4		-3.7 (-21.0 to 2.8)	8.1 (2.0 to 14.2)	5.3 (0.6 to 10.0)	2.9 (-3.5 to 9.3)
Burbot	-4.6	-6.4		-2.0	-1.8		-1.9	-12.2		-9.1
Atlantic cod		0.5 (-2.9 to 6.2)	3.1	-4.0 (-11.1 to 1.9)	-0.5 (-9.7 to 5.0)		-1.9 (-6.0 to 0.8)	-11.1 (-12.1 to -10.5)	-1.8 (-2.0 to -1.6)	-9.5 (-10.8 to -8.7)
European plaice				-18.8 (-27.2 to -13.2)	-11.3 (-22.9 to -1.8)		-14.5 (-17.3 to -10.7)	-17.5		-17.8
Lake trout										
Pike				-8.0			-1.7			
Black guillemot		0.7	-0.3	2.4	2.0		3.3	-10.1	6.1	-4.1
Common murre										
Northern fulmar	4.3	3.9	-1.8	-1.6	-1.2	-3.3	5.1	-14.4	17.1	
Thick-billed murre	2.7 (1.1 to 4.3)	-7.2	-5.6 (-7.3 to -4.4)	-4.8 (-5.1 to -4.3)	-4.9 (-5.2 to -4.4)	-1.5 (-2.9 to 0.2)	1.5 (-0.7 to 3.3)	-6.5 (-13.4 to -2.7)	4.3 (-6.2 to 13.6)	-12.8
Beluga	1.6	-0.3	-1.4	2.5	1.3		-0.4	-2.9	-1.0	-1.4
Pilot whale		-11.8 (-14.6 to -8.9)	-9.2 (-16.8 to -1.7)	-10.0 (-27.3 to 2.7)	-2.5 (-6.3 to 1.3)		-2.2 (-7.2 to 7.2)		11.9 (-4.2 to 40.3)	
Polar bear	0.9 (-0.3 to 2.2)	-1.9 (-2.2 to -1.3)	2.6 (-0.4 to 5.6)	-2.3 (-7.1 to 2.5)	-2.9 (-7.2 to 2.0)	0.9 (-1.6 to 3.0)	9.0 (6.1 to 12.3)	-13.4 (-20.7 to -1.6)	3.0 (-0.1 to 5.9)	
Ringed seal	-4.6 (-7.5 to -2.8)	-4.7 (-5.8 to -3.1)	-4.2 (-7.2 to -1.0)	-3.5 (-7.0 to -0.6)	-3.9 (-7.0 to -1.0)		0.6 (-4.6 to 5.5)	-10.5 (-11.9 to -9.0)	-1.7 (-5.5 to 6.2)	-7.7 (-9.3 to -5.5)
All species	0.2 (-7.5 to 4.6)	-0.6 (-20.1 to 19.0)	-4.3 (-24.3 to 5.6)	-3.6 (-27.3 to 15.5)	-2.4 (-22.9 to 16.5)	-0.7 (-3.3 to 3.0)	0.02 (-21.0 to 12.3)	-9.9 (-21.9 to 14.2)	3.4 (-6.2 to 40.3)	-6.2 (-17.8 to 9.3)

Cell shading: ≤-10% -10 to -3% >-3 to <3% 3 to 10% ≥10% annual change

	Mirex	Pentachloro-benzene	CB153	ΣPCB_{10}	Toxaphene Parlar-26	Toxaphene Parlar-50	BDE47	BDE99	HBCDD	PFOA	PFOS	PFOSA
Blue mussel			1.8 (-15.3 to 28.0)	6.1 (-10.9 to 33.0)	-7.9 (-11.6 to -1.5)	8.3 (1.6 to 16.0)						
Arctic char			-9.6 (-19.8 to -0.4)	-12.0 (-22.1 to -2.9)		-29.4	-12.5 (-14.8 to -8.9)	-17.2 (-25.5 to -8.8)			-2.1 (-5.2 to 1.1)	
Burbot	-6.2	-1.0	-3.9	-3.7			0.2				5.9	
Atlantic cod	7.4		-1.6 (-8.7 to 4.2)	-2.2 (-10.8 to 2.6)	-2.2 (-5.2 to 2.8)	0 (-5.7 to 10.1)						
European plaice		-5.4	-16.3 (-30.8 to -5.5)	-12.6 (-27.5 to -4.5)								
Lake trout							-2.8 (-7.0 to 1.5)	-2.4 (-3.7 to -1.0)			-36.9 (-44.9 to -28.9)	
Pike			-3.8				1.1				-5.2	
Black guillemot			2.5	2.3	-2.7	-4.2						
Common murre							-8.2	-4.1				
Northern fulmar	0.1	7.4		-1.1			-13.6	14.8	-7.5		4.7	
Thick-billed murre	-8.0 (-14.3 to -2.6)	5.2 (3.5 to 6.9)	-3.1 (-4.3 to -1.8)	-3.8 (-4.7 to -2.9)			-11.4 (-13.1 to -9.3)	40.0 (3.0 to 104.5)	-6.9		4.9	
Beluga	-3.9	2.3	0.4	-0.5								
Pilot whale	2.7 (-4.6 to 13.5)		-7.1 (-14.1 to 2.3)	-7.3 (-13.4 to 1.0)	-5.5 (-8.5 to -0.2)	-7.3 (-9.8 to -2.9)						
Polar bear		11.1 (0.2 to 22.0)	1.0 (-4.6 to 5.4)	0.6 (-4.3 to 3.7)			-3.2 (-9.4 to 4.6)	-10.7 (-12.7 to -8.0)		3.1 (0.2 to 8.2)	-2.1 (-4.7 to -0.2)	-25.3 (-30.7 to -20.4)
Ringed seal			-3.8 (-8.5 to 1.4)	-4.5 (-9.6 to 0.3)	-4.6 (-5.1 to -4.2)	-6.4 (-6.8 to -5.5)	1.7 (-3.7 to 12.4)	4.5 (-8.7 to 44.1)	3.6			
All species	-1.9 (-14.3 to 13.5)	4.5 (-5.4 to 22.0)	-2.5 (-30.8 to 28.0)	-1.5 (-27.5 to 33.0)	-5.9 (-11.6 to 2.8)	0.8 (-29.4 to 16.0)	-4.5 (-14.8 to 12.4)	4.8 (-25.5 to 104.5)	-3.6 (-7.5 to 3.6)	3.1 (0.2 to 8.2)	-6.7 (-44.9 to 5.9)	-25.3 (-30.7 to -20.4)

Table A6.4 Summary of trend results (mean and range of annual change, %) for 'adequate' and/or significant runs for time-series starting before 2000.

	Dieldrin	*trans*-Nonachlor	ΣCHL	*p,p'*-DDE	ΣDDT	Heptachlor-expoxide	HCB	α-HCH	β-HCH	γ-HCH
Blue mussel		10.3		-7.3 (-8.3 to -6.2)	0.2 (-10.9 to 11.3)			-9.1 (-10.7 to -6.3)		
Arctic char	-6.0 (-8.3 to -3.8)	-8.3	-8.5 (-9.5 to -6.9)	-8.3 (-9.5 to -7.4)	-9.4 (-10.3 to -8.4)		-3.8 (-6.4 to -1.0)	-12.0 (-16.5 to -9.6)		-9.9 (-15.5 to -5.7)
Burbot	-5.5 (-8.0 to -3.0)	-5.4		-3.7	-5.4 (-5.7 to -5.0)			-9.5 (-11.4 to -7.5)		-9.2 (-12.1 to -6.3)
Atlantic cod		-5.0 (-7.0 to -3.0)		-3.4 (-5.3 to -0.4)	-8.8		-3.2 (-3.8 to -2.3)	-8.7 (-10.3 to -6.8)		-9.1 (-10.7 to -6.1)
European plaice				-15.6	-15.5		-13.8 (-14.7 to -12.9)			
Lake trout		-17.3 (-18.1 to -16.5)	-8.2	-17.1 (-24.3 to -9.9)	-7.5 (-7.9 to -7.1)		-9.8	-7.3 (-7.4 to -7.1)		-12.9
Pike				-7.4			-2.9	-4.6		
Black guillemot							3.0	-10.2		
Black-legged Kittiwake	-2.0			-5.8	-5.8		-4.1			
Common murre			-5.9					-5.7		
Northern fulmar	-0.9		-1.6	-4.4	-4.5		-2.6			
Thick-billed murre	-0.8	-8.5	-3.4 (-5.2 to -1.6)	-3.6 (-4.3 to -2.8)	-3.5 (-4.3 to -2.7)	-0.2	-2.9	-4.9		0.8
Beluga	0.9		-1.0				-0.8	-4.9 (-5.5 to -4.3)	2.7	-5.3
Northern fur seal								-8.6		-7.3
Pilot whale					-18.3				-3.4	
Polar bear	-1.3 (-2.5 to 0.6)	-2.9 (-3.0 to -2.7)		-4.3 (-5.8 to -2.8)	-4.7 (-6.1 to -3.2)	-1.1 (-2.6 to 1.5)	0.1	-11.4 (-12.5 to -8.5)	2.7 (-1.8 to 7.2)	
Ringed seal	-4.3	-5.7 (-5.8 to -5.7)	-5.0 (-5.6 to -4.4)	-4.9 (-5.8 to -3.8)	-4.2 (-6.3 to -2.3)		-2.9 (-3.7 to -2.0)	-9.0 (-11.4 to -4.7)	0.5 (-4.7 to 5.4)	-6.3 (-8.2 to -2.3)
All species	-3.3 (-8.3 to 0.9)	-6.1 (-18.1 to 10.3)	-5.3 (-9.5 to -1.0)	-6.9 (-24.3 to -0.4)	-6.4 (-18.3 to 11.3)	-0.9 (-2.6 to 1.5)	-4.0 (-14.7 to 3.0)	-9.1 (-16.5 to -4.3)	0.8 (-4.7 to 7.2)	-7.9 (-15.5 to 0.8)

Cell shading: ≤-10% | -10 to -3% | >-3 to <3% | 3 to 10% | ≥10% annual change

	Mirex	Pentachloro-benzene	CB153	$ΣPCB_{10}$	Toxaphene Parlar-26	Toxaphene Parlar-50	BDE47	BDE99	HBCDD	PFOA	PFOS	PFOSA
Blue mussel			-6.5 (-12.8 to -2.9)	-6.5 (-7.2 to -4.7)	-12.4 (-14.5 to -10.5)							
Arctic char			-6.3 (-9.5 to -3.2)	-7.0 (-10.7 to -3.0)	-7.7	-9.9	14.9 (7.3 to 22.5)	13.5				
Burbot		-3.8										
Atlantic cod			-3.0 (-4.8 to 0.3)	-4.8 (-5.3 to -4.2)								
European plaice			-11.3	-11.7								
Lake trout	-16.6											
Pike			-3.1									
Black guillemot												
Black-legged Kittiwake			-6.5	-6.8								
Common murre	-7.3											
Northern fulmar	-1.7	-1.6	-3.8	-4.2								
Thick-billed murre		-1.2	-3.9 (-4.6 to -3.1)	-4.4 (-5.1 to -3.6)								
Beluga		1.6	-0.8	-0.7			8.4 (5.3 to 11.5)		10.1			5.6
Northern fur seal					-7.9	-7.9	12.1	13.2	13.3			
Pilot whale	-3.7											
Polar bear			-2.1	-2.0 (-2.8 to -0.8)			6.0 (2.6 to 9.3)		7.3 (6.6 to 8.0)	1.5	2.7	-19.1
Ringed seal			-4.4 (-5.9 to -2.7)	-4.6 (-5.7 to -3.6)		-7.1 (-8.4 to -5.7)	1.4 (-2.5 to 4.1)	-7.2	4.5			
All species	-7.3 (-16.6 to -1.7)	-1.3 (-3.8 to 1.6)	-5.0 (-12.8 to 0.3)	-5.3 (-11.7 to -0.7)	-10.6 (-14.5 to -7.7)	-8.0 (-9.9 to -5.7)	6.9 (-2.5 to 22.5)	6.5 (-7.2 to 13.5)	8.5 (4.5 to 13.3)	1.5	2.7	-6.8 (-19.1 to 5.6)

Table A6.5 Summary of trend results (mean and range of annual change, %) for 'adequate' and/or significant runs for time-series starting in or after 2000.

