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Levels of persistent halogenated organic pollutants (POP's) in mother's milk from first-time mothers in Uppsala, Sweden: results from year 2020 and 2021, and temporal trends for the time period 1996-2021

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Sammanfattning
Sedan 1996 har Livsmedelsverket regelbundet samlat in modersmjölk från förstföderskor i Uppsala för analys av persistenta halogenerade organiska miljöföroreningar (POP). I följande rapport redovisas halterna av industrikemikalien PCB (mono-, di- och non-*orto* PCB), oavsiktligt bildade dioxiner och furaner (PCDD/F) och bromerade flamskyddsmedel (PBDE, HBCDD) i 30 modersmjölksprover insamlade 2020 och 2021. Bland PCBerna var medelkoncentrationen i modersmjölk (2020-2021) högst för CB 153 (18 ng/g fett). Medelhalten för PCDD TEQ (1,5 pg/g fett) var något högre än för PCDF TEQ (1,4 pg/g fett). Bland de polybromerade difenyletrarna (PBDE) uppvisade BDE 153 (0,66 ng/g fett) högst medelhalt.

Utvärdering av tidstrender för perioden 1996-2021 (multipel linjär regression med hänsyn till mammans ålder, BMI och viktförändring under graviditet) visade att halterna av di-*orto* PCBer, mono-*orto* PCB TEQ och non-*orto* PCB TEQ har minskat med ca 5-6 % per år. Halterna av PCDD TEQ har minskat fortare än halterna av PCDF TEQ (6 % respektive 3 % per år). Perioden efter de trendbrott som presenterats i en tidigare rapport minskar halterna långsammare. Även om modersmjölknivåerna av total TEQ minskar, hade fortfarande 11 av 30 kvinnor (provtagna 2020-2021), nivåer över EFSAs modellerade kritiska halt för modersmjölk. Halterna av BDE 47, BDE 99 och BDE 100 har minskat med 7-12% per år. Nivåerna av BDE 153 ses minska efter det trendbrott som tidigare upptäcktes runt år 2000 men för hela tidsperioden 1996-2021 är trenden fortsatt icke-signifikant. BDE 209 har bara analyserats kontinuerligt i modersmjölk sedan 2009 och hittills kan inte någon tidstrend observeras. Trenden för HBCDD visar på en nedåtgående trend med 3% per år. Resultaten stämmer överens med det som rapporterats tidigare inom POPUP. Fortsatta undersökningar av POPar i modersmjölk kan ge svar på om halterna av PCBer och PCDD/F håller på att stabiliseras på nuvarande nivåer eller om nivåerna fortsätter att minska.

INTRODUCTION

With funding from the Swedish Environmental Protection Agency (EPA), the Swedish Food Agency (SFA) has made recurrent measurements of persistent halogenated organic pollutants (POP) in mother's milk from primiparous women in Uppsala since 1996. The study is called POPUP (Persistent Organic Pollutants in Uppsala Primiparas), and the aim is to estimate the body burdens of POP among pregnant and nursing women and to estimate temporal trends of the exposure of fetuses and breast-fed infants. Temporal trends of polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), poly-chlorinated dibenzofurans (PCDFs), brominated flame retardants (e.g. polybrominated diphenylethers (PBDE)), and hexabromocyclododecane (HBCDD) between 1996 and 2019 have been published earlier (Glynn et al. 2007a, Lignell et al. 2008, Lignell et al. 2009a, Lignell et al. 2009b, Lignell et al. 2012, Lignell et al. 2014, Lignell et al. 2015, Gyllenhammar et al 2017, Gyllenhammar et al. 2021, Hedvall Kallerman et al. 2021), and this is a follow-up.

The following report presents results of analysis of di-*ortho* PCBs, mono-*ortho* PCBs, non-*ortho* PCBs, PCDD/Fs, PBDEs, and HBCDD in mother's milk sampled in 2020 and 2021 (according to agreement 215-21-003). The new data is used to establish updated temporal trends for the period 1996-2021. The temporal trends in breast milk are also used as one of the indicators for the environmental quality objectives "A non-toxic environment" (sverigesmiljomal.se).

MATERIALS AND METHODS

Recruitment and sampling

Mothers were randomly recruited among primiparas who were Swedish by birth and delivered at Uppsala University Hospital from January 2020 to November 2021 (n=133). The participating rate was 48% for the whole study period and 45% in 2020-2021.

The participating mothers sampled milk at home during the third week after delivery (day 14-21 post-partum). Milk was sampled during nursing using a manual mother's milk pump and/or a passive mother's milk sampler. The women were instructed to sample milk both at the beginning and at the end of the breast-feeding sessions. The goal was to sample 500 mL from each mother during 7 days of sampling. During the sampling week, the milk was stored in the home freezer in acetone-washed bottles. Newly sampled milk was poured on top of the frozen milk. At the end of the sampling week, a midwife visited the mother to collect the bottles. Data on age, weight, length, lifestyle, medical history, food habits etc. of the mothers were obtained from questionnaires (Table 1). The recruitment procedure has been described earlier (Glynn et al. 2007a, Lignell et al. 2009a). Mother's milk was sampled from a total of 879 women between 1996 and 2021 (60 women in 2020-2021). From the participants in 2020-2021, 15 women per year were randomly selected for analysis.

Table 1. Characteristics of the mothers in the study in 2020-2021 (n=30).

Variable		**N**	**Mean**	**Median**	**Range**
Age of the mother (yr)		30	31.6	31.1	25.5-42.7
Pre-pregnancy body mass index (BMI, kg/m^2)		28	24.7	24.4	18.9-34
Weight gain during pregnancy (% of initial weight)		28	18.3	20.5	0-34.6
Weight reduction from delivery to sampling (%)[a]		28	8.1	8.7	2.1-13.2
Variable		**N**	**%**		
Education	max 3-4 yr high school	3	10		
	1-3 yr higher education	8	27		
	>3 yr higher education	19	63		

[a]Weight reduction minus birth weight of the child in % of the mothers weight just before delivery.

Analysis

The compounds that were analysed in the mother's milk samples from 2020 to 2021 were 6 non-dioxin like PCBs (CB 28, 52, 101, 138, 153, 180), 8 mono-*ortho* substituted PCBs (CB 105, 114, 118, 123, 156, 157, 167, 189), 4 non-*ortho* PCBs (CB 77, 81, 126, 169), 7 tetra- to octa-chlorinated PCDD congeners, 10 tetra- to octa-chlorinated PCDF congeners, 10 tri- to deca-brominated PBDE-congeners (BDE 28, 47, 66, 100, 99, 154, 153, 138, 183, 209) and hexabromocyclododecane (HBCDD).

