OSPAR COMMISSION

Background document on Background Assessment Concentrations (BAC) for Polybrominated Diphenyl Ethers (PBDE) in fish and shellfish

Hazardous Substances and Eutrophication Series

2021

Background document on Background Assessment Concentrations (BAC) for Polybrominated Diphenyl Ethers (PBDE) in fish and shellfish

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l’Espagne, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède, la Suisse et l’Union européenne.

Background document on Background Assessment Concentrations for Polybrominated Diphenyl Ethers in fish and shellfish

Contents

1. Executive Summary

To enable assessments of monitoring data for hazardous substances in marine sediment and biota, there is a need to have relevant assessment tools. OSPAR developed Background Assessment Concentrations (BACs) to assess contaminant concentrations in the environment. BACs are used to test whether concentrations are ‘near background’ or ‘close to zero” in the case of man-made substances.

BACs for selected polybrominated diphenyl ether (PBDE) congeners in fish and shellfish were first developed by MIME 2017. They were updated by MIME 2018 and MIME 2019 and trialled in the 2020 CEMP assessment (OSPAR, 2020).

It is proposed that BACs of 0.065 µg kg^{-1} lw are adopted for CEMP assessments of BDE28, 47, 66, 85, 99, 100, 126, 153, 154, 183 and 209 concentrations in fish and shellfish.

Récapitulatif

Pour permettre les évaluations des données de surveillance des substances dangereuses dans les sédiments et le biote marins, il est nécessaire de disposer d'outils d'évaluation pertinents. OSPAR a développé des concentrations d’évaluation de fond (BAC) pour évaluer les teneurs en contaminants dans l'environnement.

Les BAC sont utilisés pour vérifier si les concentrations sont "proches du fond" ou "proches de zéro" dans le cas des substances anthropiques.

Les BAC pour certains congénères d'éthers diphényliques polybromés (EDPB ou PBDE en anglais) dans le poisson et les mollusques et crustacés ont été élaborés pour la première fois par MIME 2017. Ils ont été mis à jour par MIME 2018 et MIME 2019 et testés dans l'évaluation CEMP 2020 (OSPAR, 2020).

Il est proposé d'adopter des BAC de 0,065µg kg-1 lw pour les évaluations CEMP des concentrations de BDE28, 47, 66, 85, 99, 100, 126, 153, 154, 183 et 209 dans le poisson et les mollusques et crustacés.

1. Definitions/Glossary

AICc: Akaike Information Criterion corrected for small sample size.

BAC: Background Assessment Concentration – an assessment threshold for testing whether contaminant concentrations are ‘near background’.

BC: Background Concentration – the concentration of a compound in the pristine environment.

CEMP: Coordinated Environmental Monitoring Programme.

df: degrees of freedom.

EAC: Environmental Assessment Criteria – an assessment threshold for testing whether contaminant concentrations are likely to have adverse biological effects on the marine environment.

FEQG: Federal Environmental Quality Guideline.

ICES: International Council for the Exploration of the Sea.

Background document on Background Assessment Concentrations for Polybrominated Diphenyl Ethers in fish and shellfish

LC: Low Concentration – the low, but measurable, concentration of a man-made substance used in the construction of a BAC.

MIME: Working Group on Monitoring and on Trends and Effects of Substances in the Marine Environment.

PAH: polycyclic aromatic hydrocarbon.

PBDE: polybrominated diphenyl ether.

PCB: polychlorinated biphenyl.

QSR: quality status report.

Quasimeme: Quality Assurance of Information for Marine Environmental Monitoring in Europe.

2. Introduction

Contaminant monitoring data form the basis of environmental assessments, which aim to characterise the status or quality of the marine environment with regard to chemical pollution. This means that measured concentrations are compared with assessment concentrations describing cut-offs for categories of environmental quality. These assessment concentrations have important implications as they are used to classify the status of a marine area.

OSPAR Background Assessment Concentrations (BACs) and Environmental Assessment Criteria (EACs) were primarily developed for the assessment of contaminant concentrations. BACs are used to make precautionary tests of whether observed concentrations are ‘near background’ or ‘close to zero’ in the case of man-made substances. Compounds with concentrations below the BAC fulfil the ultimate aim of the OSPAR Hazardous Substances Strategy of approaching the natural Background Concentration (BC). EACs were developed to assess whether concentrations of contaminants are likely to have adverse biological effects on the marine environment.