	Dieldrin	*trans*-Nonachlor	ΣCHL	*p,p'*-DDE	ΣDDT	Heptachlor-exopxide	HCB	α-HCH	β-HCH	γ-HCH
Blue mussel		6.3 (-0.1 to 19.0)		-15.1	0.6 (-14.0 to 16.5)			-18.2 (-21.9 to -14.5)		-9.3
Arctic char		-20.1	-24.3	-12.0 (-20.3 to -3.7)	-2.4		-21.0			
Burbot		-6.4			-1.8			-12.2		-9.1
Atlantic cod		0.5 (-2.9 to 6.2)			-0.5 (-9.7 to 5.0)		-1.4 (-2.7 to 0.5)	-12.1	-1.6	-9.5 (-10.8 to -8.7)
European plaice				-18.8 (-27.2 to -13.2)			-14.5 (-17.3 to -10.7)	-17.5		-17.8
Pike				-8.0						
Black guillemot		0.7			2.0		3.3			
Northern fulmar					-11.3 (-22.9 to -1.8)					
Thick-billed murre		-1.9 (-2.2 to -1.3)	-7.3	-5.0	-2.9 (-7.2 to 2.0)					
Beluga		-0.3			1.3					-1.4
Pilot whale		3.9	-13.0 (-16.8 to -9.1)	-27.3	-1.2	-4.6	-6.6		-4.2	
Polar bear							9.2 (6.1 to 12.3)	-16.3 (-20.7 to -6.3)	5.9	
Ringed seal	-7.5	-11.8 (-14.6 to -8.9)	-5.0 (-5.2 to -4.8)	-3.9 (-4.1 to -3.7)	-2.5 (-6.3 to 1.3)		-2.6 (-4.6 to -0.6)	-10.8 (-11.9 to -9.7)	-5.4 (-5.5 to -5.3)	-7.8 (-9.1 to -6.4)
All species	-7.5	-4.7 (-5.8 to -3.1)	-10.3 (-24.3 to -4.8)	-13.1 (-27.3 to -3.7)	-3.9 (-7.0 to -1.0)	-4.6	-4.5 (-21.0 to 12.3)	-14.1 (-21.9 to -6.3)	-2.1 (-5.5 to 5.9)	-8.9 (-17.8 to -1.4)

Cell shading: ≤-10% | -10 to -3% | >-3 to <3% | 3 to 10% | ≥10% annual change

	Mirex	Pentachloro-benzene	CB153	ΣPCB_{10}	Toxaphene Parlar-26	Toxaphene Parlar-50	BDE47	BDE99	HBCDD	PFOA	PFOS	PFOSA
Blue mussel		-9.4 (-11.0 to -7.2)	-14.0	-8.8 (-15.3 to -2.3)	-7.9 (-11.6 to -1.5)	8.3 (1.6 to 16.0)		12.2 (-6.2 to 33.0)			19.0	-4.7 (-21.9 to 33.0)
Arctic char				-12.9 (-19.8 to -5.9)		-29.4		-22.1		-29.4	-20.1	-18.5 (-29.4 to -3.7)
Burbot											-6.4	-9.2 (-12.2 to -6.4)
Atlantic cod		-4.7 (-5.2 to -4.2)	5.0		-2.2 (-5.2 to 2.8)	0 (-5.7 to 10.1)				-5.1 (-5.7 to -4.4)		-4.7 (-12.1 to 5.0)
European plaice			-19.2 (-22.9 to -15.5)	-21.7 (-30.8 to -12.6)				-19.9 (-27.5 to -12.3)				-18.4 (-30.8 to -10.7)
Pike				-3.8								-5.9 (-8.0 to -3.8)
Black guillemot					-2.7	-4.2						3.3
Northern fulmar	-13.6											-13.6
Thick-billed murre	-11.7		-5.0						-6.9			-7.2 (-11.7 to -5.0)
Beluga				0.4								-0.5 (-1.4 to 0.4)
Pilot whale		-8.5		-14.1				-11.4 (-13.4 to -9.4)		-9.5 (-9.8 to -9.2)	-14.6	-11.4 (-27.3 to -4.2)
Polar bear			-7.2	4.2			-11.4	3.7				-4.7 (-20.7 to 12.3)
Ringed seal	-3.5 (-3.7 to -3.2)	-4.8 (-5.1 to -4.5)	-4.2 (-4.5 to -3.9)	-5.1 (-5.4 to -4.7)	-5.5 (-8.5 to -0.2)	-7.3 (-9.8 to -2.9)	9.2 (-8.2 to 44.1)	-4.4 (-4.7 to -4.1)		-6.4 (-6.8 to -5.5)	-5.5 (-5.8 to -5.1)	-4.8 (-11.9 to 44.1)
All species	-8.1 (-13.6 to -3.2)	-7.0 (-11.0 to -4.2)	-8.5 (-22.9 to 5.0)	-9.2 (-30.8 to 4.2)	-4.6 (-5.1 to -4.2)	-6.4 (-6.8 to -5.5)	4.1 (-11.4 to 44.1)	-4.8 (-27.5 to 33.0)	-6.9	-9.7 (-29.4 to -4.4)	-5.5 (-20.1 to 19.0)	-8.1 (-30.8 to 44.1)

4. Challenges and new approaches to assess biological effects
4.2 temporal trends in Hg and POP exposure

The recent AMAP temporal trend report (AMAP, 2016) provides updates on temporal trends for persistent organic pollutants (POPs) in Arctic air and biota. One of its major findings is that of the more than 1100 statistical runs considered on biota time series, only ~12% are of adequate power, that is, cover a time span to detect a 5% annual change with a statistical power of 80% for the current number of years.

This highlights the need to maintain monitoring programs to achieve sufficiently powerful time series for the detection of temporal trends. The greatest annual declines (typically 5–10% per year) were observed for legacy organochlorine pesticides, including toxaphenes, hexachlorocyclohexanes (HCHs) and DDTs. Chlordanes and industrial chemicals such as polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB) have also temporally declined, but at slightly lower rates. In many cases, more recently banned POPs, including polybrominated diphenyl ethers (PBDEs), perfluorooctane sulfonic acid (PFOS) and hexabromocyclododecane (HBCD) still exhibit increasing temporal trends, although fewer timeseries datasets are currently available for these chemicals. This highlights that with temporal trends generally not being optimally resolved for POPs, this is a limitation in making connections to changes in biological effects as suggested by temporal changes in biomarker endpoint measurements.

The POPs annexed at the onset of the Stockholm Convention, including DDTs, HCHs, PCBs and chlordanes, mainly show statistically significant declining temporal trends in Arctic air and biota, confirming the continued effectiveness of their ban over 20 to 30 years ago in most developed countries. Interestingly, the downward trend in many of the time-series began decades before the Stockholm Convention entered into force. This is likely to reflect the impact of control measures introduced at the national level in the 1980s and 1990s, in Arctic countries and neighboring regions. However, the rate of decrease of these POPs in Arctic air and biota is now slowing, which suggests that their concentrations are approaching steady state in the environment and also that secondary sources are now likely to be having a more dominant influence. More recently annexed POPs, including PBDEs, HBCD and PFOS, show a more mixed temporal pattern. In several cases concentrations increase until the mid-1990s to 2000 and thereafter decrease.

There are some sites in the Arctic where increasing concentrations of highly regulated POPs, including transnonachlor, PCBs (ΣPCB10 and CB153), ΣDDTs and HCB, have been observed and this is likely to be attributable to local sources. Examples include time series of HCB and PCB congeners (CB52 and CB101) in air, and HCB (in air and biota) in the eastern Greenland-Iceland-Svalbard region. The rising levels in air have been attributed to enhanced re-emission from oceans and land surfaces as well as melting ice and snow due to climate warming. A consistent increase in levels of PCBs and other POPs in polar bears from eastern Greenland in recent years, relative to levels in the mid-2000s, seems to be related to a change in diet as a consequence of sea ice loss (McKinney et al., 2013).

Regulatory measures for PBDEs introduced in the late 1990s and 2000s have been effective at curbing increasing trends in Arctic biota post2000. Another brominated flame retardant (BFR) compound, α-HBCD, has seen declines in atmospheric levels at Svalbard since 2006, while biota trends have been increasing since the 1980s. In contrast, PFOS levels over that same period peaked around the mid-2000s in biota and declined thereafter. The declines are thought to reflect the voluntary phase-out of PFOS and PFOS-related products in 2000 by the US company 3M. However, particle phase PFOS and perfluorooctanoic acid (PFOA) are not showing a decline in Arctic air at Zeppelin, and other perfluorinated carboxylic acids (PFCAs) continue to show rising trends in biota.

Temporal trends in contaminant levels are often interpreted as a response to changes in emission levels, however, previous Arctic assessments have revealed that interpreting trends in this over-simplistic manner is not appropriate. Changes in food web structure and in species' feeding habits can strongly affect levels in biota and humans, exemplified by the increasing trend of ΣPCB10 since 2000 in polar bears from eastern Greenland. Trends can also reflect changes in environmental processes, several of which can be associated with climate change and natural variability. A detailed examination of trends in individual datasets is necessary for reliable interpretation. Nonetheless, consistency in results from a large number of trend studies, over a wide geographical area, and involving different matrices, may provide an indication that global controls on emissions or global processes are responsible for at least some of the observed results. There is also a degree of consistency in the trend results obtained from air and biota monitoring, which lends support to the argument that other media should be included under the Stockholm Convention Global Monitoring Programme to further evaluate its effectiveness. Modelling results from studies associated with the EU-ArcRisk project (www.arcrisk.eu) indicate that most legacy POP decreases associated with gradual degradation in the environment will continue to exceed any possible increases due to enhanced remobilization resulting from climate change. Notwithstanding this, however, stockpiles of banned pesticides still exist in some countries and these represent a potential source of future contamination (AMAP, 2016). Results of the ArcRisk studies highlight the need to better characterize primary and secondary sources of POPs and to improve models by including indirect effects, such as carbon cycling, catchment hydrology, land use, and vegetation cover (Pacyna et al., 2015).

OSPAR

Levels and trends in marine contaminants and their biological effects – CEMP Assessment report 2016 (2017)

The 2016-17 MIME roll-over (http://dome.ices.dk/osparmime2016/main.html) assessed 8222 time series (of three years or more) in biota, of which 5743 were assessed for trends and 7227 for status, and 4877 time series in sediment, of which 3225 were assessed for temporal trends and 4017 for status. A breakdown of trends and status by OSPAR Region and determinand is given in Tables 1-4 (*only table 1 and 2 are included here*). Interpretation of these results can be found in the common indicator assessments of OSPAR's Intermediate Assessment 2017, which are based on this assessment (oap.ospar.org).

The assessment found up to 304 temporal trends for cadmium, for the organic contaminants up to 264 temporal trends for CB128 and pesticides, and 157 for PAHs. The number of temporal trends for newer organic contaminants was far fewer, with up to 88 for BDE47, 30 for TBT and 10 for dioxins and PFOS.

In general, the trends are mainly downwards, especially for the organic contaminants of PCB, pesticides and BDEs. The individual matrices are published as Intermediate Assessment 2017 common indicator assessments with further information on the individual contaminants groups.

For the organic contaminants, status of CB118 had the most results above the EAC. But of the 256 temporal trends, more than half were decreasing (124) and only 7 showed increasing trends. This indicates that in general the legislation and conventions against PCB pollution is working, except in some special circumstances.

Table 1: Summary of trends in contaminants and biological effects in biota

	Region I			Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up	total	down	up
Metals												
CD	10	1	0	151	36	25	91	36	7	52	22	5
HG	9	3	0	163	29	21	76	11	8	53	15	0
PB	8	4	0	149	61	12	89	15	8	53	30	2
CU	9	1	1	145	29	7	86	16	5	52	4	4
ZN	11	3	1	144	33	7	86	18	3	52	17	1
PAHs (parent)												
NAP	3	1	0	63	19	2	13	1	1	15	2	0
PA	4	1	0	82	31	1	33	5	4	38	12	0
ANT	2	0	0	46	13	0	11	0	1	28	8	1
DBT				10	5	0						
FLU	4	2	0	77	22	4	34	4	3	38	12	0
PYR	4	2	0	75	19	1	32	5	1	38	12	0
BAA	4	3	0	62	21	2	16	7	1	38	8	0
CHR	4	2	0	60	18	1	19	8	0	38	10	0
BAP	3	2	0	38	6	2	9	5	0	38	4	5
BGHIP	4	3	0	55	7	0	15	7	0	38	5	0
ICDP	3	2	0	47	5	0	14	1	0	36	6	0
CBs												
CB28	5	4	0	84	43	1	51	18	1	29	10	1
CB52	5	4	0	98	40	0	55	24	1	33	16	0
CB101	6	5	0	127	71	2	64	23	0	42	25	0
CB105	4	4	0	80	62	1	33	8	0	41	20	0
CB118	9	8	0	130	79	1	73	21	2	42	16	4
CB126				7	2	0						
CB138	9	8	0	131	79	0	69	23	1	41	32	0
CB153	9	7	0	139	76	1	74	16	2	42	34	0
CB156	3	3	0	54	24	0	24	1	0	33	12	0
CB169				7	1	0						
CB180	6	4	0	102	57	1	52	7	2	38	28	0
Organobromines												
BDE28	3	2	0	12	5	0	13	2	0			
BDE47	4	3	0	31	21	0	32	15	1	21	5	1
BDE99	3	1	0	20	10	0	26	14	1	21	9	1
BD100	3	0	0	28	5	1	28	10	0	20	7	1
BD153				11	2	2	14	5	0	6	0	0
BD154	3	0	0	10	5	2	17	6	1	13	3	0
Pesticides												
DDEPP	7	6	0	79	31	1	34	1	3	39	7	1
	Region I			Region II			Region III			Region IV		
HCB	7	4	0	58	18	1	27	4	2	5	0	0
HCHA	3	3	0	24	15	0	28	7	1	23	7	0
HCHG	2	2	0	63	55	0	28	10	0	38	21	0
Dioxins, furans and POPs												
TCDD				9	2	0						
CDF2T				10	4	1						
PFOS	3	2	0	7	6	0						
Organometals												
DBTIN				18	12	0						
MBTIN				10	4	1						
TBTIN	3	3	0	27	22	0						
TPTIN				3	1	0						
Biological effects												
EROD				41	8	0	29	10	0			
PYR1OH				28	2	3	14	0	2			
PA1OH				4	2	0						
BAP3OH				3	1	0						
ACHE				1	0	0						
ALAD				3	0	0						
GST				1	0	0						
SFG										17	4	0
VDS	2	2	0	104	62	0	53	9	0	15	11	0
INTS				3	0	0						

Table 2: Summary of trends in contaminants in sediment

	Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up
Metals									
CD	66	20	0	20	2	4	29	2	1
HG	72	27	0	26	7	0	29	7	1
PB	83	15	2	26	7	2	29	3	1
AS	61	4	1	27	0	4	29	0	3
CR	76	1	4	27	4	2	29	6	0
CU	78	16	4	27	7	1	29	0	2
NI	79	3	5	27	4	2	29	0	1
ZN	74	7	1	27	8	1	29	9	0
PAHs (parent)									
NAP	45	0	1	23	6	1			
PA	70	13	2	29	2	1	29	6	0
ANT	62	10	3	24	2	0	29	6	2
DBT	14	0	0	15	5	0			
FLU	69	11	4	28	3	2	29	7	0
PYR	70	13	2	29	3	3	29	9	0
BAA	66	11	2	28	3	2	29	7	0
CHR	63	12	2	21	3	2	29	7	0
BAP	67	14	2	28	3	2	29	10	0
BGHIP	67	20	2	27	6	0	29	3	0
ICDP	67	13	2	28	5	0	29	14	0
PAHs (alkylated)									
NAPC1	10	1	1	3	0	1			
NAPC2	25	1	2	19	4	1			
NAPC3	26	0	2	19	4	1			
PAC1	16	2	1	16	3	0			
PAC2	16	1	1	16	4	0			
PAC3	13	1	1	15	3	0			
DBTC1	15	2	2	15	3	0			
DBTC2	16	2	1	15	5	0			
DBTC3	15	1	2	15	3	0			
CBs									
CB28	34	10	2	14	4	2	19	0	0
CB52	30	11	1	16	6	1	26	5	4
CB101	46	15	2	18	8	1	20	0	0
CB105	12	4	0	7	0	0	22	0	1
CB118	45	18	1	19	4	2	21	0	1
CB138	45	23	1	19	6	1	24	0	0
CB153	48	12	1	19	3	3	27	0	0
CB156	2	0	0	4	0	0	24	0	1

	Region II			Region III			Region IV		
CB180	36	11	1	14	4	3	23	0	0
Organobromines									
BDE28				2	0	0			
BDE47	5	0	0	7	2	0			
BDE66				3	1	0			
BDE99				1	1	0			
BD100				5	1	0			
BD153				2	0	0			
BD154				4	0	0			
BD183				2	1	0			
Organometals									
DBTIN	15	12	0						
MBTIN	15	5	0						
TBTIN	13	13	0						

Levels and trends in marine contaminants and their biological effects – CEMP Assessment report 2017 (2018)

The 2017-18 MIME roll-over assessed 8203 time series (of three years or more) in biota, of which 5597 were assessed for trends and 7806 for status, and 4562 time series in sediment, of which 3258 were assessed for trends and 4016 for status. A breakdown of trends and status by region and determinand is given in Tables 1-4 (*only table 1 and 2 is included here*). The assessment methodology is described in the help files that accompany the assessment.