All analyses of samples from 2020 to 2021 were performed at the SFA. PCBs and PCDD/Fs were analysed using a method based on gas chromatography coupled to high resolution mass spectrometry (GC-HRMS) (Aune et al. 2012). The clean-up and fractionations for PCBs and PCDD/Fs were performed with a Miura GO-2HT from Miura Co (Japan). PBDEs and HBCDD were analysed by gas chromatography/mass spectroscopy/electron-capture negative ionization (GC/MS/ECNI) and detected by single ion monitoring technique, SIM (Lignell et al. 2009a).

In all analyses, samples were fortified with internal standards prior to extraction to correct for analytical losses and to ensure quality control. A number of control samples were analysed together with the samples to verify the accuracy and precision of the measurements. The laboratory is accredited for analysis of PCDD/F, PCBs and brominated flame retardants in human milk.

Calculations and statistics

A few mothers recruited in the beginning of the study were not Swedish by birth, and mothers who were born in non-Nordic countries (n=13) were excluded before the statistical analysis of temporal trends 1996-2021. After this exclusion, a total of 636 women were included in the data set. Mother's milk concentrations of POP were lipid-adjusted and when the concentrations were below the limit of quantification (LOQ), half of LOQ was taken as an estimated value in the calculations. PBDE-levels below LOQ were available for breast milk samples from 2009-2021 (and in some samples 2002-2008) and these reported levels below LOQ (adjusted for levels in blank samples) were used instead of half of LOQ. Levels estimated to be zero or negative after blank reduction were in the statistical analyses set to the lowest estimated level found above zero for each compound.

Before the evaluation of temporal trends, POPs were grouped into di-*ortho* PCBs (sum of CB 153, 138, and 180), mono-*ortho* PCB TEQ (sum of CB 105, 118, 156, and 167 TEQs), non-*ortho* PCB TEQ (sum of CB 77, 126, and 169 TEQs), PCDD TEQ, PCDF TEQ and sumPBDE (sum of BDE 47, 99, 100, and 153) (Table 2 and 3). In addition, temporal trends were evaluated for the single compounds CB 28, CB 153, BDE 47, BDE 99, BDE 100, BDE 153, BDE 209, and HBCDD. BDE 209 was included in the analytical method in year 2009, and has so far only been quantified in samples collected in 2009-2021, and in some samples 2002-2008. Calculated TEQs were based on 2005 WHO TEFs (Van den Berg et al. 2006).

Temporal trends were investigated for the whole study period (1996-2021) and in addition for the time period after the change point (CP), estimated in the previous report (Hedvall Kallerman et al. 2021) (Table 4 and 5). Multiple linear regressions were used to analyse associations between concentrations of POP in mother's milk and sampling year using the software package STATA version 15.1. Logarithmically transformed POP-levels were used in order to present the association between sampling year and POP concentrations as percent change of concentrations per year. Independent variables (life-style factors) that have been shown to influence POP levels in serum and mother's milk (Glynn et al. 2007b, Lignell et al. 2011) were included as explanatory variables in the model. The variables considered were age of the mother (years), pre-pregnancy body mass index (BMI) (kg/m^2), body weight gain during pregnancy (%), and body weight change during the period from delivery to sampling (%) (Table 1).

RESULTS AND DISCUSSION

POP concentrations in mother's milk

Levels of POPs in milk samples collected in 2020 to 2021 are shown in Tables 2 and 3. Among the PCBs, the di-*ortho* congener CB 153 showed the highest mean concentration (18 ng/g lipid) followed by CB 138 (9.5 ng/g lipid) and CB 180 (9.4 ng/g lipid) (Table 2). All PCB-congeners could be quantified in all samples, except 28 samples for CB 52 and one sample for CB 180 and CB 123 respectively, although the levels of some congeners were very low (e.g. CB 52, 101, 114, 123, 157, 189). CB 126 was the non-*ortho* congener with the highest concentration followed by CB 169, and these two contributed most to the non-*ortho* PCB TEQ. Among the PCDD/Fs in Table 2, 1,2,3,7,8-PeCDD and 2,3,4,7,8-PeCDF contributed most to the total PCDD/F TEQ concentration (30% and 35% respectively), followed by 2,3,7,8-TCDD (10%) and 1,2,3,6,7,8-HxCDD (8%) (data not shown). The mean total-TEQ level was 5.5 pg/g lipid and non-*ortho* PCBs contributed most to this level (mean 2.4 pg TEQ/g lipid) followed by PCDDs (1.5 pg TEQ/g lipid), PCDFs (1.4 pg TEQ/g lipid) and mono-*ortho* PCBs (0.20 pg TEQ/g lipid) (Table 2).

In 2018, the European Food Safety Authority (EFSA) published a scientific opinion on health risks of PCDD/Fs and dioxin-like PCBs in food (EFSA 2018). EFSA has established a new tolerable weekly intake (TWI) of 2 pg TEQ/kg body weight/week. When establishing the TWI, a modelling of a lifetime maternal body burden before pregnancy was performed to protect children from negative health effects (taking into account pregnancy and 12 months of breastfeeding). As a result, an estimated safe breast milk level was determined to 5.9 pg TEQ/g lipid. During the period 2020-2021, 37% of the women (11 out of 30 women) had breast milk levels above the EFSA estimated safe level whereas for the whole study period, 1996-2021 it was estimated that 67% of the women had levels above the safe level.

Table 2. Concentrations of PCBs and PCDD/Fs in mother's milk sampled from primiparous women in Uppsala in 2020-2021 (n=30). Values <LOQ were set to ½LOQ in the calculations of means, medians and TEQs.