The concept behind BACs was first proposed by OSPAR (2004) and subsequently formalised by ICES (2004, Section 6.1). BACs were first used on a trial basis in the 2005 CEMP assessment (OSPAR, 2005a). Provisional BACs for selected metals in sediment, polycyclic aromatic hydrocarbons (PAHs) in sediment and mussels, and the polychlorinated biphenyl (PCB) CB153 in sediment, mussels and fish liver were then recalculated and agreed by OSPAR (2005b). Over the next few years, these were updated and added to, with the current set of BACs agreed by OSPAR (2009a, 2009b) in time for use in the 2010 Quality Status Report (QSR) (OSPAR, 2010). These BACs are for selected metals, PAHs and PCBs in sediment, fish and shellfish. BACs for polybrominated diphenyl ethers (PBDEs) were not developed at that time because insufficient monitoring data were available on which to base them.

The subject of BACs and EACs (or EAC equivalents) for PBDEs was revisited by MIME 2017. MIME developed BACs for selected PBDEs in sediment, fish and shellfish and trialled them in the 2018 CEMP assessment (OSPAR, 2018). The BACs were updated by MIME 2018 and used in the 2019 CEMP assessment (OSPAR, 2019). MIME 2019 proposed that the BACs for sediment[1] be formally adopted

[1] OSPAR Publication 202/761. Background document on background assessment concentrations for Polybrominated Diphenyl Ethers (PBDE) in sediment (https://www.ospar.org/documents?v=42738)

for future CEMP assessments. Further work was required to develop satisfactory BACs for fish and shellfish. These were updated by MIME 2019 and used in the 2020 CEMP assessment (OSPAR, 2020). MIME 2020 proposed that the BACs for fish and shellfish be formally adopted for future CEMP assessments.

4. Synopsis of Background Information

4.1 Methodology for constructing Background Assessment Concentrations

BACs are used to test whether concentrations are at background levels for naturally occurring substances, or 'close to background' for man-made substances. This is done by testing the null hypothesis H_0: $\mu \geq$ BAC against the alternative hypothesis H_1: $\mu <$ BAC where μ is the mean concentration (in the most recent monitoring year). The test is precautionary since concentrations are considered to be above background (H_0) unless there is sufficient evidence to show otherwise (H_1).

The BAC is chosen to give a 90% power of rejecting H_0 when μ = BC, where BC is the Background Concentration. The BC of natural occurring substances is estimated using data from near-pristine locations (assuming they exist) and, for sediment concentrations, from cores. The BC of man-made substances is zero, and to construct the BAC it is necessary to replace the BC by a Low Concentration (LC). This is typically taken to be twice the Quasimeme (Quality Assurance of Information for Marine Environmental Monitoring in Europe) external proficiency testing constant error, used in the calculation of Z-scores. The Quasimeme constant error is chosen as it is both measurable and 'close to zero' and is defined by the QUASIMEME Scientific Advisory Board. For the purposes of this section, the BC (or LC) is assumed known.

Power depends on the statistical test used, the number of years of data, and the variability in the data. It is necessary to standardise these to construct a BAC that can applied across the OSPAR area. Specifically, it is assumed that:

- there is a 10-year monitoring programme with the same sampling protocol followed every year (or equivalently, and more realistically, a 20-year monitoring programme with sampling every two years)
- the test is a one-tailed t-test at the 5% significance level based on the temporal trend regression model fitted to the monitoring data (as currently applied in CEMP assessments)
- the variability in the data is typical of that found in CEMP data; this is developed later, but for now it is assumed that the variability is characterised by a parameter ψ

The concentration measurements each year are assumed to be summarised by an annual index on the logarithmic scale (e.g., the median log concentration or the mean log concentration). Let **y** be the vector (length 10) of annual contaminant indices and assume that

$$\mathbf{y} = \mathbf{f} + \boldsymbol{\varepsilon}$$

where **f** represents a smooth systematic trend in contaminant levels over time and **ε** represents random variation, assumed to be independent between years and normally distributed with zero mean and standard deviation ψ. Let **X** be the design matrix used to estimate the systematic trend **f**. The choice of **X** is also discussed later, but it could correspond to a linear trend or a smooth on a fixed number of degrees of freedom. It is assumed that **X** estimates **f** with no bias. Let r be the rank of **X** and $\nu = 10 - r$ be the residual degrees of freedom associated with **X**. Let

$$\mathbf{H} = \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'$$

be the hat matrix. The fitted trend is then $\hat{\mathbf{f}} = \mathbf{H}\mathbf{y}$, which has variance $\mathbf{H}\psi^2$.

