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Persistent Organic Pollutants (POPs) in Human Samples from The MISA study (Northern Norway)

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The Norwegian University of Science and Technology (NTNU)

Project manager for the contractor

Jon Øyvind Odland

Contact person in the Norwegian Environment Agency

Christel Moræus Olsen

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Author(s)

Jon Øyvind Odland, Shanshan Xu, Sandra Huber, Pierre Dumas

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Summary - sammendrag

This report is based on two human cohort studies called MISA 1 and MISA 2 or “The Northern Norway mother and child contaminant cohort study". The MISA 1 implementation was done during 2007-2009. The aims of this study were to assess levels of contaminants in serum and urine from delivering women and possible associations to pregnancy outcome and child development. The database consists of biological samples, e.g., blood, serum, urine, breast milk, as well as comprehensive dietary questionnaires and medical records with pregnancy outcomes. One of the most interesting findings in the study was the relatively low contaminant concentrations found, but also a rather serious lack of some essential elements, e.g., iodine in urine. Totally 515 delivering women joined the study, with participants from several areas of Northern Norway, from Bodø to Finnmark. This report is based on 200 randomly selected participants for analytical purposes. MISA 2 is an ongoing follow up study using mainly the same protocol but also including non-pregnant young students in Bodø and Tromsø to assess the baseline levels in a non-pregnant compatible group. By using samples collected in MISA 1 and 2, this study investigates levels of the most important classical contaminants, as well as the fluorinated compounds. Pooled samples of emerging compounds have been analysed, with mostly non-detectable levels in blood. Assessment of possible associations between contaminant levels, pregnancy outcome and child development are not included in this monitoring report. The results so far demonstrate a significant reduction of the levels of all analytes. Especially the significantly reduced levels of the perfluorinated compounds are very positive observations.

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1. Introduction

1.1 Key Message

This report is based on two human cohort studies called MISA 1 and MISA 2 or "The Northern Norway mother and child contaminant cohort study". The MISA 1 implementation was done during 2007-2009. The aims of this study was to assess levels of contaminants in serum and urine from delivering women and possible associations to pregnancy outcome and child development. The database consists of biological samples, e.g., blood, serum, urine, breast milk, as well as comprehensive dietary questionnaire, and medical records with pregnancy outcomes. One of the most interesting findings in the study was the relatively low contaminant concentrations found, but also rather serious lack of some essential elements, e.g., iodine in urine. Totally 515 delivering women joined the study, with participants from several areas of Northern Norway, from Bodø to Finnmark. This report is based on 200 randomly selected participants for analytical purposes. MISA2 is an ongoing follow up study using mainly the same protocol but also including non-pregnant young students in Bodø and Tromsø to assess the basic levels before pregnancy. By using samples collected in MISA 1 and 2 this study investigates levels of the most important classical contaminants, as well as the fluorinated compounds. Pooled samples of emerging compounds have been analysed, with mostly non-detectable levels in blood. Assessment of possible associations between contaminant levels, pregnancy outcome and child development is not included in this monitoring report. The results so far demonstrate a significant reduction of the levels of most analytes. Especially the significantly reduced levels of the perfluorinated compounds are very positive observations.

1.2 Background and scope of MISA 1 and MISA 2

The background for the MISA 1 and MISA 2 was to explore the environmental exposure for contaminants for pregnant women and their outcomes, e.g., birth weight, gestational age, maternal morbidity, as well as perinatal conditions for the babies, in a combined cross-sectional and cohort study in Northern Norway. Magnus (2017)[1] has summarized the different publications arising from MISA 1 in the Norwegian Mother and Child Study. The majority of these publications display low levels of POPs in human materials. No strong associations between contaminants and health outcomes have been found, whereas others suggest adverse effects. A positive association between fetal exposure to contaminants and child growth and development was identified by Magnus (2017)[1], using data from the Norwegian Mother and Child Study, and will need replication in other cohorts and further risk assessment. As for MISA 1 the study resulted in a comprehensive database on nutrition which was developed based on a detailed dietary questionnaire, interviews, as well as information from the individual participants filling in a form for dietary information. The first assessment of the

[1] Magnus P. Looking for effects of environmental contaminants in a large birth cohort: Summarizing results of the Norwegian Mother and Child Cohort Study (MoBa). Int J Hyg Environ Health. 2017 Mar;220(2 Pt A):71-76. doi: 10.1016/j.ijheh.2016.12.011. Epub 2017 Jan 6.