Compound	**Mean**	**Median**	**Min**	**Max**	**n<LOQ**
PCBs (ng/g lipid)					
CB 28	0.93	0.65	0.31	6.0	0
CB 52	0.09	0.07	<0.08	0.36	28
CB 101	0.17	0.15	0.04	0.33	0
CB 138	9.5	8.6	3.8	31	0
CB 153	18	16	7.3	57	0
CB 180	9.4	7.0	2.3	29	1
di-*ortho* PCB[a]	37	33	14	117	-
CB 105	0.76	0.56	0.23	3.1	0
CB 114	0.16	0.12	0.06	0.38	0
CB 118	3.4	2.8	1.2	8.7	0
CB 123	0.04	0.03	0.01	0.13	1
CB 156	2.0	1.5	0.50	6.0	0
CB 157	0.35	0.27	0.10	0.98	0
CB 167	0.51	0.47	0.21	1.1	0
CB 189	0.18	0.14	0.04	0.51	0
mono-*ortho* PCB TEQ[b] (pg/g lipid)	0.20	0.18	0.09	0.47	-
non-*ortho* PCBs (pg/g lipid)					
CB 77	1.2	0.91	<0.8	4.7	14
CB 81	0.80	0.63	0.25	3.4	0
CB 126	16	16	4.5	35	0
CB 169	12	9.4	4.3	25	0
non-*ortho* PCB TEQ[c]	2.4	2.0	0.87	5.8	-
PCDDs (pg/g lipid)					
2,3,7,8-TCDD	0.31	0.30	<0.02	0.67	2
1,2,3,7,8-PeCDD	0.86	0.76	0.28	1.8	0
1,2,3,4,7,8-HxCDD	0.35	0.34	<0.03	0.74	1
1,2,3,6,7,8-HxCDD	2.0	1.8	0.73	4.3	0
1,2,3,7,8,9-HxCDD	0.54	0.49	0.17	1.4	0
1,2,3,4,6,7,8-HpCDD	3.9	2.8	0.64	18	0
OctaCDD	18	15	4.3	57	0
PCDD TEQ	1.5	1.4	0.44	3.0	-
PCDFs (pg/g lipid)					
2,3,7,8-TCDF	0.37	0.28	<0.03	2.1	2
1,2,3,7,8-PeCDF	0.26	0.22	<0.08	0.81	5
2,3,4,7,8-PeCDF	3.4	3.1	1.2	11	0
1,2,3,4,7,8-HxCDF	1.3	1.2	0.42	3.3	0
1,2,3,6,7,8-HxCDF	1.2	1.1	<0.12	3.9	1
1,2,3,7,8,9-HxCDF	0.12	0.11	<0.11	0.31	29
2,3,4,6,7,8-HxCDF	0.66	0.60	<0.11	1.9	1
1,2,3,4,6,7,8-HpCDF	0.88	0.81	0.26	2.2	0
1,2,3,4,7,8,9-HpCDF	0.04	0.02	<0.02	0.14	23
OctaCDF	0.02	0.02	<0.02	0.07	25
PCDF TEQ	1.4	1.3	0.48	4.1	-
PCDD/F TEQ[d] (pg/g lipid)	2.9	2.8	0.91	7.0	-
TOTAL-TEQ[e] (pg/g lipid)	5.5	4.9	2.1	11	-

[a]The sum of CB 153, 138 and 180. [b]The sum of CB 105, 118, 156, 167 TEQs. [c]The sum of CB 77, 126, 169 TEQs. [d]The sum of PCDD TEQ and PCDF TEQ. [e]The sum of mono-*ortho* PCB TEQ, non-*ortho* PCB TEQ, PCDD TEQ and PCDF TEQ.

Among the PBDEs, BDE 153 showed the highest mean concentration (0.66 ng/g lipids) followed by BDE 47 (0.29 ng/g lipids), BDE 99 (0.13 ng/g lipids), and BDE 209 (0.13 ng/g lipids) (Table 3). However, the levels of BDE 47, BDE 99, and BDE 209 were below LOQ in 24, 29, and 24 of the analysed samples, respectively. The level of BDE 28, and BDE 183 were also below LOQ in most samples whereas BDE 66 was all below LOQ. Estimated PBDEs and HBCDD concentrations below LOQ, adjusted for concentrations in blank samples, are presented in brackets in Table 3 and were used in the analyses of temporal trends.

Table 3. Concentrations of PBDEs and HBCDD (ng/g lipid) in mother's milk sampled from primiparous women in Uppsala in 2020-2021 (n=30). Values below the LOQ were set to ½LOQ in the calculations of means, medians and sumPBDE. Levels below LOQ were also reported and calculated results using these levels (adjusted for levels in blank samples) are presented in brackets ([ ]).

Compound	Mean	Median	Min	Max	n<LOQ[b] [n=0][c]
BDE 28	0.02	0.02 [0.01]	<0.02 [0]	0.06	27 [1]
BDE 47	0.29	0.17 [0.16]	<0.2 [0.04]	3.1	24 [0]
BDE 66	0.02 [0.006]	0.02 [0.006]	<0.02 [0.0008]	0.02	30 [0]
BDE 99	0.13 [0.05]	0.11 [0.03]	<0.13 [0.01]	0.53	29 [0]
BDE 100	0.08	0.04 [0.05]	<0.03 [0.01]	0.71	15 [0]
BDE 153	0.66	0.54	0.15	2.14	0 [0]
BDE 154	0.05	0.04	<0.02 [0.01]	0.20	12 [0]
BDE 183	0.03	0.02 [0.009]	<0.02 [0.004]	0.42	29 [0]
BDE 209	0.13 [0.12]	0.07 [0.04]	<0.08 [0.01]	1.4	24 [0]
sumPBDE(4)[a]	1.2 [1.1]	0.88 [0.86]	0.39 [0.26]	5.2	-
HBCDD	0.16	0.14	<0.07 [0.008]	0.65	7 [0]

[a]The sum of BDE 47, 99, 100, and 153. [b]Number of samples with levels below LOQ. [c]Number of samples with levels estimated to be zero or negative after adjustment for blank levels.

Temporal trends

Multiple linear regressions showed that the adjusted mean decrease in concentrations of CB 28 was 4% per year during 1996-2021, while the concentrations of CB 153, di-*ortho* PCB, and mono-*ortho* PCB TEQ decreased around 6% per year (Table 4, Appendix). The decrease in the concentration of non-*ortho* PCB TEQ was 5% per year. These results are in agreement with previous observed declining trends between 1996 and 2019 (Hedvall Kallerman et al. 2021) except for non-*ortho* PCB TEQ that had a slower declining rate 1996-2021. The decrease in levels of PCDD TEQs and PCDF TEQs (Table 4, Appendix) also confirms previous results (Hedvall Kallerman et al. 2021), showing a faster declining rate for PCDD TEQs than for

PCDF TEQs. The overall decrease in breast milk levels per year seems to slow down for all PCBs and PCDD/Fs.

CP analyses were performed for PCBs and PCDD/Fs in the previous report of breast milk levels from POPUP (Hedvall Kallerman et al. 2021). PCB/PCDD/F-congeners with significant CPs were re-examined with regression analyses in the present report including only the years after the detected CP. Slower decreasing rates after the CP were observed for all these compounds in comparison to the whole study period (Table 4). It is important to continue with the temporal trend studies of POPs in breast milk to investigate whether concentrations continue to decrease or are stabilizing at current levels.

The decline in breast milk levels of PCBs and PCDD/Fs between 1996 and 2021 is in agreement with results from four Swedish market basket studies performed 1999, 2005, 2010, and 2015, showing an annual decline of around 4.5% in the calculated per capita intake of CB 153 and PCDD/Fs from food (National Food Agency 2017).

Table 4. Percent change in concentrations of PCBs and PCDD/Fs per year in mother's milk from primiparous women in Uppsala 1996-2021 and after the estimated change point year to 2021 (Hedvall Kallerman et al. 2021). Adjusted for age of the mother, pre-pregnancy BMI, weight gain during pregnancy and weight loss after delivery. Concentrations <LOQ was recalculated to LOQ/2.