A one-tailed t-test at the 5% significance level is used to test H_0 vs H_1. Let

$$T = \frac{\hat{\mathbf{f}}_{10} - \log \text{BAC}}{\hat{\psi}\sqrt{\mathbf{H}_{10,10}}}$$

where the 10 suffix picks out the fitted value and its variance in the most recent monitoring year, and where $\hat{\psi}^2$ is the usual unbiased estimator of ψ^2. Then H_0 is rejected in favour of H_1 if $T < t_{crit}$, where t_{crit} is the 0.05 quantile of a central t-distribution on ν degrees of freedom, denoted (t; ν). That is, the value such that

$$\text{Prob}\left((t;\nu) < t_{\text{crit}}\right) = 0.05$$

When $\mathbf{f}_{10}$ = log BAC, T has a central t-distribution T ~ (t; *v*). More generally, T has a non-central t-distribution T ~ (t; *v*; δ) on *v* degrees of freedom and non-centrality parameter

$$\delta = \frac{\mathbf{f}_{10} - \log \text{BAC}}{\psi\sqrt{\mathbf{H}_{10,10}}}$$

The BAC is chosen to give 90% power when $\mathbf{f}_{10}$ = log BC. Let δ_{crit} be the value that satisfies

$$\text{Prob}\left((t;\nu;\delta_{crit}) < t_{\text{crit}}\right) = 0.90$$

Then the BAC is given by

$$\log \text{BAC} = \log \text{BC} - \delta_{\text{crit}}\psi\sqrt{\mathbf{H}_{10,10}}$$

or equivalently

$$\text{BAC} = \text{BC} \exp\left(-\delta_{\text{crit}}\psi\sqrt{\mathbf{H}_{10,10}}\right)$$

Two problems remain: choosing the appropriate form of **X** and hence **H** and estimating a suitable value of ψ. The methods for doing this have evolved to accommodate developments in the trend assessment methodology. A summary of the changes can be found in the discussions at MIME 2017.

First consider the choice of **X**. A time series with 10 years of data is assessed by fitting a linear trend and smooths on 2 and 3 degrees of freedom (df) and choosing the optimal model based on the Akaike Information Criterion corrected for small sample size (AICc). In practice, most time series reduce to a linear trend. However, the smooth on 2 df gives BACs that are closest to the previous approach and hence is used here. The corresponding values of δ_{crit} and **H** leads to BACs of the form:

$$\text{BAC} = \text{BC} \exp(2.51\psi)$$

Now consider the choice of ψ. The concentration measurements are modelled in a mixed modelling framework. This gives estimates of the between-sample and between-year random variation for each time series, denoted here as $\sigma^2_{i,\text{sample}}$ and $\sigma^2_{i,\text{year}}$ with the *i* used to index the time series. Analytical variability and the number of samples per year have tended to evolve in most time series (getting lower and fewer respectively) so, to characterise recent performance, the analytical variability $\sigma^2_{i,\text{analytical}}$ for time series is based on the median reported uncertainty in the last three monitoring years. Similarly, the number of samples per year n_i for time series i is taken to be the median number of samples in the last three monitoring years. The residual variance for time series i is then estimated to be

$$\psi_i^2 = \sigma_{i,\text{year}}^2 + \frac{1}{n_i}(\sigma_{i,\text{sample}}^2 + \sigma_{i,analytical}^2)$$

The value of ψ typical of CEMP data is estimated by fitting a robust loess smoother (Cleveland et al., 1992) to the log ψ_i as a function of the fitted log mean concentration in the final monitoring year, with a span of 1 and weighted by the number of years in each time series. The (back-transformed) fitted value of the loess smoother at the BC (LC) is taken to be the typical ψ at background (low) concentration. When the BC (LC) is outside the range of the data, the fitted value at the closest observed mean concentration is used.

One final consideration: BACs are statistical constructs and there is no guarantee that they are environmentally relevant. They should be rejected if they are higher than the EAC or equivalent (if it exists) and if they are too high based on expert judgement. For PBDEs, the Canadian Federal Environmental Quality Guidelines (FEQGs) adapted for use in CEMP assessments (OSPAR Publication 2020/760[2]) were used as EAC equivalents.

4.2 Background Assessment Concentrations for PBDEs in fish and shellfish

The BACs were developed on a lipid weight basis since PBDEs are lipophilic. However, a complicating factor was that not all time series in the 2020 CEMP assessment were assessed on a lipid weight basis. Fish time series where the typical species / tissue lipid content was ≥ 3% (flatfish liver, gadoid liver, herring muscle) were assessed on a lipid weight basis, but other fish time series and all shellfish time series were assessed on a wet weight basis[3]. To accommodate this, the BACs were developed in two stages:

1. BACs suitable for use with fish time series assessed on a lipid weight basis were estimated using the methodology described in Section 4.1 applied to the data (mean concentrations and residual standard deviations) from the fish time series assessed on a lipid weight basis.
2. These BACs were compared to the mean concentrations and residual standard deviations from the remaining fish and shellfish time series (assessed on a wet weight basis) to see if they could be generalised to all time series. To get the BACs and mean concentrations on a comparable scale, the mean concentrations were converted from a wet weight basis to a lipid weight basis using the typical species / tissue lipid content for each species / tissue combination (as estimated from the monitoring data in the ICES database)[4].