Organo-bromine concentrations have been assessed for status for the first time. Canadian Federal Environmental Quality Guidelines (FEQGs) were used as EAC equivalents for biota and sediment. Background Assessment Concentrations (BACs) were developed for BDE47 in biota and sediment and trialled. More work is required to develop BACs for other organo-bromines, and the BACs for BDE47 might need to be revised as part of that process. The development of the BACs and the use of the FEQGs are described at http://dome.ices.dk/osparmime2017/help_ac_development_organo-bromines.html.

Table 1: Summary of trends in contaminants and biological effects in biota

	Region I			Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up	total	down	up
Metals												
CD	19	6	1	162	38	25	82	32	6	54	17	4
HG	18	2	0	174	27	17	69	10	5	54	11	1
PB	18	5	0	161	46	12	79	12	7	54	15	1
CU	16	9	0	152	26	8	79	14	3	52	2	4
ZN	20	6	2	155	36	10	79	16	1	52	11	0
PAHs (parent)												
NAP	3	2	0	49	11	3	13	1	1	10	0	1
PA	4	1	0	77	13	2	35	5	4	39	3	1
ANT	2	0	0	36	7	0	11	0	1	24	9	1
DBT				11	5	0						
FLU	4	2	0	78	13	4	35	5	3	39	12	0
PYR	4	2	0	81	18	1	33	7	1	39	14	0
BAA	4	3	0	48	12	4	17	7	1	37	8	0
CHR	4	2	0	58	18	1	19	8	0	38	14	0
BAP	3	3	0	29	7	0	10	5	0	34	4	1
BGHIP	4	4	0	34	12	0	15	6	0	24	6	0
ICDP	3	3	0	26	9	0	11	1	0	23	6	0
CBs												
CB28	4	4	0	67	33	1	51	18	1	22	8	0
CB52	12	5	0	92	39	0	54	24	1	35	14	0
CB101	15	9	0	129	60	2	59	24	0	44	24	0
CB105	14	11	0	81	51	3	32	6	0	38	15	0
CB118	18	14	0	133	70	1	70	25	2	43	17	4
CB126				1	0	0						
CB138	18	14	1	125	72	0	65	23	1	39	25	0
CB153	18	12	1	144	73	1	71	21	2	44	29	0
CB156	7	4	0	46	24	0	24	1	0	23	10	0
CB169				2	0	0						
CB180	10	4	0	96	45	1	53	8	2	37	22	0
Organobromines												
BDE28	1	0	0	14	5	0	14	2	0			
BDE47	2	1	0	31	23	0	33	16	1	21	5	1
BDE99	1	0	0	20	10	0	26	15	1	21	9	1
BD100	1	0	0	28	6	1	30	13	0	20	7	1
BD153				11	2	2	17	5	0	6	0	0
BD154	1	0	0	10	5	1	20	6	2	13	3	0
Pesticides												
DDEPP	18	11	0	65	21	1	30	1	3	31	8	0
HCB	18	6	0	55	17	1	27	4	2	5	0	0
HCHA	14	11	0	22	14	0	27	7	1	17	2	0
HCHG	10	5	0	48	36	0	27	10	0	30	11	0
Dioxins, furans and PFCs												
TCDD				11	3	1						
CDF2T				10	2	0						
PFOS	1	0	0	4	4	0						
Organometals												
DBTIN				19	12	0						
MBTIN				11	4	0						
TBTIN	2	2	0	29	22	0				1	0	0
TPTIN				3	1	0						
Biological effects												
EROD				37	8	1	30	14	0			
PYR1OH				28	2	3	15	0	2			
PA1OH				4	2	0						
BAP3OH				3	1	0						
ACHE				1	0	0						
ALAD				3	0	0						
GST				1	1	0						
SFG										17	4	0
VDS	2	2	0	88	60	0	27	9	0	9	8	0
INTS				3	0	0						

Table 2: Summary of trends in contaminants in sediment

	Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up
Metals									
CD	61	17	0	19	2	3	29	2	1
HG	65	26	0	25	7	0	29	7	1
PB	71	16	5	25	7	2	29	3	1
AS	57	4	3	26	0	4	29	0	3
CR	67	2	4	26	5	1	29	6	0
CU	69	16	3	26	7	0	29	0	3
NI	70	4	4	26	4	1	29	0	1
ZN	67	8	1	26	8	1	29	10	0
PAHs (parent)									
NAP	50	3	1	24	6	0	0	0	0
PA	74	15	1	28	2	1	29	6	0
ANT	64	10	5	25	3	1	29	7	2
DBT	14	1	1	14	5	0	0	0	0
FLU	73	13	3	27	3	2	29	7	0
PYR	74	14	3	28	5	2	29	9	0
BAA	68	10	1	25	4	2	29	7	0
CHR	72	13	2	25	3	4	29	7	0
BAP	69	16	2	26	4	1	29	10	0
BGHIP	69	19	3	27	6	0	29	3	0
ICDP	69	15	2	27	4	0	29	14	0
PAHs (alkylated)									
NAPC1	10	1	1	4	0	0			
NAPC2	25	0	2	19	3	0			
NAPC3	26	0	2	19	4	0			
PAC1	16	3	1	15	2	1			
PAC2	16	2	2	15	4	0			
PAC3	14	1	2	14	2	1			
DBTC1	15	1	2	14	2	2			
DBTC2	15	1	0	14	4	0			
DBTC3	15	1	3	14	3	1			
CBs									
CB28	42	11	1	15	5	1	19	0	0
CB52	35	16	1	16	6	1	26	5	4
CB101	48	15	2	17	8	1	20	0	0
CB105	12	4	0	7	0	1	22	0	1
CB118	49	21	1	18	4	2	21	0	1
CB138	50	21	1	18	5	0	24	0	0
CB153	54	17	2	18	3	2	27	0	0
CB156	2	0	0	5	0	0	24	0	1
CB180	43	17	1	14	2	1	23	0	0
Organobromines									
BDE28				2	0	0			
BDE47	5	0	0	9	2	0			
BDE66				3	2	0			
BDE99				1	1	0			
BD100				6	1	0			
BD153				2	0	0			
BD154				5	0	0			
BD183				2	1	0			
Organometals									
DBTIN	27	13	0						
MBTIN	28	7	0						
TBTIN	25	17	0						

Levels and trends in marine contaminants and their biological effects – CEMP Assessment report 2018 (2019)

The 2018-19 annual CEMP assessment (http://dome.ices.dk/osparmime2018/main.html and https://ocean.ices.dk/oat/) assessed 7909 time series (of three years or more) in biota, of which 5401 were assessed for trends and 7518 for status; 4507 time series in sediment, of which 3253 were assessed for trends and 4022 for status; and 124 time series in water, of which 76 were assessed for trends and 124 for status. A breakdown of trends and status by region and determinand is given in Tables 1-6 (*only table 1 and 2 is included here*). The assessment methodology is described in the help files that accompany the assessment.

Table 1: Summary of trends in contaminants and biological effects in biota

	Region I			Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up	total	down	up
Metals												
CD	19	2	2	152	28	26	73	29	6	57	13	9
HG	20	3	1	164	25	29	64	8	5	55	10	5
PB	15	4	1	151	34	22	71	10	7	57	19	5
CU	18	5	1	146	25	9	70	10	2	57	1	5
ZN	23	3	4	150	24	16	72	12	1	57	10	2
PAHs (parent)												
NAP	1	0	0	46	9	2	11	0	0	10	0	0
PA	3	0	0	77	10	3	32	4	4	42	3	1
ANT	2	0	0	34	4	2	11	4	1	25	7	1
DBT				8	4	0						
FLU	3	1	0	79	11	6	34	4	2	44	11	0
PYR	2	0	0	82	14	4	33	7	2	44	12	0
BAA	2	2	0	49	8	3	18	7	0	42	11	1
CHR	2	0	0	62	16	2	22	7	0	44	14	0
BAP	2	2	0	30	6	1	10	1	0	36	4	1
BGHIP	2	2	0	31	8	0	16	3	0	28	6	0
ICDP	2	2	0	26	9	1	12	0	0	28	6	0
CBs												
CB28	6	5	0	68	31	1	47	16	1	24	10	0
CB52	14	9	0	93	33	1	48	19	1	36	13	0
CB101	16	8	1	129	53	3	55	24	0	45	23	0
CB105	10	7	0	47	23	2	30	9	1	41	13	0
CB118	18	13	0	132	61	3	62	25	2	45	16	1
CB126				3	1	0						
CB138	19	12	0	112	65	4	60	28	1	42	24	0
CB153	19	9	0	142	58	4	64	17	1	46	23	0
CB156	4	3	0	32	11	1	18	1	0	30	14	0
CB169				2	0	0						
CB180	11	3	0	99	33	3	46	10	1	41	19	0
Organobromines												
BDE28	3	2	0	16	9	0	11	3	0			

	Region I			Region II			Region III			Region IV		
BDE47	5	3	0	37	25	0	30	20	0	21	5	1
BDE99	3	2	0	26	11	1	22	14	0	21	9	1
BD100	5	3	0	33	12	1	27	16	0	20	7	1
BD153	1	1	0	14	3	1	16	8	0	6	0	0
BD154	3	0	0	15	8	1	21	9	1	13	2	0
HBCD				6	2	0						
Pesticides												
DDEPP	15	3	0	52	19	2	28	3	1	32	8	0
HCB	15	2	0	40	13	1	21	6	0	5	0	0
HCHA	10	8	0	9	5	0	19	9	0	17	2	0
HCHG	8	5	0	27	16	1	21	8	0	29	12	0
Dioxins, furans and PFCs												
TCDD				4	0	0	4	0	0			
CDF2T				3	0	0	1	0	0			
PFOS	3	3	0	5	5	0						
Organometals												
MBSN+				13	8	0						
DBSN+				19	14	0						
TBSN+	1	1	0	26	15	0	0	0	0	4	3	0
TPSN+				3	1	0						
Biological effects												
EROD				34	6	1	30	14	0			
PYR1OH				29	2	4	15	0	2			
PA1OH				4	2	0						
BAP3OH				3	1	0						
ALAD				3	0	0						
GST				1	1	0						
SFG										17	4	0
VDS	2	1	0	94	38	0	11	1	0	10	3	0
INTS				5	0	0						

Table 2: summary of trends in contaminants in sediment

	Region II			Region III			Region IV		
	total	down	up	total	down	up	total	down	up
Metals									
CD	65	14	1	19	2	3	29	1	1
HG	67	24	0	25	7	0	29	7	1
PB	76	18	4	25	7	2	29	3	1
AS	61	6	3	25	0	4	29	0	3
CR	70	4	3	25	5	1	29	6	0
CU	73	16	2	25	7	0	28	0	3
NI	75	5	5	25	4	1	29	0	1
ZN	72	10	0	25	8	1	29	10	0
PAHs (parent)									
NAP	49	2	0	23	7	0			
PA	71	20	0	27	2	2	29	7	0
ANT	67	11	6	24	2	2	29	7	1
DBT	14	1	2	14	4	0			
FLU	71	14	1	26	3	1	29	7	0
PYR	71	19	2	27	4	2	29	9	0
BAA	69	11	1	24	3	2	28	7	0
CHR	71	13	3	24	3	3	29	7	0
BAP	70	17	2	25	3	1	29	10	0
BGHIP	70	17	3	26	6	1	29	3	0
ICDP	70	16	2	26	4	1	29	15	0
PAHs (alkylated)									
NAPC1	10	3	0	4	0	0			
NAPC2	25	2	1	19	3	0			
NAPC3	26	3	1	19	4	0			
PAC1	16	2	1	15	2	2			
PAC2	16	2	2	15	5	0			
PAC3	10	0	2	11	3	1			
DBTC1	15	1	2	14	2	2			
DBTC2	15	1	0	14	4	0			
DBTC3	15	1	3	14	3	2			
CBs									
CB28	42	11	2	13	2	2	20	0	2
CB52	39	11	1	15	3	1	26	5	5
CB101	47	14	2	16	5	1	19	0	0
CB105	12	4	0	7	0	1	20	0	0
CB118	48	18	1	17	2	2	19	0	1
CB138	51	22	0	16	3	0	22	0	0
CB153	53	16	1	18	2	4	26	0	0
CB156	2	0	0	6	0	0	19	0	1
CB180	44	15	1	13	1	1	21	0	0

	Region II			Region III			Region IV		
Organobromines									
BDE28				2	0	0			
BDE47	5	0	0	10	1	0			
BDE66				4	1	0			
BDE85				1	1	0			
BDE99				5	2	0			
BD100				2	1	0			
BD153				6	0	0			
BD154				3	2	0			
BD183				5	1	0			
BD209				1	0	0			
Organometals									
MBSN+	29	6	1						
DBSN+	27	15	0						
TBSN+	26	18	0						

Intermediate Assessment 2017

Status and Trends of Polychlorinated Biphenyls (PCB) in Fish and Shellfish

Accessed 19.11.19

Seven PCB congeners were selected as indicators of wider PCB contamination due to their relatively high concentrations and toxic effects.

As per the OSPAR Coordinated Environmental Monitoring Programme (CEMP) (OSPAR, 2016) Contracting Parties are required to monitor the seven PCB congeners CB28, CB52, CB101, CB118, CB138, CB153, and CB180 (OSPAR, 1997) on a mandatory basis in biota (fish and mussels) and sediments for temporal trends and spatial distribution. Marine sediments, in particular those with a high organic carbon content, may accumulate hydrophobic compounds like PCBs to considerably higher concentrations than surrounding waters. The sampling strategy is defined by the purpose of the monitoring programme and the natural conditions of the region to be monitored (OSPAR, 1997). Typically sampling approaches include fixed-site sampling, stratified random sampling, or stratified fixed sampling.