Compound	Period	n	n year	Change/year (%) Mean	95% CI	R^{2a}	p
CB 28	1996-2021	600	25	-4.0	-3.2/-4.8	17	<0.001
CB 153	1996-2021	599	25	-6.0	-5.7/-6.4	69	<0.001
After change point 2000	2001-2021	389	20	-5.2	-4.5/-5.9	55	<0.001
di-*ortho* PCB[b]	1996-2021	600	25	-5.9	-5.5/-6.2	69	<0.001
After change point 2000	2001-2021	390	20	-5.2	-4.6/-5.9	55	<0.001
mono-*ortho* PCB TEQ[c]	1996-2021	588	23	-5.9	-5.5/-6.3	68	<0.001
After change point 2002	2003-2021	344	16	-5.2	-4.5/-6.0	52	<0.001
non-*ortho* PCB TEQ[d]	1996-2021	457	22	-5.0	-4.6/-5.5	59	<0.001
After change point 2007	2008-2021	224	11	-2.6	-1.4/-3.7	39	<0.001
PCDD TEQ	1996-2021	423	22	-6.3	-5.9/-6.6	76	<0.001
After change point 2003	2004-2021	293	14	-5.1	-4.4/-5.8	55	<0.001
PCDF TEQ	1996-2021	423	22	-3.0	-2.6/-3.5	43	<0.001
After change point 2000	2001-2021	316	17	-2.0	-1.3/-2.8	29	<0.001
PCDD/F TEQ[e]	1996-2021	423	22	-5.0	-4.6/-5.4	67	<0.001
After change point 2001	2002-2021	308	16	-4.0	-3.3/-4.6	48	<0.001
Total-TEQ[f]	1996-2021	422	22	-5.1	-4.7/-5.4	68	<0.001
After change point 2001	2002-2021	308	16	-4.0	-3.3/-4.6	51	<0.001

[a]Coefficient of determination for the regression model. [b]sum of CB 153, 138, 180. [c]sum of CB 105, 118, 156, 167 TEQs based on 2005 WHO TEFs (Van den Berg et al. 2006). [d]sum of CB 77, 126, 169 TEQs based on 2005 WHO TEFs (Van den Berg et al. 2006). [e]sum of PCDD TEQ and PCDF TEQ. [f]sum of mono-*ortho* PCB TEQ, non-*ortho* PCB TEQ, PCDD TEQ and PCDF TEQ.

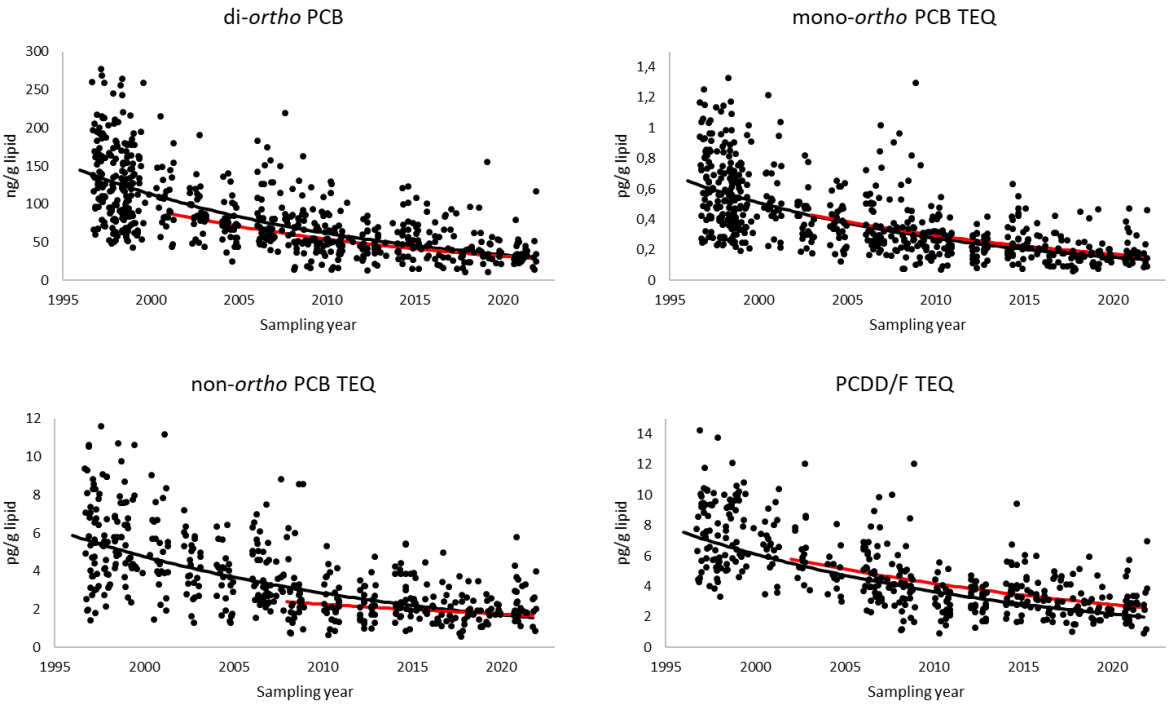

Figure 1. Levels of di-*ortho* PCBs (n=600), mono-*ortho* PCB TEQs (n=588), non-*ortho* PCB TEQs (n=457), and PCDD/F TEQs (n=423) in mother's milk from first-time mothers in Uppsala, Sweden sampled in 1996-2021. Each point corresponds to the concentration in a milk sample from an individual woman. Concentrations <LOQ was recalculated to LOQ/2. The black lines show the temporal trend from the multiple linear regression analysis adjusted for maternal age, pre-pregnancy BMI, body weight gain during pregnancy, and body weight change during the period from delivery to sampling. The red lines show the temporal trend after the CP year if.

The levels of BDE 47, BDE 99, BDE 100, sumPBDE, and HBCDD in the present report decreased with similar rates as were previously reported for the period 1996-2019 (Hedvall Kallerman et al. 2021) (Table 5). However, for BDE 153 and BDE 209 there are still non-significant changes during the whole study period which are in agreement with previous findings (Hedvall Kallerman et al. 2021, Gyllenhammar et al. 2021). The PBDEs were re-examined with multiple regression analyses for the years after the CP year which was detected in the previous report (Hedvall Kallerman et al. 2021). For all the PBDEs with a detected CP year, faster declining trends were observed for the time period after the CP year compared with the whole study period (Table 5). In addition, a significant decrease of BDE 153 levels around 1% per year was observed (2001-2021). Decreasing levels of PBDEs in humans and faster declining rates during the latter part of the study are expected since the use of lower brominated congeners has been voluntarily reduced since the 1990s and the use of PBDEs in electric and electronic products has been restricted by law since 2008 (European Parliament 2011). In agreement with our results, Swedish market basket studies performed between 1999 and 2015, showed that the mean intake of BDE 47 and BDE 99 has decreased around 10% per year during the study period (National Food Agency 2017).