---

[2] OSPAR Publication 2020/760. Background document for Canadian Federal Environmental Quality Guidelines (FEQGs) for Polybrominated Diphenyl Ethers (PBDEs) in sediment and biota (https://www.ospar.org/documents?v=42746)

[3] From 2021, all shellfish time series will be assessed on a dry weight basis.

[4] This is the reverse of the process used in the CEMP assessment where BACs expressed on a lipid weight basis are applied to time series assessed on a wet weight basis by converting the BACs to a wet weight basis using the typical species / tissue lipid content. The two processes are equivalent but, here, converting the mean concentrations to a lipid weight basis makes it easier to present the results from all the time series simultaneously.

The two stages are now described in more detail.

The Quasimeme constant error for PBDEs in biota is 0.005 µg kg^{-1} ww, so the standard choice of LC is 0.01 µg kg^{-1} ww (see Section 4.1). This was converted to a lipid weight basis using the typical species / tissue lipid content of the six species / tissue combinations assessed on a lipid weight basis in the 2020 CEMP assessment (Table 1). The lipid contents ranged from 4.6 % to 42.0 %, which suggested multiplying 0.01 by anywhere between 2.4 (cod liver) and 21.7 (herring muscle). The choice was somewhat subjective, but it was decided to use a factor or 3. This was about right for the two gadoids, precautionary for the flat fish and very precautionary for herring. It was decided to err on the precautionary side because, in earlier development work, MIME 2018 had expressed concerns that a LC of 0.01 µg kg^{-1} ww was too high. Multiplying by 3 gave an LC of 0.03 µg kg^{-1} lw.

Table 1. Typical lipid content (%) in the six species / tissue combinations assessed on a lipid weight basis in the 2020 CEMP assessment.

species	tissue	lipid (%)
herring	muscle	4.6
plaice	liver	11.4
flounder	liver	14.7
common dab	liver	19.4
whiting	liver	36.9
cod	liver	42.0

Figure 1 shows, by PBDE, the estimates of the residual standard deviation ψ from each fish time series (assessed on a lipid weight basis) plotted against the estimated mean concentration in the most recent monitoring year. They are taken from the 2020 CEMP assessment (OSPAR, 2020).

A smoother, fitted to the data for each PBDE, was used to estimate the value of ψ typical of mean concentrations close to the LC. For BDE153, this was the value of the smoother where it cut the LC (the grey vertical line in Figure 1). For the other PBDEs, it was the value of the smoother at the lowest observed mean concentration (since all the observed mean concentrations were above the LC). There were insufficient time series to fit the smoother for BDE85, 126, 183 and 209. The estimated value of ψ at the LC was then used to estimate the BAC (blue vertical line) for each PBDE.

The BACs were all well below the FEQGs (green vertical lines). Note that the FEQGs for BDE28 and 47 are not plotted because they are off the scale of the plot, and there are no FEQGs for BDE66, 85, 126, 183 or 209.

The estimates of ψ at the LC, the resulting BACs and the FEQGs are given in Table 2.