Polychlorinated biphenyl (PCB) concentrations are measured in fish liver and shellfish. Samples are taken annually (or every few years) from sites mainly along the coast of the Greater North Sea, Celtic Seas, Iberian Coast and Bay of Biscay and at some coastal monitoring sites in Arctic Waters.

All areas assessed still have historical PCB contamination but concentrations in biota are reducing slowly (1995–2014) in nine out of ten, and show no statistically significant change in the other (Celtic Sea).

There is high confidence in the assessment and sampling methodology and high confidence in the data used.

Downward trends can be observed in all assessment areas except in the Celtic Sea where concentrations in biota show no statistically significant change (**Figure b**).

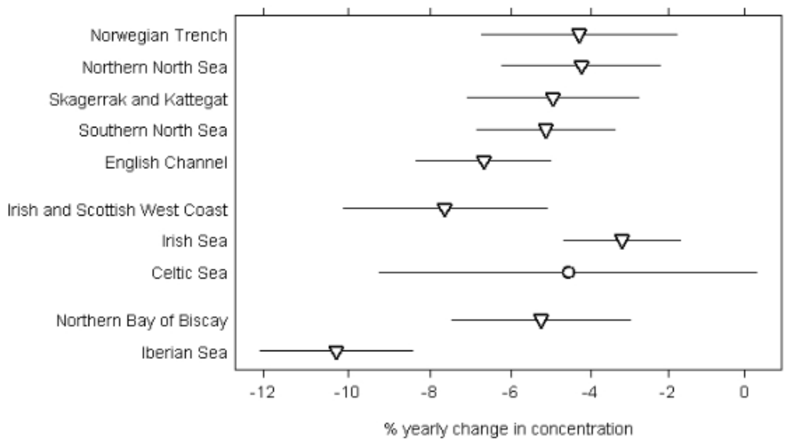


Figure b: Percentage yearly change in overall PCB concentrations in biota in each OSPAR contaminants assessment area.

No statistically significant (p <0.05) change in mean concentration (circle), mean concentration is significantly decreasing (downward triangle). 95% confidence limits (lines)

A summary of individual time series results at monitoring sites across the OSPAR Maritime Area for PCB in biota is presented here http://dome.ices.dk/osparmime2016/regional_assessment_biota_chlorobiphenyls.html. In total, mean concentrations of PCB in biota are above the EAC in 390 out of 2178 time series. In 20 out of 1565 time series where trend assessments have been undertaken, mean concentrations have increased over the assessment period (1995–2015). It should be noted that not all individual time series results are included in the regional assessments, due to the criteria set out in the Assessment Methods.

More than 25 years after polychlorinated biphenyls (PCBs) were banned the majority of PCB concentrations in fish and shellfish have decreased to acceptable ecological concentrations in most assessment areas. With the exception of the most toxic PCB congener (CB118), the concentrations of PCBs in fish and shellfish are below the level at which they could present an unacceptable risk to the environment. Mean concentrations of CB118 in biota are above this level in eight of the 11 areas assessed, and so adverse effects on marine organisms may still be possible in these areas.

MIME regional assessment of status and trends in CB concentrations in biota

- Info in the link above. Accessed 25.11.19

The 2017 MIME assessment describes the trends and status of contaminant concentrations in biota and sediment at monitoring stations in the OSPAR area. Assessments are made for a large number of time series, each of a single contaminant in a single species (for biota) at a single monitoring station. This document is one of a series that synthesises the results of the individual time series to assess status and trends at the MIME regional level. In particular, it considers CB concentrations in biota, where the CBs are CB28, CB52, CB101, CB118, CB138, CB153, CB180. For simplicity, the term 'region' is used throughout to describe MIME regions. OSPAR regions are always referred to as such.

A time series of CB concentrations is assessed for status if:

- there is at least one year with data in the period 2010 to 2015
- there are at least three years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the mean concentration in the final monitoring year (or, occasionally, if a non-parametric test of status is applied)

The conditions are more stringent for trends. Specifically, a time series is assessed for trends if:

- there is at least one year with data in the period 2010 to 2015
- there are at least five years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the trend in mean concentrations

Note that all trend assessments for individual time series and most status assessments are based on the fit of a parametric model. This is important because only the parametric results are passed into the regional assessments in the following sections. Only 210 of 2185 CB time series were assessed for status using a non-parametric test.

Table 1. Trend summary (numbers)

Number of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	CB28	CB52	CB101	CB118	CB138	CB153	CB180	total
1	Barents Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	1	1	1	1	1	2	2	9
		downward trend	3	3	4	7	7	6	3	33
	Norwegian Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	0	0	0	0	0	0	0	0
		downward trend	1	1	1	1	1	1	1	7
	total	upward trend	0	0	0	0	0	0	0	0
		no trend	1	1	1	1	1	2	2	9
		downward trend	4	4	5	8	8	7	4	40
2	Norwegian Trench	upward trend	1	0	0	0	0	1	0	2
		no trend	3	7	8	7	9	5	7	46
		downward trend	9	9	13	14	12	15	8	80
	Northern North Sea	upward trend	0	0	2	1	0	0	0	3
		no trend	4	2	9	16	18	26	9	84
		downward trend	3	5	6	6	8	5	4	37
	Skagerrak and Kattegat	upward trend	0	0	0	0	0	0	1	1
		no trend	14	13	9	6	9	8	8	67
		downward trend	8	13	20	22	19	20	10	112
	Southern North Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	12	16	19	13	13	18	16	107
		downward trend	7	6	12	16	15	12	10	78
	Channel	upward trend	0	0	0	0	0	0	0	0
		no trend	7	20	9	8	3	5	4	56
		downward trend	16	7	20	21	25	24	25	138
	total	upward trend	1	0	2	1	0	1	1	6
		no trend	40	58	54	50	52	62	44	360
		downward trend	43	40	71	79	79	76	57	445
3	Irish and Scottish West Coast	upward trend	0	0	0	0	0	1	0	1
		no trend	7	7	7	14	13	13	14	75
		downward trend	6	10	7	5	5	5	0	38
	Irish Sea	upward trend	1	1	0	2	1	1	2	8
		no trend	19	19	31	30	27	38	24	188
		downward trend	10	11	11	14	14	7	4	71
	Celtic Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	6	4	3	6	5	5	5	34
		downward trend	2	3	5	2	4	4	3	23
	total	upward trend	1	1	0	2	1	2	2	9
		no trend	32	30	41	50	45	56	43	297
		downward trend	18	24	23	21	23	16	7	132
4	Northern Bay of Biscay	upward trend	1	0	0	0	0	0	0	1
		no trend	9	12	9	12	2	2	2	48
		downward trend	3	4	7	4	13	14	14	59
	Iberian Sea	upward trend	0	0	0	4	0	0	0	4
		no trend	8	4	7	9	6	5	7	46
		downward trend	7	12	18	12	19	20	14	102
	Gulf of Cadiz	upward trend	0	0	0	0	0	0	0	0
		no trend	1	1	1	1	1	1	1	7
		downward trend	0	0	0	0	0	0	0	0
	total	upward trend	1	0	0	4	0	0	0	5
		no trend	18	17	17	22	9	8	10	101
		downward trend	10	16	25	16	32	34	28	161

Table 2. Trend summary (proportions).

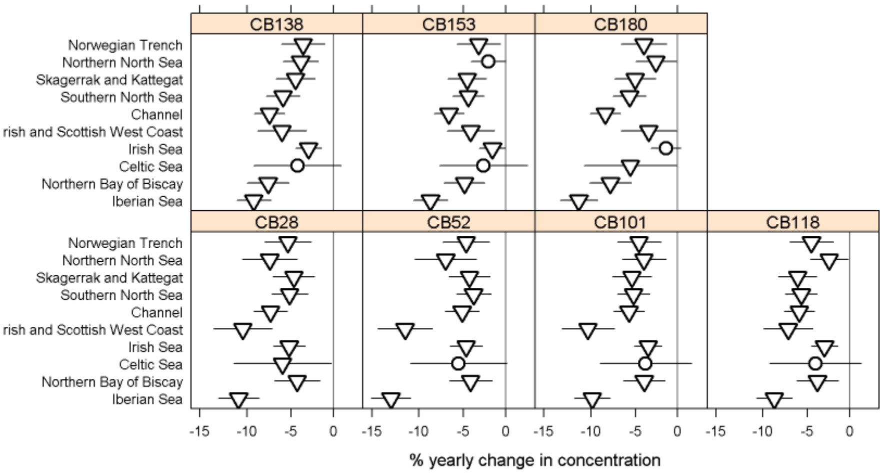
Proportion of time series with upwards, downwards or no trend by MIME and OSPAR region

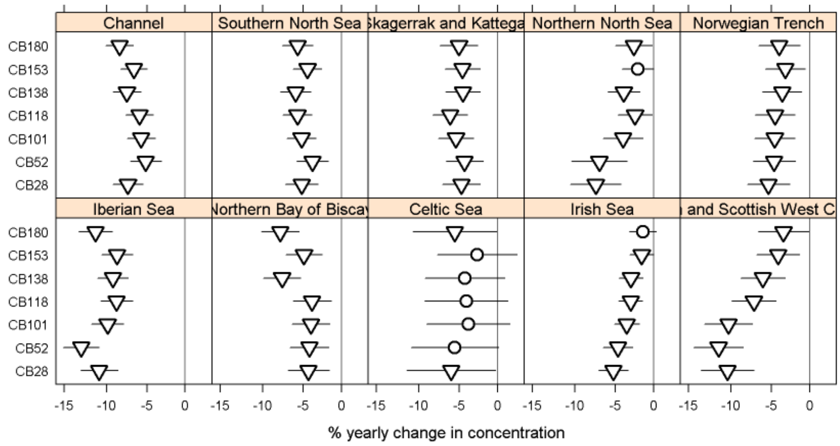
OSPAR region	MIME region	status	CB28	CB52	CB101	CB118	CB138	CB153	CB180	total
1	Barents Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	25	25	20	12	12	25	40	21
		downward trend	75	75	80	88	88	75	60	79
	Norwegian Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	0	0	0	0	0	0	0	0
		downward trend	100	100	100	100	100	100	100	100
	total	upward trend	0	0	0	0	0	0	0	0
		no trend	20	20	17	11	11	22	33	18
		downward trend	80	80	83	89	89	78	67	82
2	Norwegian Trench	upward trend	8	0	0	0	0	5	0	2
		no trend	23	44	38	33	43	24	47	36
		downward trend	69	56	62	67	57	71	53	62
	Northern North Sea	upward trend	0	0	12	4	0	0	0	2
		no trend	57	29	53	70	69	84	69	68
		downward trend	43	71	35	26	31	16	31	30
	Skagerrak and Kattegat	upward trend	0	0	0	0	0	0	5	1
		no trend	64	50	31	21	32	29	42	37
		downward trend	36	50	69	79	68	71	53	62
	Southern North Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	63	73	61	45	46	60	62	58
		downward trend	37	27	39	55	54	40	38	42
	Channel	upward trend	0	0	0	0	0	0	0	0
		no trend	30	74	31	28	11	17	14	29
		downward trend	70	26	69	72	89	83	86	71
	total	upward trend	1	0	2	1	0	1	1	1
		no trend	48	59	42	38	40	44	43	44
		downward trend	51	41	56	61	60	55	56	55
3	Irish and Scottish West Coast	upward trend	0	0	0	0	0	5	0	1
		no trend	54	41	50	74	72	69	100	66
		downward trend	46	59	50	26	28	26	0	33
	Irish Sea	upward trend	3	3	0	4	3	2	7	3
		no trend	64	61	74	65	64	83	80	70
		downward trend	33	36	26	31	33	15	13	27
	Celtic Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	75	57	38	75	56	56	62	60
		downward trend	25	43	62	25	44	44	38	40
	total	upward trend	2	2	0	3	2	3	4	2
		no trend	63	54	64	68	65	76	83	68
		downward trend	35	44	36	29	33	21	13	30
4	Northern Bay of Biscay	upward trend	8	0	0	0	0	0	0	1
		no trend	69	75	56	75	13	12	12	44
		downward trend	23	25	44	25	87	88	88	55
	Iberian Sea	upward trend	0	0	0	16	0	0	0	3
		no trend	53	25	28	36	24	20	33	30
		downward trend	47	75	72	48	76	80	67	67
	Gulf of Cadiz	upward trend	0	0	0	0	0	0	0	0
		no trend	100	100	100	100	100	100	100	100
		downward trend	0	0	0	0	0	0	0	0
	total	upward trend	3	0	0	10	0	0	0	2
		no trend	62	52	40	52	22	19	26	38
		downward trend	35	48	60	38	78	81	74	60

The symbols in all these plots have the following interpretation:

- downward triangle: the mean concentration is significantly decreasing ($p < 0.05$)
- circle: there is no change in mean concentration ($p > 0.05$)
- upward triangle: the mean concentration is significantly increasing ($p < 0.05$)

The 2 figures show the estimates of the regional trend (averaged over CBs) and the regional trend by CB.





MIME region	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Norwegian Trench	-4.39	1.32	-6.98	-1.80	-4.30	-6.75	-1.79
Northern North Sea	-4.34	1.07	-6.44	-2.24	-4.25	-6.24	-2.21
Skagerrak and Kattegat	-5.09	1.17	-7.38	-2.81	-4.97	-7.11	-2.77
Southern North Sea	-5.29	0.93	-7.12	-3.46	-5.15	-6.87	-3.40
Channel	-6.94	0.91	-8.73	-5.15	-6.70	-8.36	-5.02
Irish and Scottish West Coast	-7.96	1.38	-10.67	-5.25	-7.65	-10.12	-5.12
Irish Sea	-3.27	0.79	-4.82	-1.72	-3.22	-4.71	-1.71
Celtic Sea	-4.69	2.56	-9.70	0.32	-4.58	-9.25	0.32
Northern Bay of Biscay	-5.41	1.21	-7.77	-3.04	-5.26	-7.47	-3.00
Iberian Sea	-10.85	1.04	-12.88	-8.82	-10.28	-12.09	-8.44

The tables (above and below) show the estimates of the regional trend:

- trend: the estimated mean yearly change in log concentration across the region (multiplied by 100 for presentation)
- se: the corresponding standard error
- lower, upper: the corresponding pointwise 95% confidence limits
- % yearly change: the estimated mean % yearly change in concentration across the region
- %yc lower, %yc upper: the corresponding pointwise 95% confidence limit.