MISA 1 results led to increased focus on the nutritional variables in MISA 2. Even so, the same contaminant variables are analysed in MISA 2, providing a good and reliable assessment of the trends and levels during the period from MISA 1 to MISA 2 (2007-2020).

In MISA 1 totally 515 participants were recruited, pregnant women age 18-35 years, varied parity 0-3 children before this pregnancy. A representative number are included in this report. For the included participants, biological samples were collected in the beginning of pregnancy, postpartum and in the breastfeeding period. The selected biological samples were serum and full blood, but also urine samples and breast milk were employed for a variety of substances. This provides information from the beginning of pregnancy to compare for both studies. The trends through pregnancy and the postpartum period were assessed and were published in the last AMAP[2] report and baseline papers[3,4]. In MISA 1 we have enough data to show the rather non-significant change in levels of contaminants through the pregnancy and postpartum period[4]. The MISA 1 and MISA 2 are by all means compatible, but we still have no results from the end of pregnancy or postpartum for MISA 2. These results will be available after the final sampling during 2021.

The basic pregnancy information from MISA 1 was compared with data from the Norwegian Birth Registry. The data for medical records and pregnancy outcome were totally compatible, giving evidence that the MISA 1 participants are representative also for the general Norwegian population. The most interesting findings in the human biological samples were the very low urine iodine levels, pointing out a generally worrying iodine status. This is a main follow up topic in MISA 2. The contaminant levels and trends in the MISA 1 and MISA 2 studies are described later in the report for the delivering women.

2. Materials and methods

2.1 Sampling of the relevant blood samples for this report

The recruitment to MISA 1 was performed in the period 2007-2009. The participants were followed up as described by Hansen et al. (2011)[4]. For MISA 1 new information about POPs in biological materials and nutritional variables was obtained, as well as how these variables change during pregnancy and the postpartum period. This was done as described above; questionnaires, medical records, biological samples, and analyses at the quality controlled laboratories employed. The database was stored at UiT in Tromsø for assessment purposes. The ongoing MISA 2 implementation is performed based on the same protocols (still ongoing

[2] AMAP, 2015. AMAP Assessment 2015: Human Health in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vii + 165 pp.

[3] Hansen S, Nieboer E, Odland JØ, Wilsgaard T,Veyhe AS, Sandanger TM.
Levels of organochlorines and lipids across pregnancy, delivery and postpartum periods in women from Northern Norway. J Environ Monit. 2010 Nov;12(11):2128-37

[4] Hansen S, Nieboer E, Sandanger TM, Wilsgaard T, Thomassen Y, Veyhe AS, Odland JØ. Changes in maternal blood concentrations of selected essential and toxic elements during and after pregnancy.
J Environ Monit. 2011 Aug;13(8):2143-52.

2020-2021). For our current report we recruited enough participants to get a representative comparison between pregnancy and the postpartum period (N = 100 for pregnant and N = 50 for the postpartum period). Additionally, a smaller number of non-pregnant students is included to create baseline pre-pregnancy information. A detailed description of inclusion criteria, informed consent, dietary questionnaires, sampling of biological materials, and pregnancy outcome is provided by Veyhe et al. (2012)[5]. Five hundred and fifteen eligible women were enrolled in early pregnancy, with 391 completing the study protocol that included a self-administrated food frequency questionnaire (FFQ) and donation of biological samples for contaminant analysis in the 2nd trimester, just after delivery, and 6 weeks postpartum. Macronutrient consumption was converted to energy intake, and the amounts of both macro- and micronutrients ingested were estimated.

2.2 Sampling procedures

Both MISA 1 and 2 follow the same sampling protocol. Collection of blood samples, urine, hair samples, and breast milk is described in detail by Hansen et al. (2011)[4].

2.3 Chemical analysis

Analyses of POPs were performed at two laboratories specialised in analysis of environmental pollutants. Substances listed in Table XY were analysed at the Environmental Pollutant Laboratory at the University Hospital North Norway, Norway.