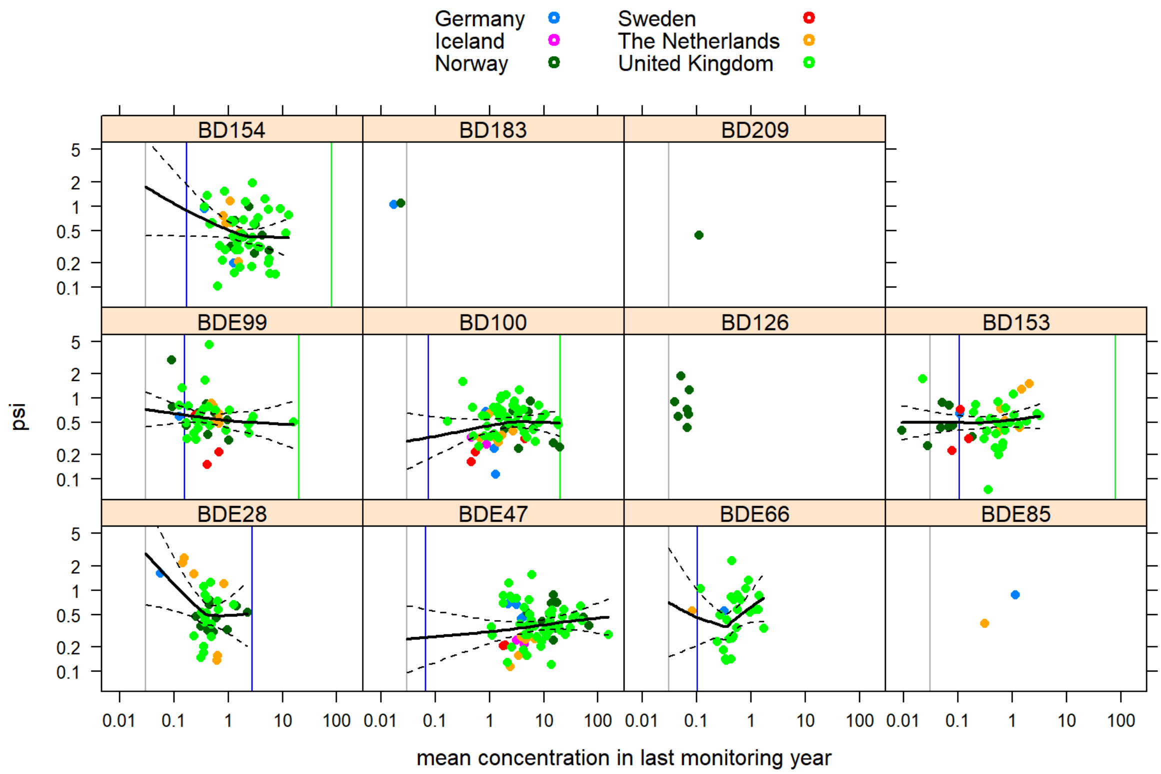

Figure 1. Estimates of the residual standard deviation ψ from each fish time series assessed on a lipid weight basis plotted against the estimated mean concentration (µg kg^{-1} lw) in the most recent monitoring year by PBDE congener. The points are coloured by Contracting Party. The fitted loess smoother (black line) with 95% pointwise confidence limits (dashed lines) is also shown. The three vertical lines are the LC (grey), the BAC (blue) estimated using the methodology described in Section 4.1, and the FEQG (green). BACs could not be estimated for BDEs 85, BDE126, BDE183 or BDE209. The FEQGs for BDE28 and BDE47 are not shown as they are off the scale of the plot. There are no FEQGs for BDE66, BDE85, BD126, BD183 or BD209. Note that the BACs shown here are based on the monitoring and analytical characteristics of the individual congeners and, apart from BDE47, not the BACs eventually proposed for adoption.

Table 2. Estimates of ψ typical of CEMP data at concentrations close to the LC, with lower and upper 95% confidence limits, the BACs derived from them, and the FEQGs. Concentration units are µg kg^{-1} lw.

Congener	Ψ			LC	BAC	FEQG
	lower cl	estimate	upper cl			
BDE28	0.61	1.80	5.31	0.03	2.752	2400
BDE47	0.22	0.31	0.42	0.03	0.065	880
BDE66	0.20	0.49	1.24	0.03	0.103	
BDE85				0.03		
BDE99	0.48	0.65	0.88	0.03	0.154	20
BDE100	0.23	0.36	0.56	0.03	0.074	20
BDE126				0.03		
BDE153	0.36	0.50	0.69	0.03	0.105	80
BDE154	0.42	0.69	1.13	0.03	0.170	80
BDE183				0.03		
BDE209				0.03		

The BACs in Table 2 are environmentally acceptable in the sense that they are below the FEQGs. However, the wide variation in BACs between compounds (0.065 – 2.752 µg kg^{-1} lw) was considered unsatisfactory by MIME 2019, as it tended to reflect variation in analytical performance rather than environmental characteristics, and as it often resulted in higher BACs for compounds that would be expected to have lower concentrations based on a typical PBDE profile. MIME 2019 therefore agreed to use the BAC for BDE47 of 0.065 µg kg^{-1} lw for all the PBDE congeners in the 2020 CEMP assessment. The value for BDE47 was chosen because a) it was based on the most data; b) BDE47 had the lowest value of ψ and hence the lowest BAC; c) all Contracting Parties had monitoring data for BDE47, so the value of ψ was representative of a wide range of CEMP data sources.

To see if the BAC of 0.065 µg kg^{-1} lw could be generalised to fish time series assessed on a wet weight basis and to shellfish, the estimates of the residual standard deviation ψ were plotted against the estimated mean concentration in the most recent monitoring year for all time series in the 2020 CEMP assessment (Figure 2). Where necessary, the mean concentrations were converted from a wet weight basis to a lipid weight basis using the typical species / tissue lipid content. MIME 2019 found little evidence in Figure 2 that mean concentrations in fish were higher than in shellfish, as might be expected due to biomagnification. This could be due to the choice of monitoring locations for fish and shellfish, or because differences were masked due to measurements often being close to or below the limit of detection. However, MIME 2019 agreed that a BAC of 0.065 µg kg^{-1} lw was reasonable for all PBDE congeners for all fish and shellfish time series and should be used in the 2020 CEMP assessment.