MIME region	CB	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Norwegian Trench	CB28	-5.54	1.45	-8.38	-2.70	-5.39	-8.04	-2.66
	CB52	-4.78	1.45	-7.62	-1.93	-4.67	-7.34	-1.91
	CB101	-4.69	1.37	-7.37	-2.01	-4.58	-7.11	-1.99
	CB118	-4.66	1.36	-7.33	-1.98	-4.55	-7.07	-1.96
	CB138	-3.71	1.36	-6.37	-1.05	-3.65	-6.17	-1.05
	CB153	-3.29	1.36	-5.95	-0.63	-3.24	-5.78	-0.63
	CB180	-4.09	1.42	-6.88	-1.31	-4.01	-6.65	-1.30
Northern North Sea	CB28	-7.76	1.72	-11.13	-4.39	-7.47	-10.53	-4.30
	CB52	-7.29	1.92	-11.05	-3.52	-7.03	-10.46	-3.46
	CB101	-4.11	1.36	-6.78	-1.44	-4.02	-6.55	-1.43
	CB118	-2.49	1.18	-4.79	-0.19	-2.46	-4.68	-0.19
	CB138	-4.00	1.10	-6.15	-1.84	-3.92	-5.96	-1.83
	CB153	-2.09	1.08	-4.21	0.03	-2.07	-4.12	0.03
	CB180	-2.64	1.27	-5.13	-0.16	-2.61	-5.00	-0.16
Skagerrak and Kattegat	CB28	-4.84	1.30	-7.39	-2.30	-4.73	-7.12	-2.27
	CB52	-4.41	1.28	-6.92	-1.91	-4.32	-6.69	-1.89
	CB101	-5.57	1.21	-7.94	-3.20	-5.42	-7.63	-3.15
	CB118	-6.35	1.20	-8.71	-3.99	-6.15	-8.34	-3.91
	CB138	-4.63	1.20	-6.98	-2.28	-4.52	-6.74	-2.25
	CB153	-4.69	1.20	-7.03	-2.34	-4.58	-6.79	-2.31
	CB180	-5.16	1.29	-7.70	-2.63	-5.03	-7.41	-2.59
Southern North Sea	CB28	-5.33	1.12	-7.53	-3.13	-5.19	-7.26	-3.08
	CB52	-3.90	1.08	-6.02	-1.78	-3.83	-5.84	-1.76
	CB101	-5.35	1.01	-7.33	-3.36	-5.21	-7.07	-3.31
	CB118	-5.90	1.00	-7.86	-3.93	-5.73	-7.56	-3.86
	CB138	-6.14	1.04	-8.18	-4.10	-5.95	-7.85	-4.02
	CB153	-4.54	0.98	-6.46	-2.61	-4.44	-6.26	-2.58
	CB180	-5.86	1.04	-7.89	-3.83	-5.69	-7.59	-3.76
Channel	CB28	-7.68	1.04	-9.72	-5.65	-7.40	-9.26	-5.49
	CB52	-5.29	1.07	-7.38	-3.19	-5.15	-7.12	-3.14
	CB101	-5.92	0.96	-7.80	-4.04	-5.75	-7.50	-3.96

	CB118	-6.15	0.95	-8.00	-4.29	-5.96	-7.69	-4.20
	CB138	-7.82	0.95	-9.67	-5.96	-7.52	-9.22	-5.79
	CB153	-6.89	0.93	-8.70	-5.07	-6.66	-8.34	-4.95
	CB180	-8.82	0.95	-10.69	-6.95	-8.44	-10.14	-6.72
Irish and Scottish West Coast	CB28	-11.05	1.82	-14.63	-7.48	-10.46	-13.61	-7.20
	CB52	-12.23	1.71	-15.58	-8.88	-11.51	-14.43	-8.50
	CB101	-10.90	1.64	-14.11	-7.70	-10.33	-13.16	-7.41
	CB118	-7.49	1.52	-10.48	-4.51	-7.22	-9.95	-4.41
	CB138	-6.29	1.53	-9.28	-3.30	-6.10	-8.86	-3.24
	CB153	-4.24	1.48	-7.15	-1.33	-4.15	-6.90	-1.32
	CB180	-3.53	1.73	-6.92	-0.13	-3.47	-6.69	-0.13
Irish Sea	CB28	-5.39	1.01	-7.36	-3.41	-5.24	-7.10	-3.35
	CB52	-4.79	1.02	-6.78	-2.80	-4.68	-6.56	-2.77
	CB101	-3.60	0.86	-5.28	-1.91	-3.53	-5.15	-1.89
	CB118	-3.07	0.82	-4.68	-1.46	-3.03	-4.58	-1.45
	CB138	-3.04	0.82	-4.65	-1.43	-2.99	-4.55	-1.42
	CB153	-1.60	0.81	-3.18	-0.01	-1.59	-3.13	-0.01
	CB180	-1.43	0.93	-3.25	0.39	-1.42	-3.20	0.39
Celtic Sea	CB28	-6.21	3.03	-12.16	-0.27	-6.03	-11.45	-0.27
	CB52	-5.72	3.00	-11.59	0.15	-5.56	-10.95	0.15
	CB101	-3.90	2.85	-9.48	1.68	-3.83	-9.05	1.69
	CB118	-4.18	2.85	-9.76	1.40	-4.10	-9.30	1.41
	CB138	-4.37	2.72	-9.71	0.96	-4.28	-9.25	0.97
	CB153	-2.70	2.73	-8.05	2.65	-2.66	-7.73	2.68
	CB180	-5.75	2.87	-11.38	-0.13	-5.59	-10.76	-0.13
Northern Bay of Biscay	CB28	-4.41	1.42	-7.19	-1.63	-4.32	-6.94	-1.62
	CB52	-4.27	1.33	-6.88	-1.66	-4.18	-6.65	-1.64
	CB101	-4.07	1.29	-6.59	-1.55	-3.99	-6.38	-1.54
	CB118	-3.93	1.31	-6.49	-1.36	-3.85	-6.29	-1.36
	CB138	-7.96	1.29	-10.50	-5.42	-7.65	-9.97	-5.28
	CB153	-5.01	1.26	-7.48	-2.55	-4.89	-7.20	-2.52
	CB180	-8.19	1.30	-10.74	-5.64	-7.86	-10.18	-5.49
Iberian Sea	CB28	-11.54	1.27	-14.02	-9.05	-10.90	-13.09	-8.65
	CB52	-13.95	1.24	-16.38	-11.52	-13.02	-15.11	-10.88
	CB101	-10.41	1.11	-12.58	-8.25	-9.89	-11.82	-7.91
	CB118	-9.20	1.11	-11.38	-7.02	-8.79	-10.76	-6.78
	CB138	-9.70	1.06	-11.79	-7.62	-9.25	-11.12	-7.34
	CB153	-9.13	1.07	-11.23	-7.04	-8.73	-10.62	-6.80
	CB180	-12.02	1.16	-14.28	-9.75	-11.32	-13.31	-9.29

Also contained regional status compared to the Environmental Assesment Criterion (EAC) and the Background Assessment Concentrations (BAC).

Status and Trend of Polychlorinated Biphenyls (PCB) in Sediment

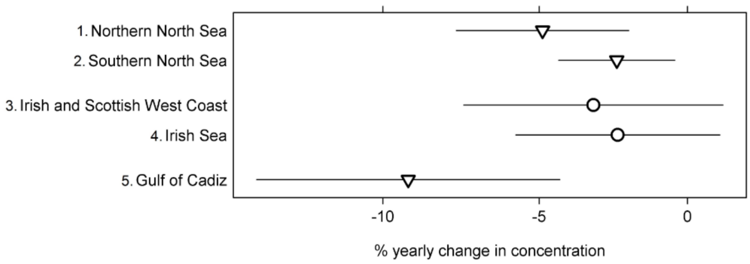
(Accessed 19.11.19).

Seven PCB congeners were selected as indicators of wider PCB contamination due to their relatively high concentrations and toxic effects.

Polychlorinated biphenyl (PCB) concentrations are measured in sediment samples taken annually (or every few years) from monitoring sites throughout much of the Greater North Sea, Celtic Seas, Iberian Coast and Bay of Biscay.

The time series used to inform this assessment started in 1995. The data are used to investigate trends in PCB concentration over the period 1995–2015 and to compare concentrations against two sets of assessment values: Background Assessment Concentrations (BACs) and Environmental Assessment Criteria (EACs). Where concentrations are below the EAC they should not cause chronic effects in sensitive marine species and so should present no significant risk to the environment. BACs are used to assess whether concentrations are close to zero for man-made substances, the ultimate aim of the OSPAR Hazardous Substances Strategy.

PCB concentrations are decreasing in the Northern North Sea, Southern North Sea and Gulf of Cadiz. In contrast, concentrations show no statistically significant change in the Irish and Scottish West Coast and the Irish Sea (Figure 2, *figure below*).



Concentrations in sediment for six out of seven PCB congeners are below the EAC in all OSPAR contaminants assessment areas (**Figure 3**) within the period 1995–2015. However, there are differences between congeners, with concentrations in sediment for one of the most toxic PCBs (CB118) close to or above the EAC in three assessment areas (English Channel, Southern North Sea and Irish Sea), indicating possible adverse effects on marine life in these areas. In the Irish and Scottish West Coast, Northern North Sea and Gulf of Cadiz assessment areas, CB118 concentrations in sediment are below the EAC, but still above the BAC. CB28 in the Irish and Scottish West Coast assessment area is the only measured concentration in sediment below the BAC.

There is high confidence in the assessment and sampling methodology and high confidence in the data used.

A summary of individual time series results at monitoring sites across the OSPAR Maritime Area for PCB concentrations in sediment is presented here http://dome.ices.dk/osparmime2016/regional_assessment_sediment_chlorobiphenyls.html. In total, mean concentrations of PCBs in sediment are above the EAC in 207 out of 1016 time series. In 27 out of 563 time series, mean concentrations have increased over the assessment period (1996–2015). It should be noted that not all individual time series results are included in the regional assessments, due to the criteria set out in the assessment methodology.

There is high confidence in the quality of the data used for this assessment. The data have been collected over many years using established sampling methodologies. There is sufficient temporal and spatial coverage and no significant data gaps in the areas assessed over the relevant time period (1995–2015). The methods are based on established and internationally recognised protocols for monitoring and assessment per monitoring site, with a new secondary step of synthesising monitoring site data at the assessment area scale. Therefore there is also high confidence in the methodology.

PCBs are found in all marine sediments. While concentrations are decreasing in the Greater North Sea and Gulf of Cadiz, they show no statistically significant change in the Celtic Seas. With the exception of the most toxic congener (CB118), concentrations of all PCB congeners in sediment are below the level at which they could present an unacceptable risk to the environment. Mean concentrations of CB118 in sediment are at or above this level in three of the six assessment areas assessed.

There is a lack of monitoring data for some parts of the OSPAR Maritime Area, particularly in Arctic Waters, some parts of the Celtic Seas and the Iberian Coast and Bay of Biscay.

MIME regional assessment of status and trends in CB concentrations in sediment

- *Info in the link above. Accessed 25.11.19*

The 2017 MIME assessment describes the trends and status of contaminant concentrations in biota and sediment at monitoring stations in the OSPAR area. Assessments are made for a large number of time series, each of a single contaminant in a single species (for biota) at a single monitoring station. This document is one of a series that synthesises the results of the individual time series to assess status and trends at the MIME regional level. In particular, it considers CB concentrations in sediment, where the CBs are CB28, CB52, CB101, CB118, CB138, CB153, CB180. For simplicity, the term ‘region’ is used throughout to describe MIME regions. OSPAR regions are always referred to as such.

Summary of individual time series results

A time series of CB concentrations is assessed for status if:

- there is at least one year with data in the period 2010 to 2015
- there are at least three years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the mean concentration in the final monitoring year (or, occasionally, if a non-parametric test of status is applied)

The conditions are more stringent for trends. Specifically, a time series is assessed for trends if:

- there is at least one year with data in the period 2010 to 2015
- there are at least five years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the trend in mean concentrations

Note that all trend assessments for individual time series and most status assessments are based on the fit of a parametric model. This is important because only the parametric results are passed into the regional assessments in the following sections. Only 119 of 1016 CB time series were assessed for status using a non-parametric test.

The final set of tabs give:

- the number of time series with upwards, downwards or no trend in each MiME and OSPAR region

- the same information presented as proportions
- the number of time series with blue, green, or red status in each MIME and OSPAR region
- the same information presented as proportions

Note that there are no BACs for the Gulf of Cadiz and the Iberian Sea. Time series in these regions are only assessed against the EAC, so can only be coloured green and red.

Table 1. Summary (numbers).