Table 5. Percent change in concentrations of PBDEs and HBCDD per year in mother's milk from primiparous women in Uppsala 1996-2021 and after the estimated change point year to 2021 (Hedvall Kallerman et al. 2021). Adjusted for age of the mother, pre-pregnancy BMI, weight gain during pregnancy and weight loss after delivery. Reported PBDE and HBCDD concentrations, adjusted for concentrations in blank samples, were used instead of LOQ/2 when available.

Compound	Period	n	n year	Change/year (%) Mean	95% CI	R^{2a}	p
BDE 47	1996-2021	562	25	-9.8	-8.9/-10.7	45	<0.001
After change point 2000	2001-2021	390	20	-12.3	-10.8/-13.7	38	<0.001
BDE 99	1996-2021	562	25	-11.5	-10.3/-12.7	39	<0.001
BDE 100	1996-2021	562	25	-7.0	-6.1/-7.9	30	<0.001
After change point 2000	2001-2021	390	20	-9.7	-8.2/-11.1	29	<0.001
BDE 153	1996-2021	562	25	0.2	+0.9/-0.5	7	ns
After change point 2000	2001-2021	390	20	-1.2	+0.0/-2.4	7	<0.05
BDE 209	2009-2021	268	16	-3.4	0.7/-7.3	0	ns
sumPBDE[b]	1996-2021	562	25	-5.6	-4.9/-6.3	32	<0.001
After change point 2001	2002-2021	381	19	-7.0	-5.8/-8.2	25	<0.001
HBCDD	1996-2021	467	25	-3.4	-2.5/-4.4	9	<0.001
After change point 2000	2001-2021	382	20	-6.1	-4.7/-7.5	16	<0.001

[a]Coefficient of determination for the regression model. [b]Sum of BDE 47, 99, 100, 153.

BDE 209 has been analysed continuously in mother's milk collected 2009-2019 and in a few samples before 2009, in total fewer samples (n=268) compared to the other PBDEs. An evaluation of temporal trend for BDE 209 showed no significant change during this period (Table 5, Figure 2). A recent study of BDE 209 in pooled blood serum samples from women in the POPUP-study showed a significant decreasing temporal trend between 1996 and 2021 (Hedvall Kallerman et al. 2023). More data-points are needed before a possible temporal trend can be detected in mother's milk.

For HBCDD, there was a significant downward trend for the whole study period with a declining rate of 3.4% per year (Table 5). In addition, the trend after the detected CP was also declining but at a higher rate (6%) than for the whole study period (Table 5). In agreement with our results, Swedish market basket studies showed a 3-fold decrease in median intake of HBCDD between 2010 and 2015 (National Food Agency 2017).

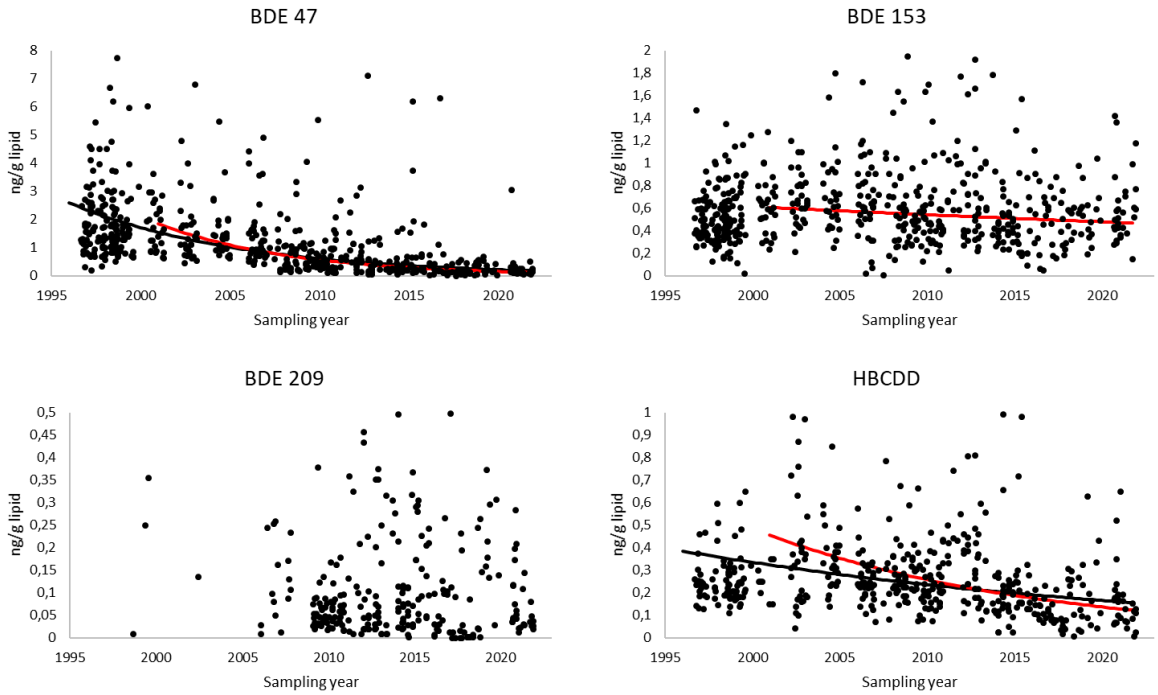

Figure 2. Levels of BDE 47 (n=562), BDE 153 (n=562), BDE 209 (n=268), and HBCDD (n=467) in mother's milk from first-time mothers in Uppsala, Sweden. Each point corresponds to the concentration in a milk sample from an individual woman. Reported PBDE and HBCDD concentrations, adjusted for concentrations in blank samples, were used instead of LOQ/2 when available. The black lines show the temporal trend from the multiple linear regression analysis adjusted for maternal age, pre-pregnancy BMI, body weight gain during pregnancy, and body weight change during the period from delivery to sampling. The temporal trends of BDE 153 and BDE 209 were not statistically significant and hence no black lines are shown. The red lines show the temporal trend after the CP year.

CONCLUSION

The levels of PCBs and PCDD/Fs in mothers milk from the POPUP-cohort showed over all decreasing temporal trends between 1996 and 2021. Even if concentrations of tot TEQ is decreasing in breast milk, still 11 out of 30 women (37%), sampled 2020-2021, had levels above the EFSA estimated safe level. In addition, BDE 47, BDE 99, BDE 100, and HBCDD showed decreasing trends 1996-2021 but BDE 153 did not. However, BDE 153 showed a decreasing trend of about 1% after the CP year. More data points are needed before any conclusions can be drawn about trends regarding BDE 209. For PCBs and PCDD/Fs with a significant CP, the declining trends after the CP were slightly slower than for the years between 1996 and 2021, whereas for the PBDEs and HBCDD the levels have decreased slightly faster after the CP than for the whole time period. It is important to continue monitoring concentrations of POPs in breast milk from Swedish mothers in order to follow and further investigate if the concentrations of PCBs, PCDD/Fs are stabilizing at current levels or continue to decrease.