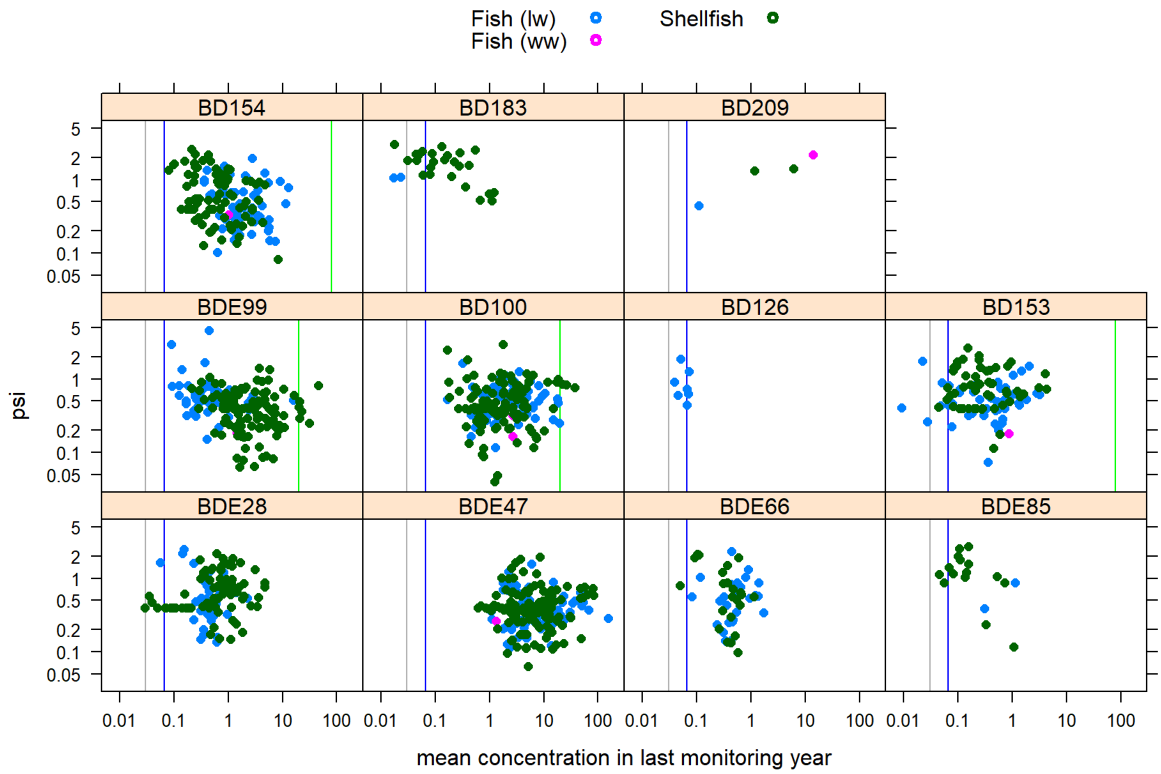

Figure 2. Estimates of the residual standard deviation ψ from each time series (including fish assessed on a wet weight basis and shellfish) plotted against the estimated mean concentration (µg kg^{-1} lw) in the most recent monitoring year by PBDE congener. The colour of the points differentiate fish time series assessed on a lipid and wet weight basis and shellfish time series. The three vertical lines are the LC of 0.03 µg kg^{-1} lw (grey), the BAC of 0.065 µg kg^{-1} lw (blue) and the FEQG (green). As before, the FEQGs for BDE28 and BDE47 are off the scale of the plot and there are no FEQGs for BDE66, BDE85, BD126, BD183 or BD209.

To illustrate, Figures 3 and 4 respectively show status assessments for BDE47 and BDE99 from the 2020 CEMP assessment using a BAC of 0.065 µg kg^{-1} lw. Points are coloured

- blue if the mean concentration is significantly ($p < 0.05$) below the BAC
- green if the mean concentration is significantly ($p < 0.05$) below the FEQG
- red if the mean concentration is not significantly below the FEQG

Status assessments for all the PBDE congeners considered in the 2020 CEMP assessment can be explored in more detail in the 2020 OSPAR Hazardous substances Assessment Tool.