Number of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	CB28	CB52	CB101	CB118	CB138	CB153	CB180	total
2	Northern North Sea	upward trend	2	1	1	1	1	1	1	8
		no trend	2	2	7	8	7	13	6	45
		downward trend	1	5	4	3	3	1	1	18
	Southern North Sea	upward trend	0	0	1	0	0	0	0	1
		no trend	20	16	21	17	14	21	17	126
		downward trend	9	6	10	14	18	10	10	77
	Channel	upward trend	0	0	0	0	0	0	0	0
		no trend	0	0	1	1	0	1	1	4
		downward trend	0	0	1	1	2	1	0	5
	total	upward trend	2	1	2	1	1	1	1	9
		no trend	22	18	29	26	21	35	24	175
		downward trend	10	11	15	18	23	12	11	100
3	Irish and Scottish West Coast	upward trend	0	0	0	1	0	1	1	3
		no trend	2	2	2	4	5	4	2	21
		downward trend	0	2	3	1	1	1	0	8
	Irish Sea	upward trend	2	1	1	1	1	2	2	10
		no trend	6	6	7	9	7	9	5	49
		downward trend	3	4	4	2	4	1	3	21
	Celtic Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	0	1	0	0	0	0	0	1
		downward trend	1	0	1	1	1	1	1	6
	total	upward trend	2	1	1	2	1	3	3	13
		no trend	8	9	9	13	12	13	7	71
		downward trend	4	6	8	4	6	3	4	35
4	Iberian Sea	upward trend	0	4	0	0	0	0	0	4
		no trend	13	10	15	15	15	15	15	98
		downward trend	0	0	0	0	0	0	0	0
	Gulf of Cadiz	upward trend	0	0	0	1	0	0	0	1
		no trend	6	7	5	5	9	12	8	52
		downward trend	0	5	0	0	0	0	0	5
	total	upward trend	0	4	0	1	0	0	0	5
		no trend	19	17	20	20	24	27	23	150
		downward trend	0	5	0	0	0	0	0	5

Table 2. Trend summary (proportions)

Proportion of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	CB28	CB52	CB101	CB118	CB138	CB153	CB180	total
2	Northern North Sea	upward trend	40	13	9	8	9	7	13	11
		no trend	40	25	58	67	64	86	75	64
		downward trend	20	62	33	25	27	7	12	25
	Southern North Sea	upward trend	0	0	3	0	0	0	0	0
		no trend	69	73	66	55	44	68	63	62
		downward trend	31	27	31	45	56	32	37	38
	Channel	upward trend			0	0	0	0	0	0
		no trend			50	50	0	50	100	44
		downward trend			50	50	100	50	0	56
	total	upward trend	6	3	4	2	2	2	3	3
		no trend	65	60	63	58	47	73	67	62
		downward trend	29	37	33	40	51	25	30	35
3	Irish and Scottish West Coast	upward trend	0	0	0	16	0	16	33	9
		no trend	100	50	40	67	83	67	67	66
		downward trend	0	50	60	17	17	17	0	25
	Irish Sea	upward trend	18	9	9	8	9	17	20	13
		no trend	55	55	58	75	58	75	50	61
		downward trend	27	36	33	17	33	8	30	26
	Celtic Sea	upward trend	0	0	0	0	0	0	0	0
		no trend	0	100	0	0	0	0	0	14
		downward trend	100	0	100	100	100	100	100	86
	total	upward trend	14	6	6	11	5	16	21	11
		no trend	57	56	50	68	63	68	50	60
		downward trend	29	38	44	21	32	16	29	29
4	Iberian Sea	upward trend	0	29	0	0	0	0	0	4
		no trend	100	71	100	100	100	100	100	96
		downward trend	0	0	0	0	0	0	0	0
	Gulf of Cadiz	upward trend	0	0	0	17	0	0	0	2
		no trend	100	58	100	83	100	100	100	90
		downward trend	0	42	0	0	0	0	0	8
	total	upward trend	0	15	0	5	0	0	0	3
		no trend	100	66	100	95	100	100	100	94
		downward trend	0	19	0	0	0	0	0	3

Also contain MIME regional assessment – methods, regional assessment availability of time series (map of stations if the 4 different OSPAR regions), regional status compared to the Environmental Assessment Criterion (EAC), and regional status compared to the Backgroun Assessment Concentrations (BAC).

Regional trends

The figures show:

- Regional trends by CB: regional trend estimates for each CB with pointwise 95% confidence limits plotted by CB
- Regional trends by region: regional trend estimates for each CB with pointwise 95% confidence limits plotted by biogeographic region

The symbols in all these plots have the following interpretation:

- downward triangle: the mean concentration is significantly decreasing ($p < 0.05$)
- circle: there is no change in mean concentration ($p > 0.05$)
- upward triangle: the mean concentration is significantly increasing ($p < 0.05$)

The final 2 tables show the estimates of the regional trend (averaged over CBs) and the regional trend by CB.

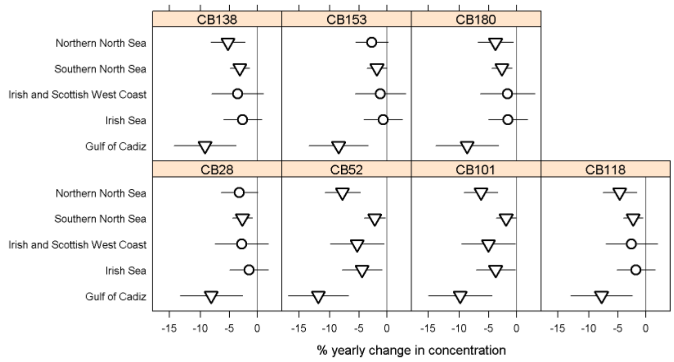


Figure 10. Regional trends by CB.

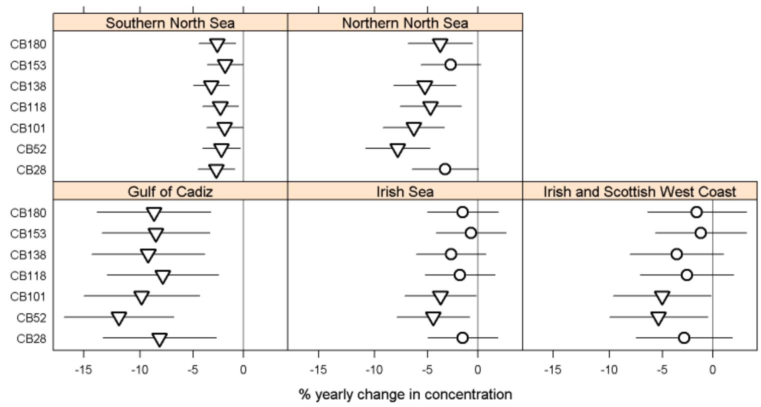


Figure 12. Individual time series.

Table 5. Estimates by region.

MIME region	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	-5.01	1.52	-7.99	-2.03	-4.89	-7.68	-2.01
Southern North Sea	-2.44	1.02	-4.45	-0.44	-2.41	-4.35	-0.44
Irish and Scottish West Coast	-3.25	2.29	-7.74	1.23	-3.20	-7.44	1.24
Irish Sea	-2.41	1.80	-5.94	1.12	-2.38	-5.77	1.13
Gulf of Cadiz	-9.66	2.68	-14.90	-4.41	-9.21	-13.84	-4.32

Table 6. Estimates by region and CB.

MIME region	CB	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	CB28	-3.35	1.72	-6.73	0.02	-3.30	-6.51	0.02
	CB52	-8.20	1.68	-11.49	-4.92	-7.88	-10.86	-4.80
	CB101	-6.57	1.60	-9.70	-3.43	-6.35	-9.24	-3.38
	CB118	-4.85	1.60	-7.98	-1.71	-4.73	-7.67	-1.70
	CB138	-5.45	1.62	-8.62	-2.27	-5.30	-8.26	-2.25
	CB153	-2.79	1.56	-5.84	0.26	-2.75	-5.67	0.26
	CB180	-3.86	1.68	-7.15	-0.57	-3.79	-6.90	-0.57
Southern North Sea	CB28	-2.78	0.96	-4.67	-0.90	-2.74	-4.56	-0.90
	CB52	-2.26	0.99	-4.19	-0.32	-2.23	-4.10	-0.32
	CB101	-1.91	0.94	-3.76	-0.06	-1.89	-3.69	-0.06
	CB118	-2.36	0.94	-4.20	-0.53	-2.33	-4.11	-0.52
	CB138	-3.27	0.93	-5.10	-1.44	-3.22	-4.97	-1.43
	CB153	-1.86	0.94	-3.69	-0.02	-1.84	-3.63	-0.02
	CB180	-2.67	0.97	-4.56	-0.77	-2.63	-4.46	-0.77
Irish and Scottish West Coast	CB28	-2.93	2.51	-7.84	1.99	-2.88	-7.54	2.01
	CB52	-5.53	2.55	-10.53	-0.53	-5.38	-9.99	-0.53
	CB101	-5.16	2.54	-10.14	-0.18	-5.03	-9.65	-0.18
	CB118	-2.64	2.44	-7.43	2.14	-2.61	-7.16	2.17
	CB138	-3.67	2.44	-8.45	1.10	-3.61	-8.10	1.11
	CB153	-1.21	2.37	-5.86	3.45	-1.20	-5.69	3.51
	CB180	-1.64	2.58	-6.69	3.42	-1.62	-6.47	3.48
Irish Sea	CB28	-1.56	1.82	-5.13	2.02	-1.54	-5.00	2.04
	CB52	-4.59	1.89	-8.29	-0.88	-4.48	-7.95	-0.88
	CB101	-3.85	1.85	-7.48	-0.22	-3.78	-7.20	-0.22
	CB118	-1.84	1.82	-5.41	1.74	-1.82	-5.27	1.75
	CB138	-2.75	1.81	-6.31	0.80	-2.72	-6.12	0.81
	CB153	-0.71	1.82	-4.28	2.87	-0.70	-4.19	2.91
	CB180	-1.58	1.85	-5.20	2.04	-1.57	-5.07	2.06
Gulf of Cadiz	CB28	-8.54	2.95	-14.33	-2.76	-8.19	-13.35	-2.72
	CB52	-12.70	2.85	-18.29	-7.12	-11.93	-16.72	-6.87
	CB101	-10.37	3.01	-16.27	-4.47	-9.85	-15.02	-4.37
	CB118	-8.21	2.91	-13.91	-2.51	-7.88	-12.99	-2.48
	CB138	-9.70	2.94	-15.46	-3.94	-9.25	-14.33	-3.87
	CB153	-8.94	2.81	-14.44	-3.44	-8.55	-13.45	-3.38
	CB180	-9.12	2.96	-14.93	-3.32	-8.72	-13.87	-3.26

The tables show the estimates of the regional trend by determinand:

- trend: the estimated mean yearly change in log concentration across the region (multiplied by 100 for presentation)
- se: the corresponding standard error
- lower, upper: the corresponding pointwise 95% confidence limits
- % yearly change: the estimated mean % yearly change in concentration across the region
- %yc lower, %yc upper: the corresponding pointwise 95% confidence limits.

Trends in Concentration of Polybrominated Diphenyl Ethers (PBDEs) in Fish and Shellfish

(Accessed 21.11.19)

Polybrominated diphenyl ether (PBDE) concentrations are measured in biota (fish, mussels and oysters) taken annually (or every few years) from monitoring sites throughout much of the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast. A few samples are also taken from Arctic Waters. Data recorded between 2010 and 2015 were used to investigate temporal trends in PBDE concentrations and to compare concentrations and patterns between OSPAR contaminants assessment areas. There were too few monitoring sites in Arctic Waters to give sufficient information for a trend assessment for that region.

Temporal trends in mean PBDE concentrations were assessed in seven assessment areas where there were more than five years of data. The results indicate that mean concentrations of PBDEs are decreasing in the majority of assessed areas (Figure 3). The Skagerrak and Kattegat is the exception, where concentrations in biota show no statistically significant change.

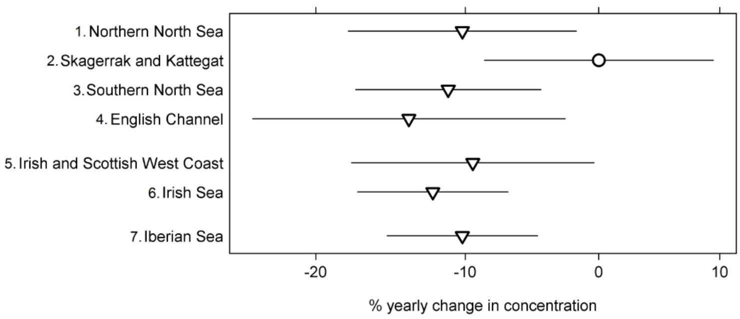


Figure 3: Percentage annual change in overall PBDE concentrations in fish and shellfish in each OSPAR contaminants assessment area. No statistically significant ($p < 0.05$) change in mean concentration (circle), mean concentration is significantly decreasing (downward triangle). 95% confidence limits (lines)

Mean PBDE concentrations are <1 µg/kg wet weight in ten assessment areas. The assessment areas showing the highest mean concentrations of PBDE in biota are the English Channel and Irish Sea. The lowest concentrations are found in the Iberian Sea. However, the species monitored differ between assessment areas and this may be reflected in the results. In the Iberian Sea only mussels are analysed, which may explain the low mean concentrations of PBDEs, since mussels across the assessment areas show lower concentrations than fish.

There is high confidence in the assessment and sampling methodology and high confidence in the data used.

Concentrations of six polybrominated diphenyl ether (PBDE) congeners (BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154) are measured in biota samples (fish, mussels and oysters). None of the areas in Arctic Waters were considered to have enough monitoring sites to give sufficient information for an assessment. Monitoring sites defined as polluted and assessment areas with too few monitoring sites were excluded from the assessment. The data were used to investigate temporal trends in PBDE concentrations and to compare concentrations and patterns between assessment areas.

No status assessment was made for the PBDEs in biota.

Figure a shows the estimated mean PBDE concentration for each assessment area, showing concentrations for the most recent year of available data (usually 2015). Mean PBDE concentrations are all <1 µg/kg wet weight. The assessment areas showing the highest concentrations were the English Channel, Northern North Sea, Southern North Sea and the Irish Sea. The lowest concentrations were found in the Iberian Sea. However, the species monitored differ between assessment areas and this may be reflected in the overall mean for a given area. Samples from the Iberian Sea, the assessment area with the lowest mean PBDE concentration, are taken only from mussels, which is likely to explain the low mean concentrations of PBDEs since mussels across the assessment areas show lower PBDE concentrations than fish on a wet weight basis. The pattern is similar between assessment areas with BDE-47, a tetra-brominated congener (one of the two main components in the penta-commercial mixture) dominating.

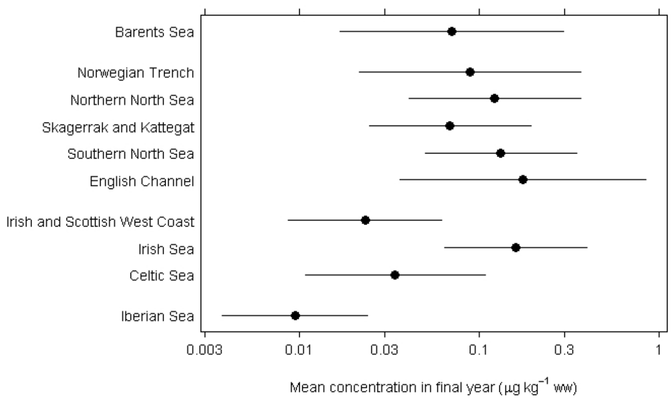


Figure a: Mean concentrations of PBDEs in fish and shellfish for each OSPAR contaminants assessment area for the most recent year of measurements (generally 2015), 95% confidence limits (lines)

Temporal trends in PBDE concentrations were assessed in areas where there were more than five years of data. The results indicate downward trends in the majority of assessment areas. Downward trends are seen in the Southern North Sea, Northern North Sea, English Channel, Irish and Scottish West Coast, Irish Sea, and Iberian Sea. The PBDE congener BDE-99 (the other main congener in the penta-commercial mixture) consistently shows the largest annual decrease in all assessment areas.