Fully validated automatised high-throughput methods based on solid-phase-extraction techniques for sample preparation were applied according to Huber et al. (2015)[6] for PFASs and Huber et al.(2020)[7] for halogenated POPs. For organochlorine pesticides, PCBs and PBDEs the extracts were treated by an additional clean-up step prior instrumental analysis on an atmospheric pressure gas- chromatograph coupled to a tandem mass spectrometer (APGC-MS/MS). Instrumental analysis for PFASs was conducted on a ultra-high pressure liquid chromatograph coupled to a tandem mass spectrometer (UHPLC-MS/MS). Analysis was performed by the internal standard method. Further details regarding the analytical methods are described previously[6,7].

Substances listed in table XZ were analysed at Centre du Toxicologie du Québec (CTQ), Institut National de Santé Publique du Québec (INSPQ), Québec, Canada. Three different and fully validated methods, according to ISO17025 criteria, have been used to quantify the listed compounds. These methods used hexane liquid-liquid extraction of carbon 13 analogues spiked serum denaturated with reagent alcohol and saturated ammonium solution.

[5] Veyhe AS, Hansen S, Sandanger TM, Nieboer E, Odland JØ. The Northern Norway mother-and-child contaminant cohort study: implementation, population characteristics and summary of dietary findings. Int J Circumpolar Health. 2012;71:18644

[6] Huber S., Brox, J. "An automated high-throughput SPE micro-elution method for perfluoroalkyl substances in human serum." Analytical and Bioanalytical Chemistry 2015 ;Volum 407.(13) s. 3751-3761.

[7] Huber, S., Averina, M., Brox, J. "Automated sample preparation and GC-API-MS/MS as a powerful tool for analysis of legacy POPs in human serum and plasma." Analytical Methods 2020; Volum 7.(12) s. 912-929

For polychlorinated dioxins/furans (PCDDs/Fs) and dioxin-like PCBs, the serum extracts were purified and separated on neutral aluminum column with dichloromethane: hexane (50:50). Then they were quantified on an atmospheric pressure gas-chromatograph coupled to a tandem mass spectrometer (APGC-MS/MS) on an analytical column DB-XLB 30 m x 0.25 µm x 0.1 µm.

For chlorinated paraffins, the serum extracts were purified on two layers (acidified-neutral) silica gel column with dichloromethane: hexane (50:50). Purified extracts were quantified on an ultra-high-pressure liquid chromatograph with UPLC column BEH C18, 50 x 2,1 mm, 1,7 µm and coupled to a time of flight high resolution mass spectrometer (UPLC-QToF) where negative atmospheric chemical ionization (APCI-) was performed based on chlorine adduct formation with dichloromethane.

For the other POPs, the serum extracts were purified on a florisil column. The elution was separated in two steps: the first fraction was eluted with a mixture of dichloromethane: hexane (25:75) and contains PCBs, organochlorinated pesticides, toxaphenes, PBB-153 and PBDEs except heptachlor epoxide, endrin, dieldrin, α-endosulfan and ß-endosulfan, which were eluted in the second fraction with a mixture of acetone:dichloromethane (2:98). The POP extracts reconstituted in hexane were quantified on a gas-chromatograph coupled to a single quadrupole mass spectrometer operating in electron capture negative chemical ionization (GC-ECNI-MS) with an analytical column DB-XLB 15 m x 0.25 µm x 0.1 µm for PBDEs and with a DB-XLB 60 m x 0.25 µm x 0.25 µm for the other compounds (fraction 1). The fraction 2 was reconstituted in acetonitrile before to be injected on a gas-chromatograph coupled to a single quadrupole mass spectrometer operating in electron capture negative chemical ionization (GC-ECNI-MS) with an analytical column DB-XLB 60 m x 0.25 µm x 0.25 µm.

Table XY. Overview on POPs analysed at the Environmental Pollutant Laboratory at the University Hospital of North Norway (UNN)

Analyte		CAS no	Method for analysis
DDT (6 isomers og sumDDT)	o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE o,p'-DDT p,p'-DDT ΣDDT	53-19-0 72-54-8 3424-82-6 72-55-9 789-02-6 50-29-3	APGC-MS/MS
Heptachlor	Heptachlor cis-Heptachlor epoxid		APGC-MS/MS
Hexachlorocyclohexane	α- Hexachlorocyclohexane ß- Hexachlorocyclohexane γ- Hexachlorocyclohexane (Lindane)	319-84-6 319-85-7 608-73-1	APGC-MS/MS
Chlordane	cis-Chlordane trans-Chlordane cis-Nonachlor trans-Nonachlor Oxychlordane Σklordaner	5103-71-9 5103-74-2 39765-80-5 5103-73-1	APGC-MS/MS
Mirex		2385-85-5	APGC-MS/MS