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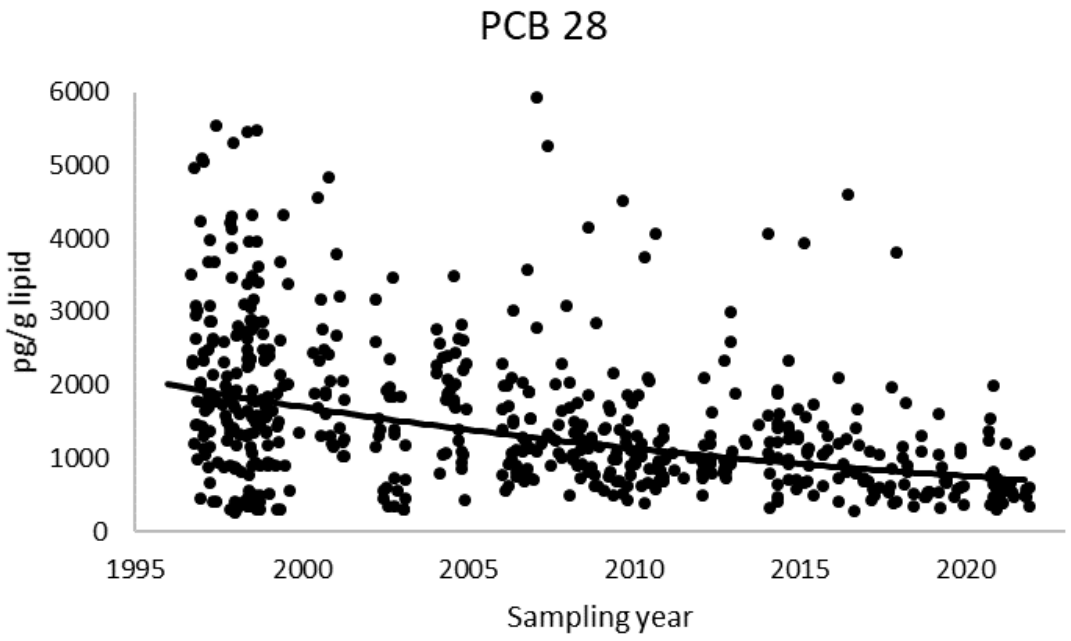
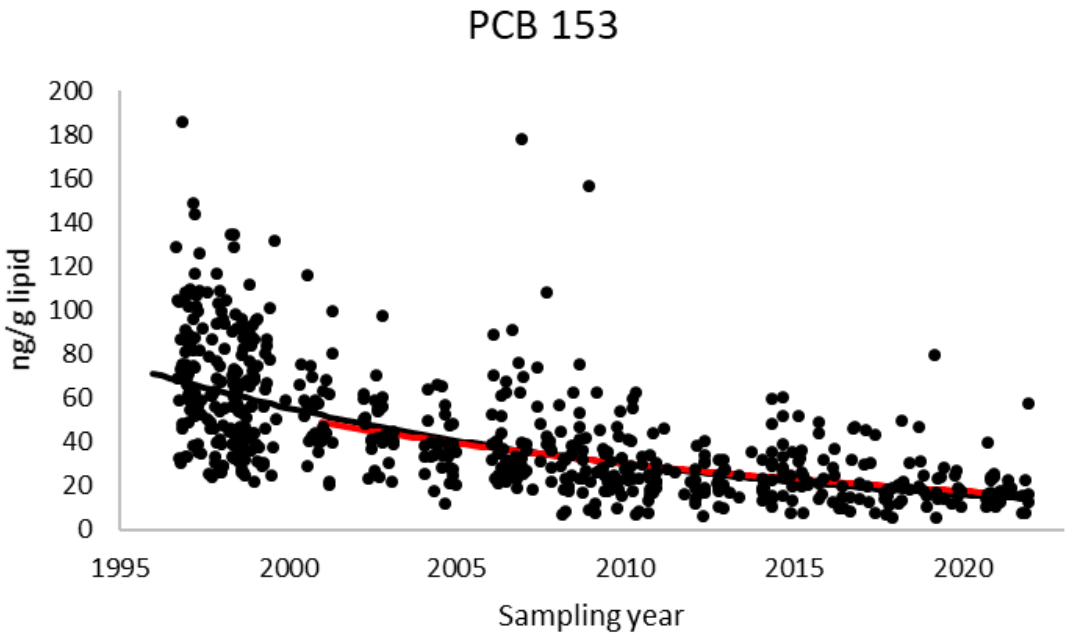
APPENDIX