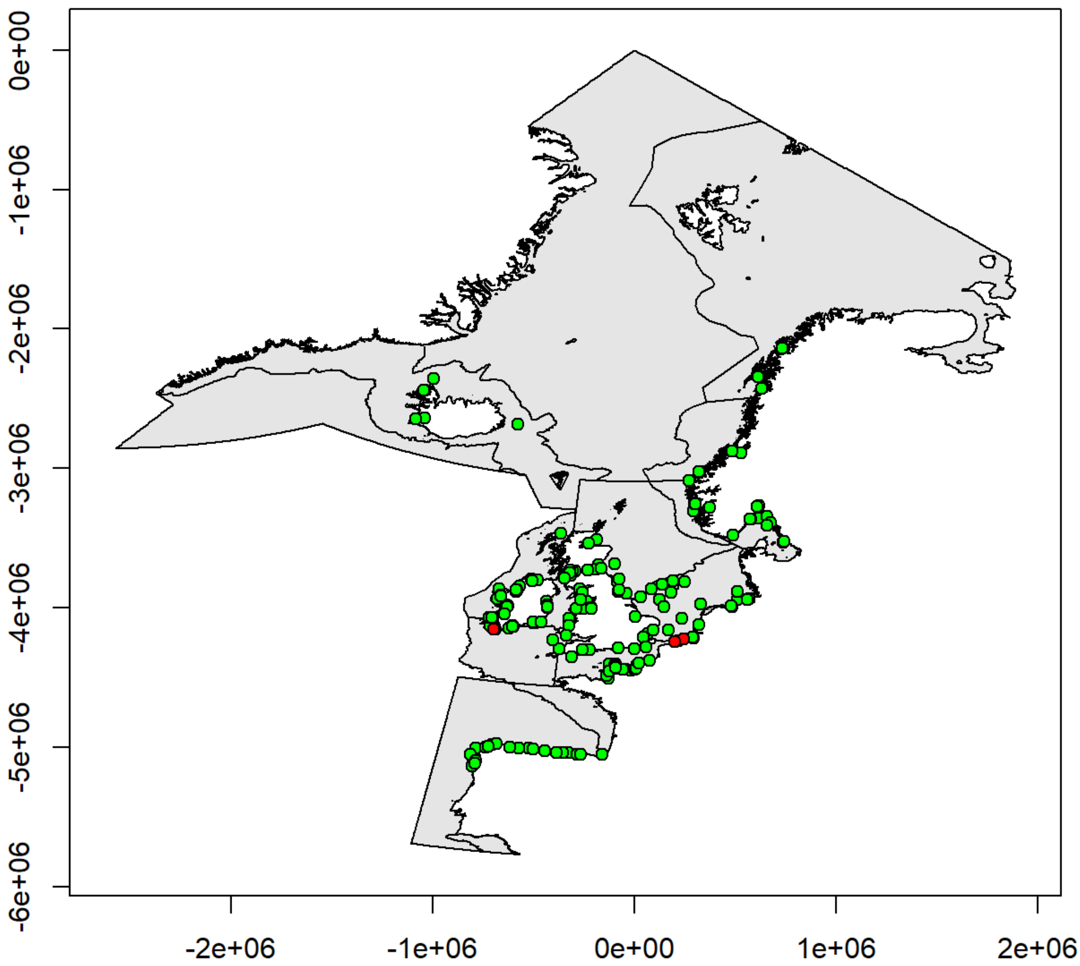

Figure 3. Status assessment of BDE47 from the 2020 CEMP assessment.