PCB (PCB6)	PCB-28 PCB-52 PCB-101 PCB-138 PCB-153 PCB-180 ΣPCB	7012-37-5 3563-99-3 37680-73-2 35065-28-2 35065-27-1 35065-29-3	APGC-MS/MS
Dioxin similar Polychlorinated biphenyl (PCB-dl)	PCB-118 PCB-156 PCB-157 PCB-167 PCB-169 PCB-189	31508-00-6 38380-08-4 69782-90-7 52663-72-6 32774-16-6 39635-31-9	APGC-MS/MS
Polybrominated diphenyl ether (PBDE)	BDE-47 BDE-49 BDE-66 BDE-99 BDE-100 BDE-153 BDE-154 BDE-183 ΣPBDE	5436-43-1 243982-82-3 189084-61-5 60348-60-9 189084-64-8 68631-49-2 207122-15-4 207122-16-5	APGC-MS/MS
PFAS	PFHxA PFHpA PFOA (linear og forgrenet) PFNA PFDA PFUDA PFDoDA PFTriDA PFTeDA PFBS PFPS PFHxS (linear og forgrenet) PFHpS PFOS (linear og forgrenet) PFNS PFDS PFDoS PFOSA	307-24-4 375-85-9 33567-1 375-95-1 335-76-2 2058-94-8 307-55-1 72629-94-8 376-06-7 375-73-5 355-46-4 375-92-8 2795-39-3 67906-42-7 754-91-6	UHPLC-MS/MS

Table XZ. Overview on POPs analysed by the Centre du Toxicologie du Québec (CTQ)

Analyte		CAS no	Method for analysis
Hexachlorobenzene		118-74-1	GC-ECNI-MS
Aldrin		309-00-2	GC-ECNI-MS
Dieldrin		60-57-1	GC-ECNI-MS
Endrin		72-20-8	GC-ECNI-MS
Endosulfan	α-, ß-endosulfan	959-98-8	GC-ECNI-MS
Hexabromobifenyl	PBB 153	08.01.3655	GC-ECNI-MS
Toxaphene	Kongener P26, P50	8001-35-2	GC-ECNI-MS

Short-chain Chlorinated paraffins (SCCP)	SCCP (C10-C-13)	85535-84-8	MSUPLC-APCI⁻Qtof
Medium-chain chlorinated paraffins (MCCP)	MCCP (C14-C17)	85535-84-8	MSUPLC-APCI⁻Qtof
Dioxin similar polychlorinated biphenyl (PCB-dl)	PCB-77 PCB-81 PCB-126	32598-13-3 70362- 50-4 57465-28-8	APGC-MS/MS
Polybrominated diphenyl ether (PBDE)	BDE-209	1163-19-5	GC-ECNI-MS
Dioxin similar 7 Polychlorinated dibenzodioxins (PCDDs)	2,3,7,8-T4CDD, 1,2,3,7,8-P5CDD 1,2,3,4,7,8- H6CDD 1,2,3,6,7,8- H6CDD 1,2,3,7,8,9-H6CDD 1,2,3,4,6,7,8-H7CDD 1,2,3,4,6,7,8,9-O8CDD	1746-01-6 40321-76-4 39227-28-6 57653-85-7 19408-74-3 35822-46- 9 3268-87-9	APGC-MS/MS
10 Polychlorinated dibenzofurans (PCDFs):	2,3,7,8-T4CDF 1,2,3,7,8-P5CDF 2,3,4,7,8-P5CDF 1,2,3,4,7,8-H6CDF 1,2,3,6,7,8-H6CDF 1,2,3,7,8,9-H6CDF 2,3,4,6,7,8-H6CDF 1,2,3,4,6,7,8-H7CDF 1,2,3,4,7,8,9-H7CDF 1,2,3,4,6,7,8,9-O8CDF	51207-31-9 57117-41-6 57117-31-4 70648-26-9 57117-44-9 72918- 21-9 60851-34-5 67562-39-4 55673-89-7 39001-02-0	APGC-MS/MS
Total Lipids			