A summary of individual time series results at monitoring sites across the OSPAR Maritime Area for PBDEs in biota is presented here http://dome.ices.dk/osparmime2016/regional_assessment_biota_organo-bromines.html. In summary, in 11 out of 339 monitoring sites, mean concentrations of PBDE in biota increased over the assessment period (1996–2015). It should be noted that not all individual time series results are included in the area assessments, in accordance with the criteria set out in the Assessment Methods.

Since PBDEs were regulated, concentrations in fish and shellfish have decreased for the majority of the assessment areas.

Temporal trends in polybrominated diphenyl ether (PBDE) concentrations in biota are declining by approximately 10% per year in six of the seven areas assessed. In one assessment area, the Skagerrak and Kattegat, the trend shows no statistically significant change.

PBDE concentrations in biota vary between the assessed areas. The highest concentrations occur in the English Channel and the Irish Sea, with the lowest in the Iberian Sea. These differences could reflect the contamination load in the respective assessment areas, but could also be influenced by differences in the species monitored. As there are no assessment criteria available for PBDEs in biota, it is not possible to assess the environmental significance of the concentrations observed.

MIME regional assessment of status and trends in BDE concentrations in biota

- *Info in the link above. Accessed 25.11.19*

The 2017 MIME assessment describes the trends and status of contaminant concentrations in biota and sediment at monitoring stations in the OSPAR area. Assessments are made for a large number of time series, each of a single contaminant in a single species (for biota) at a single monitoring station. This document is one of a series that synthesises the results of the individual time series to assess status and trends at the MIME regional level. In particular, it considers BDE concentrations in biota, where the BDEs are BDE28, BDE47, BDE99, BD100, BD153, BD154. For simplicity, the term 'region' is used throughout to describe MIME regions. OSPAR regions are always referred to as such.

Summary of individual time series results

A time series of BDE concentrations is assessed for status if:

- there is at least one year with data in the period 2010 to 2015
- there are at least three years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the mean concentration in the final monitoring year (or, occasionally, if a non-parametric test of status is applied)

The conditions are more stringent for trends. Specifically, a time series is assessed for trends if:

- there is at least one year with data in the period 2010 to 2015
- there are at least five years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the trend in mean concentrations

Note that all trend assessments for individual time series and most status assessments are based on the fit of a parametric model. This is important because only the parametric results are passed into the regional assessments in the following sections. Only 0 of 583 BDE time series were assessed for status using a non-parametric test.

The following set of tables give:

- the number of time series with upwards, downwards or no trend in each MIME and OSPAR region
- the same information presented as proportions

Table 1. Trend summary (numbers)

Number of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	BDE28	BDE47	BDE99	BD100	BD153	BD154	total
1	Barents Sea	upward trend	0	0	0	0	0	0	0
		no trend	1	1	1	2	0	2	7
		downward trend	1	2	1	0	0	0	4
	Norwegian Sea	upward trend	0	0	0	0	0	0	0
		no trend	0	0	1	1	0	1	3
		downward trend	1	1	0	0	0	0	2
	total	upward trend	0	0	0	0	0	0	0
		no trend	1	1	2	3	0	3	10
		downward trend	2	3	1	0	0	0	6
2	Norwegian Trench	upward trend	0	0	0	0	0	1	1
		no trend	2	1	0	2	2	1	8
		downward trend	0	1	2	0	0	0	3
	Northern North Sea	upward trend	0	0	0	0	0	0	0
		no trend	0	4	2	4	0	0	10
		downward trend	1	4	2	2	1	2	12
	Skagerrak and Kattegat	upward trend	0	0	0	1	1	1	3
		no trend	1	3	3	6	1	1	15
		downward trend	2	5	4	1	1	1	14
	Southern North Sea	upward trend	0	0	0	0	1	0	1
		no trend	4	2	4	8	3	1	22
		downward trend	2	8	1	1	0	1	13
	Channel	upward trend	0	0	0	0	0	0	0
		no trend	0	0	1	2	1	0	4
		downward trend	0	3	1	1	0	1	6
	total	upward trend	0	0	0	1	2	2	5
		no trend	7	10	10	22	7	3	59
		downward trend	5	21	10	5	2	5	48
3	Irish and Scottish West Coast	upward trend	0	0	0	0	0	0	0
		no trend	3	6	4	4	1	1	19
		downward trend	0	1	2	1	0	0	4
	Irish Sea	upward trend	0	0	0	0	0	1	1
		no trend	5	7	5	11	7	7	42
		downward trend	2	13	10	8	5	6	44
	Celtic Sea	upward trend	0	1	1	0	0	0	2
		no trend	3	3	2	3	1	2	14
		downward trend	0	1	2	1	0	0	4
	total	upward trend	0	1	1	0	0	1	3
		no trend	11	16	11	18	9	10	75
		downward trend	2	15	14	10	5	6	52
4	Iberian Sea	upward trend	0	1	1	1	0	0	3
		no trend	0	15	11	12	6	10	54
		downward trend	0	5	9	7	0	3	24
	total	upward trend	0	1	1	1	0	0	3
		no trend	0	15	11	12	6	10	54
		downward trend	0	5	9	7	0	3	24

Table 2. Trend summary (proportions)

Number of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	BDE28	BDE47	BDE99	BD100	BD153	BD154	total
1	Barents Sea	upward trend	0	0	0	0	0	0	0
		no trend	1	1	1	2	0	2	7
		downward trend	1	2	1	0	0	0	4
	Norwegian Sea	upward trend	0	0	0	0	0	0	0
		no trend	0	0	1	1	0	1	3
		downward trend	1	1	0	0	0	0	2
	total	upward trend	0	0	0	0	0	0	0
		no trend	1	1	2	3	0	3	10
		downward trend	2	3	1	0	0	0	6
2	Norwegian Trench	upward trend	0	0	0	0	0	1	1
		no trend	2	1	0	2	2	1	8
		downward trend	0	1	2	0	0	0	3
	Northern North Sea	upward trend	0	0	0	0	0	0	0
		no trend	0	4	2	4	0	0	10
		downward trend	1	4	2	2	1	2	12
	Skagerrak and Kattegat	upward trend	0	0	0	1	1	1	3
		no trend	1	3	3	6	1	1	15
		downward trend	2	5	4	1	1	1	14
	Southern North Sea	upward trend	0	0	0	0	1	0	1
		no trend	4	2	4	8	3	1	22
		downward trend	2	8	1	1	0	1	13
	Channel	upward trend	0	0	0	0	0	0	0
		no trend	0	0	1	2	1	0	4
		downward trend	0	3	1	1	0	1	6
	total	upward trend	0	0	0	1	2	2	5
		no trend	7	10	10	22	7	3	59
		downward trend	5	21	10	5	2	5	48
3	Irish and Scottish West Coast	upward trend	0	0	0	0	0	0	0
		no trend	3	6	4	4	1	1	19
		downward trend	0	1	2	1	0	0	4
	Irish Sea	upward trend	0	0	0	0	0	1	1
		no trend	5	7	5	11	7	7	42
		downward trend	2	13	10	8	5	6	44
	Celtic Sea	upward trend	0	1	1	0	0	0	2
		no trend	3	3	2	3	1	2	14
		downward trend	0	1	2	1	0	0	4
	total	upward trend	0	1	1	0	0	1	3
		no trend	11	16	11	18	9	10	75
		downward trend	2	15	14	10	5	6	52
4	Iberian Sea	upward trend	0	1	1	1	0	0	3
		no trend	0	15	11	12	6	10	54
		downward trend	0	5	9	7	0	3	24
	total	upward trend	0	1	1	1	0	0	3
		no trend	0	15	11	12	6	10	54
		downward trend	0	5	9	7	0	3	24

Regional trends

The figures show:

- Regional trends by BDE: regional trend estimates for each BDE with pointwise 95% confidence limits plotted by BDE
- Regional trends by region: regional trend estimates for each BDE with pointwise 95% confidence limits plotted by biogeographic region

The symbols in all these plots have the following interpretation:

- downward triangle: the mean concentration is significantly decreasing ($p < 0.05$)
- circle: there is no change in mean concentration ($p > 0.05$)
- upward triangle: the mean concentration is significantly increasing ($p < 0.05$)

The following 2 tables show the estimates of the regional trend (averaged over BDEs) and the regional trend by BDE.

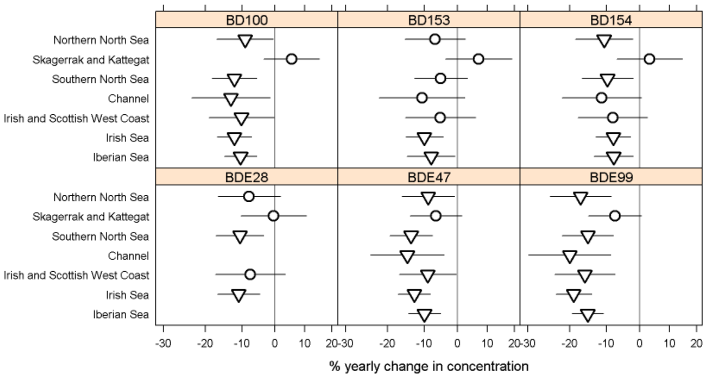


Figure 9. Regional trends by BDE.

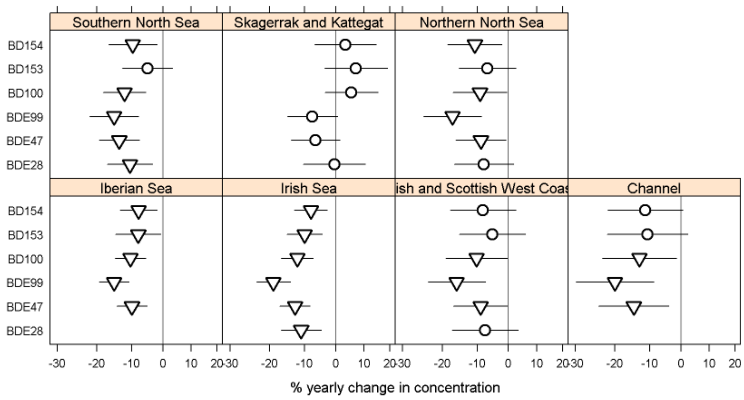


Figure 10. Regional trends by region.

Table 3. Estimates by region

MIME region	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	-10.76	4.58	-19.74	-1.78	-10.20	-17.91	-1.76
Skagerrak and Kattegat	0.01	4.60	-9.00	9.03	0.01	-8.61	9.44
Southern North Sea	-11.87	3.72	-19.17	-4.58	-11.20	-17.44	-4.47
Channel	-14.98	6.28	-27.29	-2.66	-13.91	-23.89	-2.63
Irish and Scottish West Coast	-9.94	4.88	-19.49	-0.38	-9.46	-17.71	-0.38
Irish Sea	-13.09	3.02	-19.02	-7.16	-12.27	-17.32	-6.91
Iberian Sea	-10.76	3.02	-16.68	-4.84	-10.20	-15.36	-4.72

Table 4. Estimates by region and BDE.

MIME region	BDE	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	BDE28	-8.27	5.12	-18.30	1.75	-7.94	-16.72	1.77
	BDE47	-9.33	4.33	-17.81	-0.85	-8.91	-16.31	-0.85
	BDE99	-18.85	5.00	-28.65	-9.06	-17.18	-24.91	-8.66
	BD100	-9.62	4.63	-18.69	-0.54	-9.17	-17.05	-0.54
	BD153	-7.14	4.93	-16.80	2.53	-6.89	-15.47	2.56
	BD154	-11.34	4.68	-20.51	-2.17	-10.72	-18.54	-2.15
Skagerrak and Kattegat	BDE28	-0.46	5.36	-10.96	10.05	-0.46	-10.38	10.57
	BDE47	-6.89	4.23	-15.18	1.40	-6.66	-14.08	1.41
	BDE99	-7.88	4.34	-16.38	0.62	-7.58	-15.11	0.62
	BD100	5.27	4.55	-3.66	14.19	5.41	-3.59	15.25
	BD153	6.78	5.43	-3.87	17.44	7.02	-3.79	19.05
	BD154	3.25	5.35	-7.23	13.73	3.30	-6.98	14.71
Southern North Sea	BDE28	-11.25	3.91	-18.91	-3.59	-10.64	-17.23	-3.52
	BDE47	-14.80	3.48	-21.63	-7.97	-13.76	-19.45	-7.66
	BDE99	-16.58	4.21	-24.83	-8.32	-15.27	-21.98	-7.99
	BD100	-13.05	3.65	-20.21	-5.89	-12.24	-18.30	-5.72
	BD153	-5.30	4.32	-13.77	3.16	-5.16	-12.86	3.21
	BD154	-10.25	4.19	-18.47	-2.04	-9.75	-16.87	-2.01
Channel	BDE28	-13.90	7.25	-28.10	0.31	-12.97	-24.49	0.31
	BDE47	-16.01	6.05	-27.86	-4.16	-14.80	-24.32	-4.08
	BDE99	-22.37	6.72	-35.54	-9.20	-20.05	-29.91	-8.79
	BD100	-14.12	6.40	-26.66	-1.58	-13.17	-23.40	-1.56
	BD153	-11.33	6.98	-25.00	2.35	-10.71	-22.12	2.38
	BD154	-12.14	6.48	-24.85	0.56	-11.43	-22.00	0.56
Irish and Scottish West Coast	BDE28	-7.90	5.72	-19.12	3.31	-7.60	-17.40	3.37
	BDE47	-9.43	4.66	-18.55	-0.30	-9.00	-16.93	-0.30
	BDE99	-17.50	4.95	-27.21	-7.79	-16.06	-23.82	-7.50
	BD100	-10.77	5.31	-21.17	-0.36	-10.21	-19.08	-0.36
	BD153	-5.44	5.73	-16.67	5.80	-5.29	-15.36	5.97
	BD154	-8.59	5.69	-19.74	2.55	-8.23	-17.91	2.59
Irish Sea	BDE28	-11.69	3.45	-18.45	-4.93	-11.03	-16.85	-4.81
	BDE47	-13.78	2.62	-18.93	-8.64	-12.88	-17.24	-8.28
	BDE99	-21.08	2.92	-26.81	-15.36	-19.01	-23.52	-14.24
	BD100	-13.03	2.79	-18.50	-7.56	-12.21	-16.89	-7.28
	BD153	-10.53	3.06	-16.52	-4.54	-9.99	-15.23	-4.44
	BD154	-8.42	2.85	-14.00	-2.84	-8.07	-13.06	-2.80
Iberian Sea	BDE28	-9.67	4.71	-18.91	-0.44	-9.22	-17.23	-0.44
	BDE47	-10.52	2.65	-15.72	-5.33	-9.99	-14.55	-5.19
	BDE99	-16.59	2.60	-21.68	-11.50	-15.29	-19.49	-10.86
	BD100	-11.05	2.64	-16.23	-5.88	-10.46	-14.98	-5.71
	BD153	-8.38	3.91	-16.05	-0.72	-8.04	-14.82	-0.72
	BD154	-8.32	3.23	-14.64	-2.00	-7.98	-13.62	-1.98

The tables show the estimates of the regional trend by determinand:

- trend: the estimated mean yearly change in log concentration across the region (multiplied by 100 for presentation)
- se: the corresponding standard error
- lower, upper: the corresponding pointwise 95% confidence limits
- % yearly change: the estimated mean % yearly change in concentration across the region
- %yc lower, %yc upper: the corresponding pointwise 95% confidence limits
-

Also contain MIME regiona assessment – methods and regional assessment – availability of time series.