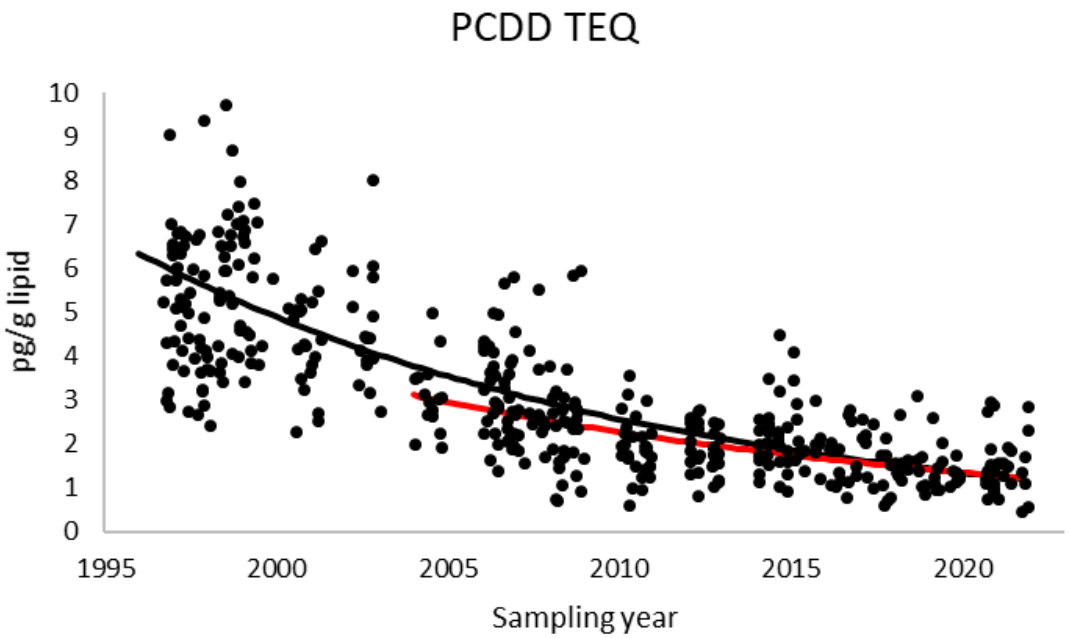
Additional figures

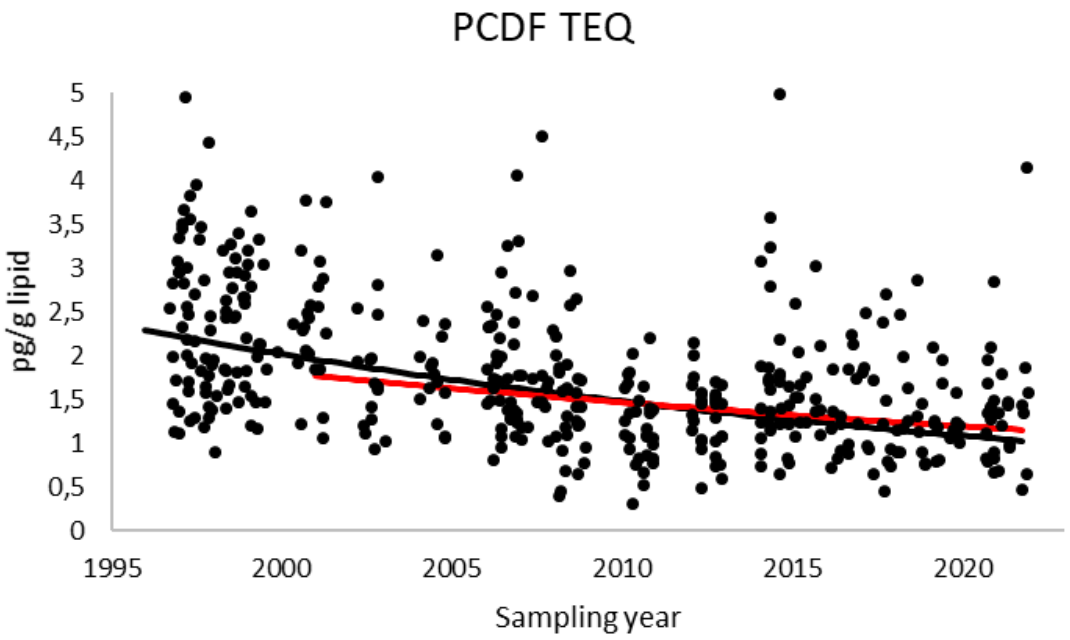
The figures below are not included in the report.

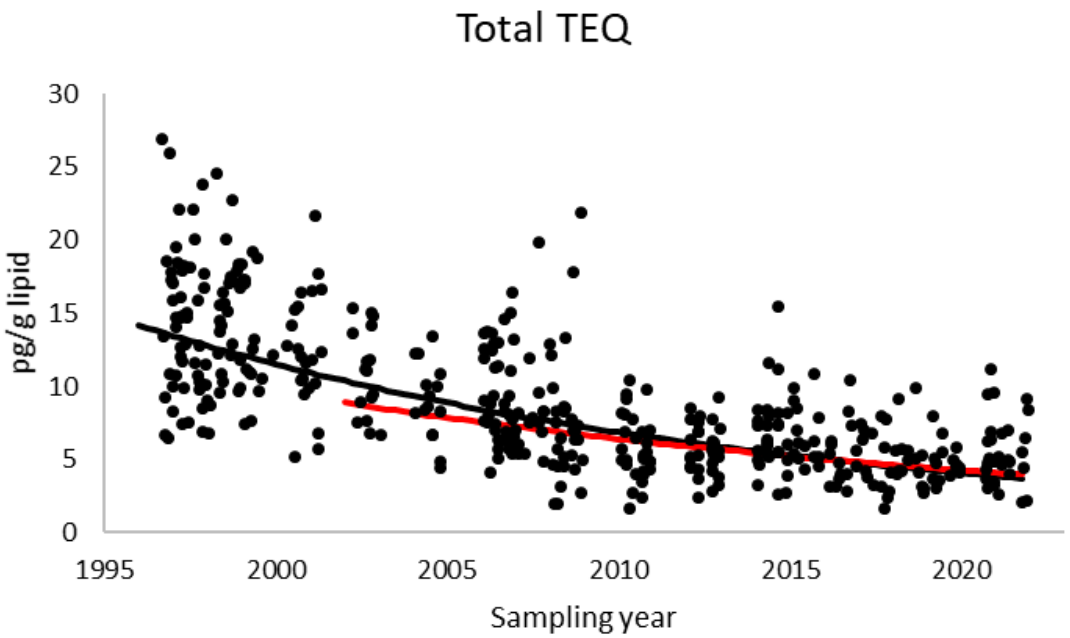
Levels of PCB 28 (n=600), PCB 153 (n=599), PCDD TEQ (n=423), PCDF TEQ (n=423), total TEQ (n=422), BDE 99 (n=562), BDE 100 (n=562) and sumPBDE (the sum of BDE 47, 99, 100 and 153) (n=562) in mother's milk from first-time mothers in Uppsala, Sweden in 1996-2021. Each point corresponds to the concentration in a milk sample from an individual woman. Concentrations <LOQ was recalculated to LOQ/2. PBDE-levels below LOQ were available for breast milk samples from 2009-2021 (and in some samples 2002-2008) and these reported levels below LOQ (adjusted for levels in blank samples) were used instead of half of LOQ. Levels estimated to be zero or negative after blank reduction were in the statistical analyses set to the lowest estimated level found above zero. The black lines show the temporal trend from the multiple linear regression analysis adjusted for maternal age, pre-pregnancy BMI, body weight gain during pregnancy, and body weight change during the period from delivery to sampling. The red lines show the temporal trend after the CP year.