2.4 Data comparability

Both laboratories participate on a regular basis at the AMAP external quality assessment scheme for persistent organic pollutants in human serum (QA/QC standard, AMAP Human Health in the Arctic 2015)[2]. The proficiency testing was initiated in 2001 out of a need expressed by laboratories participating the Arctic Monitoring and Assessment Programme (AMAP.no) to ensure comparability of the data provided for conventional POPs, PFASs and PCDDs/Fs. The proficiency testing is organized and conducted by the Centre du Toxicologie du Québec (CTQ), Institut National de Santé Publique du Québec (INSPQ), Québec, Canada. CTQ also participates to the German External Quality Assessment Scheme (G-EQUAS; Erlangen, Germany) for some PCBs, organochlorinated pesticides and PFASs.

2.5 Statistical analysis

Statistical analyses were carried out using IBM SPSS for Windows statistical package version 26. Descriptive details are reported as arithmetic means, geometric means, median, minimum, maxmium and percentiles. Due to the skewed data distribution of chemicals

concentrations, Mann-Whitney U test was applied for trend analysis of levels of chemical concentrations in blood samples between MISA 1 and MISA 2.

2.6 Data storage

The complete database and the connection to medical data, questionnaires and chemical analyses are stored in the EUTRO bank at The Arctic University of Tromsø (UiT) with the PI Odland as the responsible manager.

2.7 Sample banks

All remaining samples for follow up analysis are stored in an accredited biobank at UiT.

3. Results

3.1 Concentrations of PCBs and pesticides in MISA1

Table 1 presents the results from MISA 1 in 2007-2009. The samples were collected at delivery time or three days postpartum. Originally, 513 samples were analyzed for PCBs and pesticides. 200 randomly selected samples were employed for this report for MISA 1 and 40 for MISA 2 from the ongoing study. The individual levels of PCBs and nonachlor are very low compared to available literature from northern areas and the AMAP data discussed in the Introduction (AMAP 2015)[2]. In this AMAP report, a systemic assessment of the levels in all Arctic countries was performed. The data from our Norwegian study turned out to be at the lowest level of measurement[2].

Table 1. Concentration of PCBs and pesticides in wet weight (pg/g) and lipid weight (mg/dL) from MISA 1

Compound	Wet weight (pg/g)				Lipid weight (mg/dL)			
	GM*	Median	Minimum	Maximum	GM*	Median	Minimum	Maximum
PCB99	14	14	4	133	2	2	0	18
PCB101	5	5	1	39	1	1	0	5
PCB118	26	26	7	228	4	4	1	38
PCB138	96	95	16	860	15	15	2	118
PCB163	22	22	6	181	3	3	1	25
PCB153	160	159	26	1470	25	24	3	201
PCB156	15	15	4	192	2	2	0	26
PCB170	41	41	6	434	6	6	1	59

PCB180	107	105	17	1163	16	16	3	159
PCB183	10	10	3	151	2	1	0	21
PCB187	28	29	4	216	4	4	1	30
PCB194	13	12	4	142	2	2	0	19
P,P'DDE	251	242	56	2445	39	37	7	351
HCB	62	62	21	317	10	9	3	53
Trans-nonachlor	18	18	4	129	3	3	1	18
Cis-nonachlor	4	4	0	33	1	1	0	4
*** Geometric mean**								

3.2 Comparison of PCBs and PBDEs

Altogether 35 different PCBs and PBDEs were assessed in the MISA 1 and MISA 2. This report is restricted to the PCBs and PBDEs with a detection frequency above 30% of the samples. Figure 1 shows a comparison of PCB and PBDE congeners concentrations in MISA 1 and MISA 2. A significant decreasing trend was observed for PCB congeners when comparing the MISA 1 with MISA 2with *p* value < 0.05 for all selected compounds. The levels of PBDE-47 and -100 were similar between MISA 1 and MISA 2.