Trends in Concentrations of Polybrominated Diphenyl Ethers (PBDEs) in Sediments

(Accessed 21.11.19)

The spatial distribution of PBDEs in marine sediments is variable. PBDEs do not dissolve in water and bind strongly to soil or sediment. As a result, PBDEs in sediment are not very mobile.

The OSPAR Hazardous Substances Strategy has the ultimate aim of achieving concentrations in the marine environment close to zero for man-made synthetic substances, and PBDEs are included in the group of brominated flame retardants on the OSPAR List of Chemicals for Priority Action. The status of PBDE concentrations in sediment is calculated but not assessed because there are no OSPAR assessment values developed with which to assess status.

Polybrominated diphenyl ether (PBDE) concentrations are measured in sediment samples taken annually (or every few years) from monitoring sites in the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast. Concentrations of six polybrominated diphenyl ether (PBDE) congeners (BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154) are measured in sediment samples for OSPAR's CEMP.

The number of time series used in each area assessed is very limited. Some of the PBDE in sediment data for the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast could not be taken into account, either because some time series include data below concentration levels that can be accurately measured or because time series are too short for analysis. Furthermore, an OSPAR contaminants assessment area was only assessed if at least three monitoring sites had enough years of data and a representative geographic spread across a contaminants assessment area. It is expected that more monitoring sites can be included for future assessments.

Temporal trends in mean PBDE concentrations were assessed in two areas where there were at least five years of data (**Figure 3**). Mean PBDE concentrations in sediment show no statistically significant change in the Northern North Sea and decreasing in the Irish Sea.

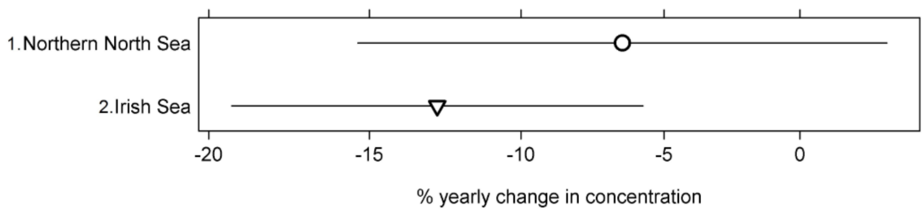


Figure 3: Percentage annual change in overall PBDE concentrations in sediment in each OSPAR contaminants assessment area No statistically significant ($p < 0.05$) change in mean concentration (circle), mean concentration is significantly decreasing (downward triangle). 95% confidence limits (lines)

The mean concentrations of PBDE in sediment were analysed for five assessment areas; Northern North Sea, Southern North Sea, Irish Sea, Irish and Scottish West Coasts and the Gulf of Cadiz. Concentrations in sediment are low (<1 µg/kg dry weight) and often below detection levels. The Gulf of Cadiz has the lowest concentrations of PBDE in any assessed area (<0.01 µg/kg dry weight), while the Irish Sea and Southern North Sea have the highest.

There is high confidence in the assessment and sampling methodology and high confidence in the data used.

None of the areas in Arctic Waters were considered to have enough monitoring sites to give sufficient information for an assessment. The data were used to investigate temporal trends in PBDE concentrations and to compare concentrations and patterns between assessment areas.

No status assessment was made for the PBDEs in sediment.

Figure a shows the estimated mean PBDE concentration for each assessment area, showing concentrations for the most recent year of available data (usually 2015). Mean PBDE concentrations in sediment are low (<1 µg/kg dry weight) and often below detection levels. However, this is not the case in industrialised areas. For those congeners measured, the Gulf of Cadiz has the lowest concentrations of PBDE in any assessed area (<0.01 µg/kg dry weight), while the Irish Sea and Southern North Sea have the highest.

The lack of data for some of the individual PBDE congeners is in most cases indicative of a very low value that cannot be accurately measured. The most common PBDE congener used in flame retardants is BDE-209 and this is found to occur at the highest concentrations in sediments within the OSPAR Maritime Area (>1 µg/kg dry weight).

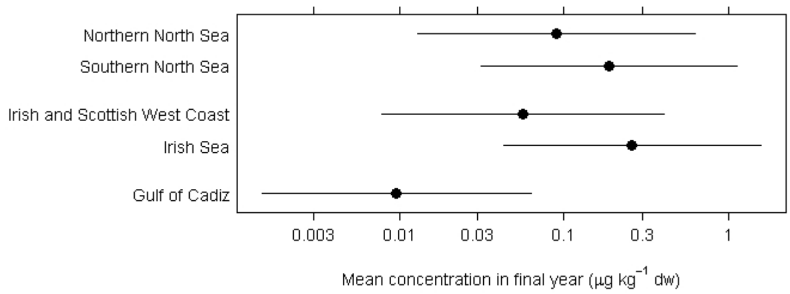


Figure a: Mean concentrations of PBDEs in sediment for each OSPAR contaminants assessment area for the most recent year of measurements (generally 2015), 95% confidence limits (lines)

In summary, none of the 27 monitoring sites showed an increase in mean PBDE concentrations in sediment over the assessment period (2010–2015). It should be noted that not all individual time series results are included in the area assessments, in accordance with the criteria set out in the Assessment Methods.

Polybrominated diphenyl ether (PBDE) concentrations in sediment are measured at very few monitoring sites in the Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast. As there are no assessment criteria available for PBDEs in sediment, it is not possible to assess the environmental significance of the concentrations observed.

There were enough years of data from some of the monitoring sites in the Northern North Sea and Irish Sea to carry out temporal trend analyses. PBDE concentrations are declining in Irish Sea and show no statistically significant change in the Northern North Sea.

The majority of measured concentrations of PBDE in sediment are low and often below detection levels. The Gulf of Cadiz has the lowest concentrations of PBDE in any assessed area, while the Greater North Sea has the highest.

MIME regional assessment of status and trends in BDE concentrations in sediment

- *Info in the link above. Accessed 25.11.19*

The 2017 MIME assessment describes the trends and status of contaminant concentrations in biota and sediment at monitoring stations in the OSPAR area. Assessments are made for a large number of time series, each of a single contaminant in a single species (for biota) at a single monitoring station. This document is one of a series that synthesises the results of the individual time series to assess status and trends at the MIME regional level. In particular, it considers BDE concentrations in sediment, where the BDEs are BDE28, BDE47, BDE99, BD100, BD153, BD154, BD209. For simplicity, the term 'region' is used throughout to describe MIME regions. OSPAR regions are always referred to as such.

Summary of individual time series results.

A time series of BDE concentrations is assessed for status if:

- there is at least one year with data in the period 2010 to 2015
- there are at least three years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the mean concentration in the final monitoring year (or, occasionally, if a non-parametric test of status is applied)

The conditions are more stringent for trends. Specifically, a time series is assessed for trends if:

- there is at least one year with data in the period 2010 to 2015
- there are at least five years of data over the whole time series
- a parametric model can be fitted to the data and used to estimate the trend in mean concentrations

Note that all trend assessments for individual time series and most status assessments are based on the fit of a parametric model. This is important because only the parametric results are passed into the regional assessments in the following sections. Only 0 of 257 BDE time series were assessed for status using a non-parametric test.

The final set of tables give:

- the number of time series with upwards, downwards or no trend in each MiME and OSPAR region
- the same information presented as proportions

Table 1. Trend summary (numbers)

Number of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	BDE28	BDE47	BDE99	BD100	BD153	BD154	total
2	Northern North Sea	upward trend	0	0	0	0	0	0	0
		no trend	0	5	0	0	0	0	5
		downward trend	0	0	0	0	0	0	0
	total	upward trend	0	0	0	0	0	0	0
		no trend	0	5	0	0	0	0	5
		downward trend	0	0	0	0	0	0	0
3	Irish and Scottish West Coast	upward trend	0	0	0	0	0	0	0
		no trend	0	2	0	0	0	0	2
		downward trend	0	0	0	0	0	0	0
	Irish Sea	upward trend	0	0	0	0	0	0	0
		no trend	2	3	4	2	4	1	16
		downward trend	0	2	1	0	0	1	4
	total	upward trend	0	0	0	0	0	0	0
		no trend	2	5	4	2	4	1	18
		downward trend	0	2	1	0	0	1	4

Table 2. Trend summary (proportions)

Proportion of time series with upwards, downwards or no trend by MIME and OSPAR region

OSPAR region	MIME region	status	BDE28	BDE47	BDE99	BD100	BD153	BD154	total
2	Northern North Sea	upward trend		0					0
		no trend		100					100
		downward trend		0					0
	total	upward trend		0					0
		no trend		100					100
		downward trend		0					0
3	Irish and Scottish West Coast	upward trend		0					0
		no trend		100					100
		downward trend		0					0
	Irish Sea	upward trend	0	0	0	0	0	0	0
		no trend	100	60	80	100	100	50	80
		downward trend	0	40	20	0	0	50	20
	total	upward trend	0	0	0	0	0	0	0
		no trend	100	71	80	100	100	50	82
		downward trend	0	29	20	0	0	50	18

Regional trends

The figures show:

 Regional trends by BDE: regional trend estimates for each BDE with pointwise 95% confidence limits plotted by BDE
 Regional trends by region: regional trend estimates for each BDE with pointwise 95% confidence limits plotted by biogeographic region

The symbols in all these plots have the following interpretation:

- downward triangle: the mean concentration is significantly decreasing (p < 0.05)
- circle: there is no change in mean concentration (p > 0.05)
- upward triangle: the mean concentration is significantly increasing (p < 0.05)

The final 2 tables show the estimates of the regional trend (averaged over BDEs) and the regional trend by BDE.

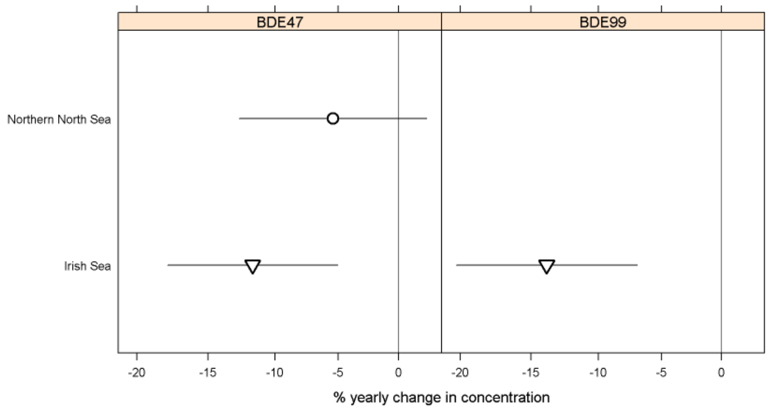


Figure 10. Regional trends by BDE.

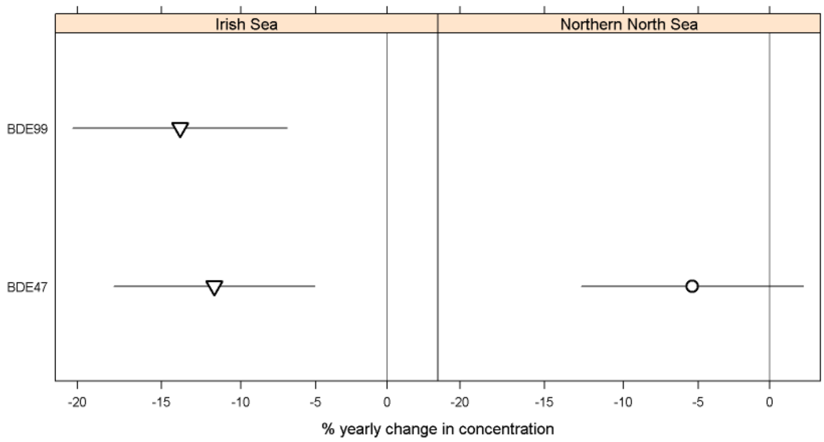


Figure 11. Regional trends by region.

Table 3. Estimates by region.

MIME region	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	-6.71	5.10	-16.69	3.28	-6.49	-15.37	3.34
Irish Sea	-13.69	3.96	-21.45	-5.93	-12.80	-19.31	-5.76

Table 4. Estimates by region and BDE

MIME region	BDE	trend	se	lower	upper	% yearly change	%yc lower	%yc upper
Northern North Sea	BDE47	-5.59	4.08	-13.59	2.42	-5.43	-12.71	2.45
	BDE99	-7.82	5.81	-19.21	3.56	-7.53	-17.48	3.63
Irish Sea	BDE47	-12.45	3.70	-19.71	-5.19	-11.71	-17.89	-5.06
	BDE99	-14.93	3.94	-22.67	-7.20	-13.87	-20.28	-6.95

The tables show the estimates of the regional trend by determinand:

- trend: the estimated mean yearly change in log concentration across the region (multiplied by 100 for presentation)
- se: the corresponding standard error
- lower, upper: the corresponding pointwise 95% confidence limits
- % yearly change: the estimated mean % yearly change in concentration across the region
- %yc lower, %yc upper: the corresponding pointwise 95% confidence limits

Also include MIME regional assessment – methods and regional assessment – availability of time series.