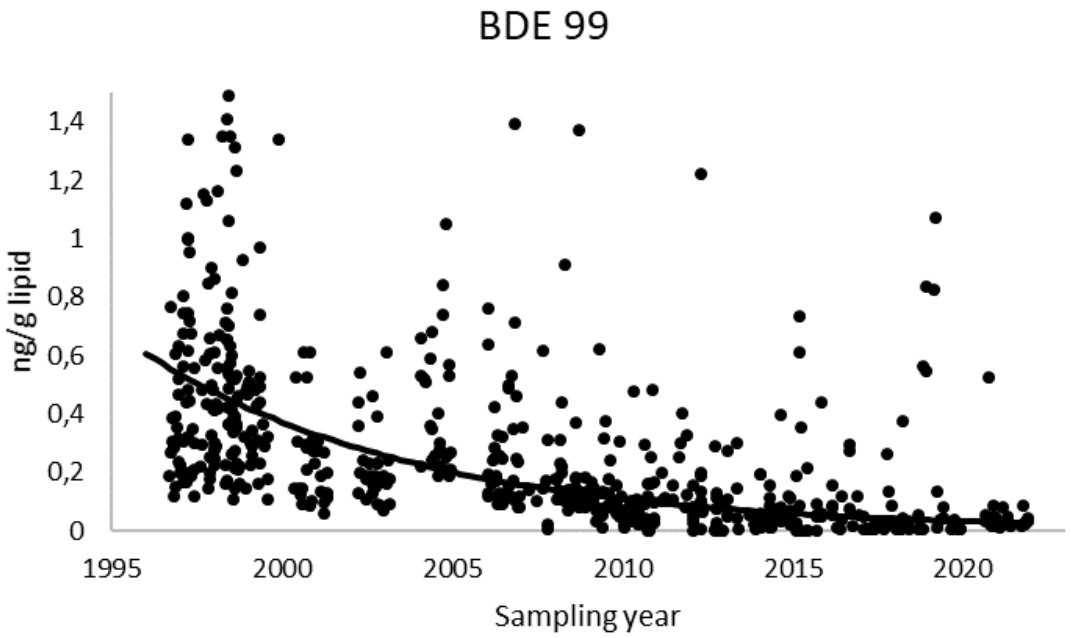


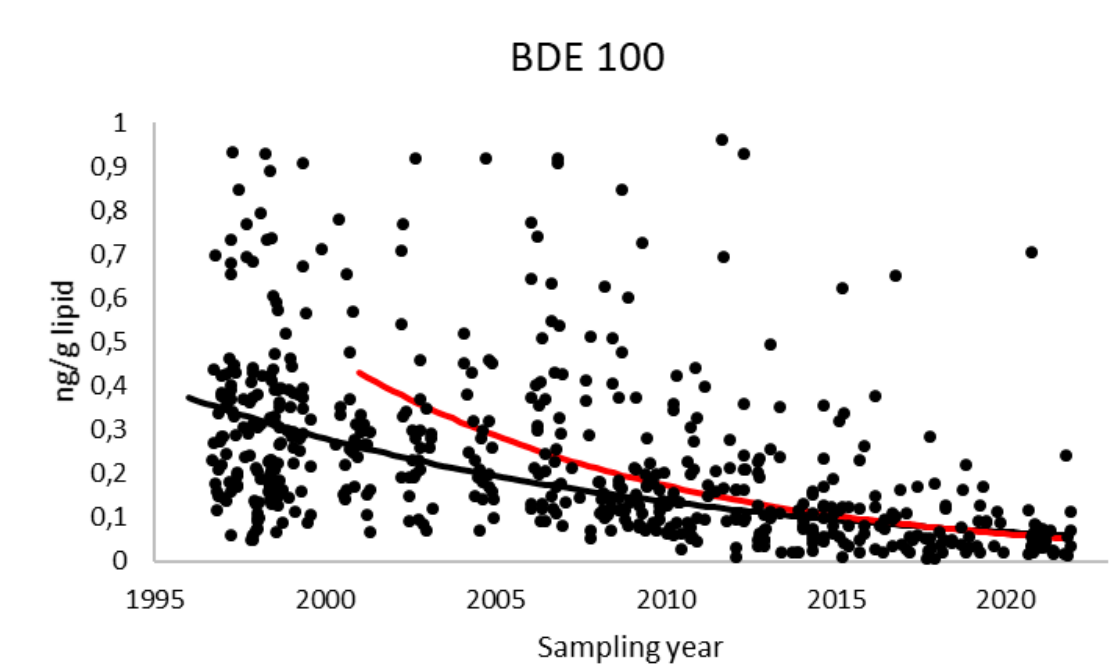

PCB 153
ng/g lipid
200
180
160
140
120
100
80
60
40
20
0
1995
2000
2005
2010
2015
2020
Sampling year

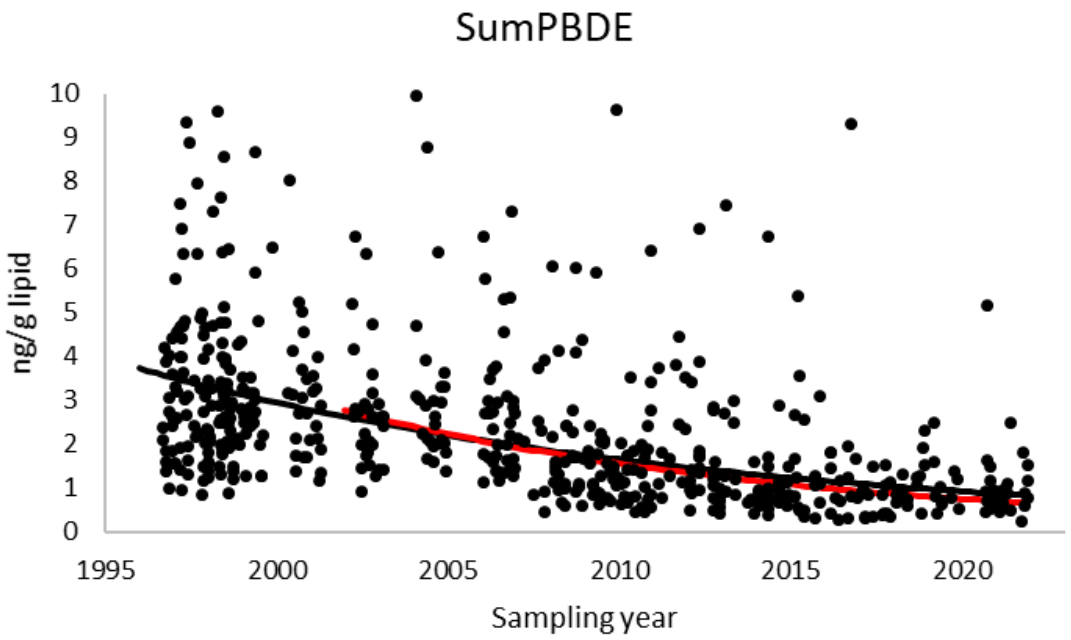

PCDD TEQ
pg/g lipid
10
9
8
7
6
5
4
3
2
1
0
1995
2000
2005
2010
2015
2020
Sampling year


PCDF TEQ
pg/g lipid
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1995
2000
2005
2010
2015
2020
Sampling year


Total TEQ
pg/g lipid
30
25
20
15
10
5
0
1995
2000
2005
2010
2015
2020
Sampling year


BDE 99
1,4
1,2
1
0,8
0,6
0,4
0,2
0
ng/g lipid
1995
2000
2005
2010
2015
2020
Sampling year


BDE 100
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
ng/g lipid
1995
2000
2005
2010
2015
2020
Sampling year


SumPBDE
ng/g lipid
10
9
8
7
6
5
4
3
2
1
0
1995
2000
2005
2010
2015
2020
Sampling year