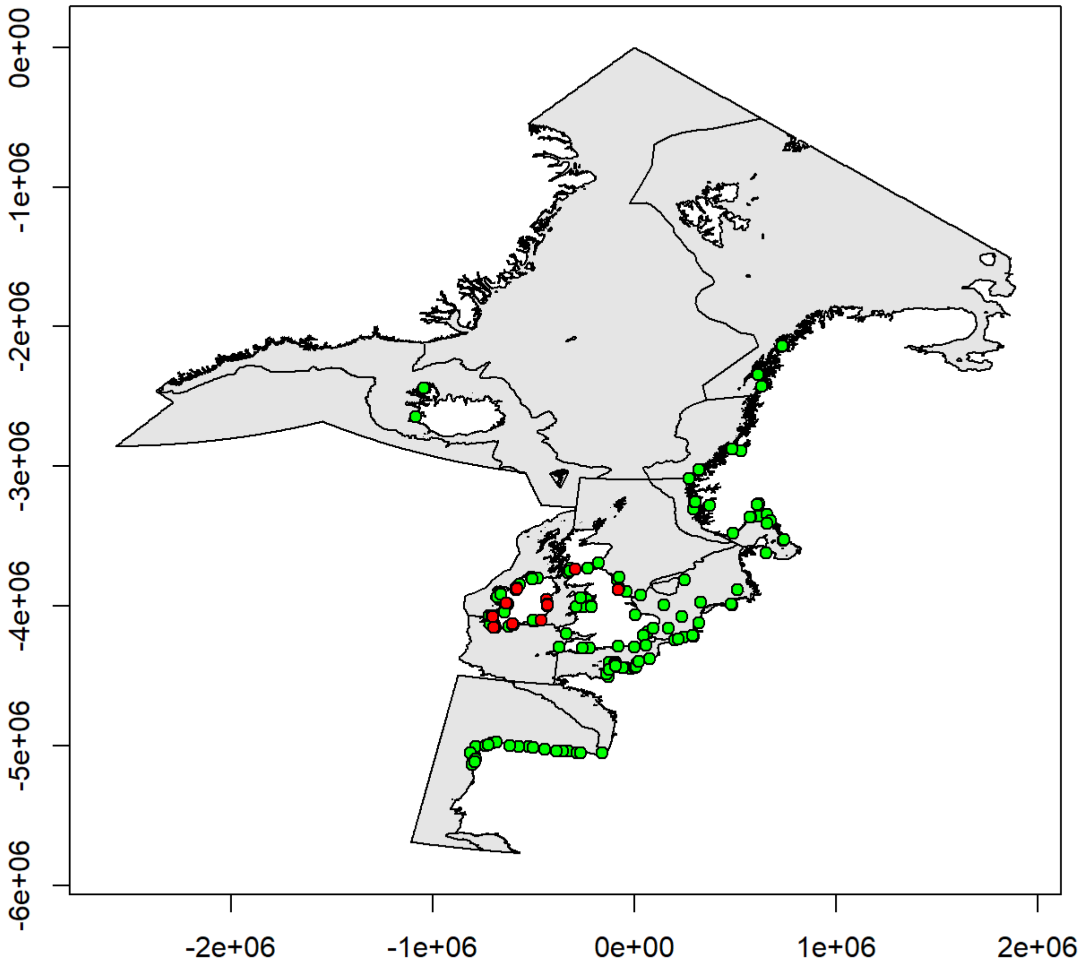

Figure 4. Status assessment of BDE99 from the 2020 CEMP assessment.

The PBDE congeners assessed in the 2020 CEMP assessment (BDE28, 47, 66, 85, 99, 100, 126, 153, 154, 183 and 209) are only a selection of those measured and reported to the ICES database. If other congeners are considered in future assessments, then it is anticipated that analytical performance and biological uptake for these compounds will be similar and a BAC of 0.065 µg kg^{-1} lw could be applied on a trial basis.

The BAC of 0.065 µg kg^{-1} lw should only be applied to the concentrations of individual PBDE congeners. If the sum of several PBDE congeners is to be assessed (for example, the sum BDE28, 47, 99. 100, 153 and 154) for comparison with the European Commission Environmental Quality Standard, then a new BAC appropriate for this sum would have to be calculated.

5 Conclusions

BACs of 0.065 µg kg^{-1} lw should be adopted for OSPAR CEMP assessments of BDE28, 47, 66, 85, 99, 100, 126, 153, 154, 183 and 209 concentrations in fish and shellfish.

6 Proposals

BACs of 0.065 µg kg^{-1} lw should be adopted for OSPAR CEMP assessments of BDE28, 47, 66, 85, 99, 100, 126, 153, 154, 183 and 209 concentrations in fish and shellfish.

7. References

Cleveland WS, Grosse E and Shyu WM (1992). Local regression models. Chapter 8 of Statistical Models in S. Editors Chambers JM and Hastie TJ. Wadsworth & Brooks/Cole.

ICES (2004). Report of the ICES Advisory Committee on the Marine Environment, 2004. ICES Advice. Volume 1, Number 1. 283 pp.

OSPAR (2004). OSPAR/ICES Workshop on the evaluation and update of Background Reference Concentrations (BRCs) and Ecotoxicological Assessment Criteria (EACs) and how these assessment tools should be used in assessing contaminants in water, sediment, and biota. The Hague, 9-13 February 2004. ISBN 1-904426-52-2.

OSPAR (2005a). 2005 assessment of data collected under the Co-ordinated Environmental Monitoring Programme (CEMP). Publication no. 235/2005. ISBN 1-904426-77-8.

OSPAR (2005b). Agreement on Background Concentrations for Contaminants in Seawater, Biota and Sediment. OSPAR Agreement 2005-6.

OSPAR (2009a). Background Document on CEMP Assessment Criteria for QSR 2010. Monitoring and Assessment Series. Publication no. 461/2009. ISBN 978-1-907390-08-1.

OSPAR (2009b). Agreement of OSPAR CEMP Assessment Criteria for the QSR 2010. OSPAR Agreement 2009-2.

OSPAR (2010). Quality Status Report 2010. OSPAR Commission, London. 176 pp.

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

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

The Aspect
12 Finsbury Square
London EC2A 1AS
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7242 3737
e: secretariat@ospar.org
www.ospar.org

Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

Publication Number: 796/2021