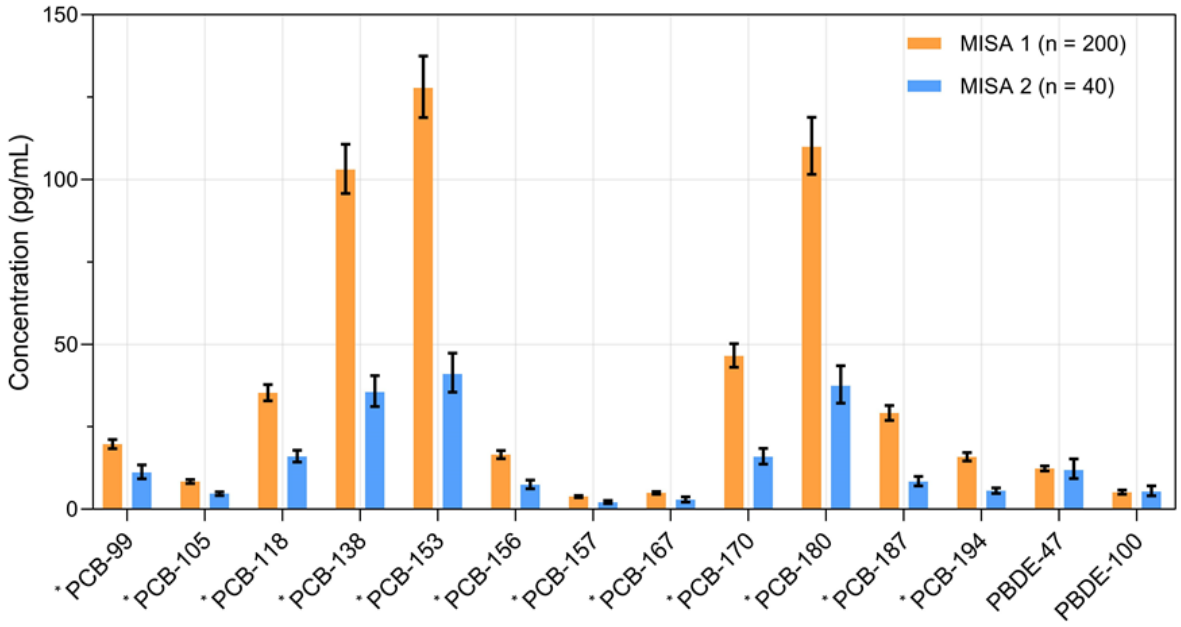


***Figure 1**. Geometric means of the PCBs and PBDEs congeners concentrations with 95% confidence interval in the participants from MISA 1 and MISA 2. * Mann-Whitney U test, the difference is significant between MISA 1 and MISA 2 (p < 0.05).*

3.3 Serum pesticides levels from MISA 1 and MISA 2

Table 2 demonstrates the levels of pesticides from MISA 1 and MISA 2. P,p-DDE, heptachlor, t-CD, t-NC, cis-NC were found detection frequency above the 30% in MISA 1 and MISA 2 (Table 2). In addition, p,p-DDT, ß-HCH and oxychlordane were detected in > 30% of the samples in MISA 1 and γ-HCH were detected in >30% of the samples in MISA 2.

P,p-DDE concentrations were significantly decreased from MISA 1 to MISA 2 ($p < 0.001$) (Figure 2). The similar decreasing trend also observed in the levels of γ-HCH, t-NC and cis-NC across MISA 1 and MISA 2 (Table 2, Figure 2).

Table 2. Pesticides with trends comparing MISA 1 and MISA 2 (pg/mL)

Pesticides	MISA 1 (n = 200)				MISA 2 (n = 40)				P value[c]
	DF (%)[a]	GM[b]	Median	Min-Max	DF (%)[a]	GM[b]	Median	Min-Max	
op-DDE	20	1	1	0.5-3	15	1	1.69	1-3	0.254
pp-DDE	100	185	176	38-1778	98	81	71.91	43-394	**< 0.001**
pp-DDD	1	14	14	11 -18	-[d]				
op-DDT	10	9	9	3-26	-[d]				
Mirex	18	11	11	5-30	5	7	7.35	5-9	0.182
α-HCH	11	14	14	8-24	10	15	14.72	13-17	0.758
γ-HCH	27	25	23	16-42	48	17	17.88	10-24	**< 0.001**
ß-HCH	42	20	18	6-203	5	18	18.96	13-25	0.767
Heptachlor	37	1.6	2	0.4-5	58	1.6	1.47	1-6	0.722
t-CD	35	0.87	1	0.1-2	48	0.89	0.83	0.3-4	0.570
c-CD	14	0.7	1	0.2-2	30	0.8	0.78	0.4-1	0.221
t-NC	99	24	28	3-317	95	8	7.51	2-52	**< 0.001**
cis-NC	90	5	6	1-55	55	3	2.83	1-18	**< 0.001**
Oxy-chlordane	34	28	28	10-122	5	21	20.88	20.8-21.0	0.292
cis-Heptachlor epoxide	11	8	8	4-22	-[d]				

[a] Detection Frequency, % of samples above the method detection limit.
[b] Geometric mean.
[c] Mann-Whitney U test. Bold p values are statistically significant ($p < 0.05$).
[d] The concentration of the compound < LOD.

Some studies suggested that plasma volume expansion during the pregnancy may dilute environmental chemical concentrations in blood[8,9]. The MISA 2 is now including young, non-pregnant participants. The levels so far in MISA 2 are relatively low. Further investigation of its relationship between pregnancy and pesticides levels need to be conducted in larger studies in larger groups.

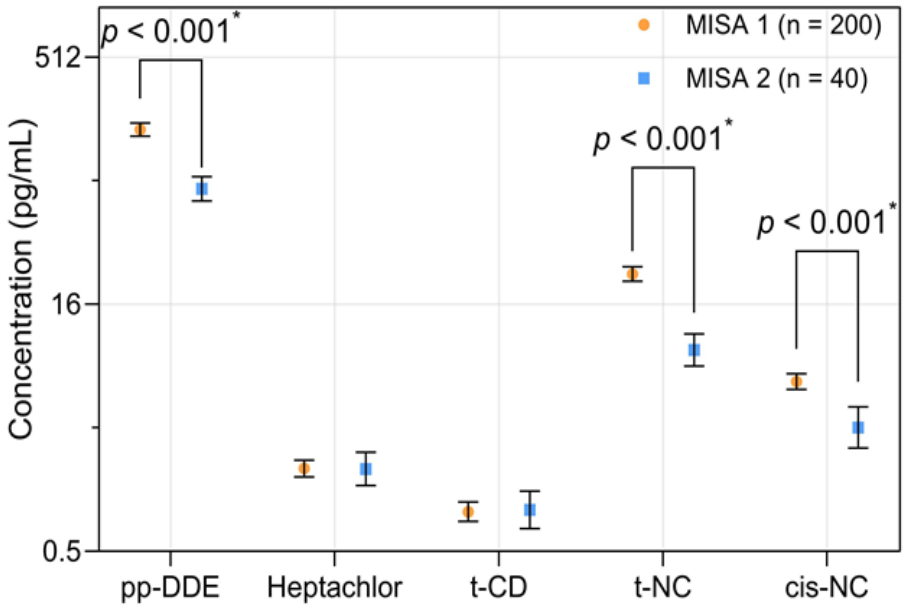


***Figure 2**. Geometric means of the pesticides compounds concentrations (pg/mL) in MISA 1 and MISA 2. The selected compounds were restricted to detection frequency > 30% of the samples from the MISA 1 and MISA 2. The vertical bars plot the 95% confidence interval. * Mann-Whitney U test.*

3.4 The levels of per- and polyfluoroalkyl substances (PFASs)

Table 3 shows the concentration of PFASs from MISA 1 and MISA 2[10]. The presented PFASs are limited to the detection frequency ≥ 50% of the samples. The PFOA, PFOS, PFNA were entirely detected in the samples from MISA 1 and MISA 2 (Table 3). A decreasing trend of PFAS concentration was observed from MISA 1 to MISA 2 (Figure 4). In MISA 1 and MISA 2, the most abundant PFAS was PFOS, with a geometric mean of 7.7 ng/mL and 2.3 ng/mL, respectively, followed by PFOA, PFNA, PFHxS. Average PFOS represented 71% and 54% of total PFAS in MISA

[8] Woodruff TJ, Zota AR, Schwartz JM. Environmental chemicals in pregnant women in the United States: NHANES 2003-2004. Environ Health Perspect. 2011 Jun;119(6):878-85. doi: 10.1289/ehp.1002727. Epub 2011 Jan 14. PMID: 21233055; PMCID: PMC3114826.

[9] Fisher M, Arbuckle TE, Liang CL, LeBlanc A, Gaudreau E, Foster WG, Haines D, Davis K, Fraser WD. Concentrations of persistent organic pollutants in maternal and cord blood from the maternal-infant research on environmental chemicals (MIREC) cohort study. Environ Health. 2016 May 4;15(1):59. doi: 10.1186/s12940-016-0143-y. PMID: 27142700; PMCID: PMC4855498.

[10] Berg V, Nøst TH, Huber S, Rylander C, Hansen S, Veyhe AS, Fuskevåg OM, Odland JØ, Sandanger TM.Maternal serum concentrations of per- and polyfluoroalkyl substances and their predictors in years with reduced production and use. Environ Int. 2014 Aug;69:58-66

1 and MISA 2 respectively and PFOA came to the next, representing 14% of the PFAS in MISA 1 and 20% in MISA 2.

Table 3. The levels of perfluorinated substances (ng/mL) in MISA 1 and 2

PFAS	MISA 1 (n = 391)				PFASs	MISA 2 (n= 40)			
	DF (%)[a]	GM[b]	Median	Min-Max		DF (%)[a]	GM[b]	Median	Min-Max
PFOA	100	1.5	1.5	0.3-10.9	**PFOA**	100	0.8	0.77	0.2-6.9
PFOS	100	7.7	8.0	0.3-35.8	**PFOS**	100	2.3	2.46	0.4-7.2
PFNA	100	0.6	0.6	0.2-4.4	**PFNA**	100	0.4	0.33	0.1-1.7
PFUnA	100	0.2	0.3	0.03-1.46	**PFUnA**	98	0.1	0.11	0.04-0.5
PFHxS	99	0.4	0.4	0.1-14.8	**PFHxS**	100	0.4	0.35	0.1-1.0
PFHpS	79	0.1	0.1	0.1-1.1	**PFHpS**	98	0.1	0.05	0.02-0.2
PFDcA	100	0.2	0.2	0.1-2.3	**PFHpA**	50	0.03	0.03	0.01-0.2
PFDoA	51	0.05	0.1	0.03-0.20	**PFDA**	100	0.2	0.14	0.1-1.0

[a] Detection Frequency, % of samples above the method detection
[b] Geometric mean

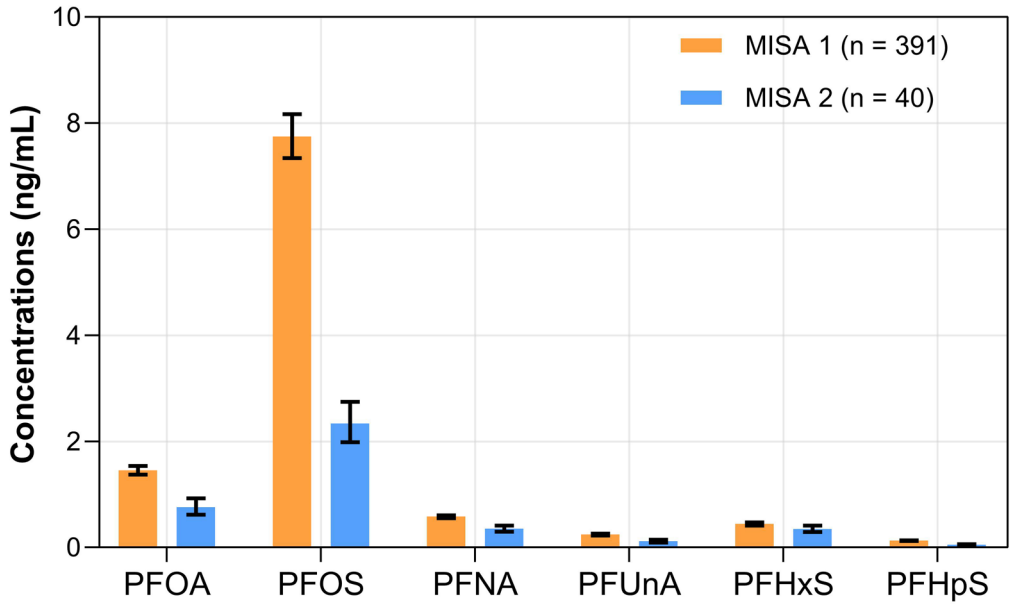
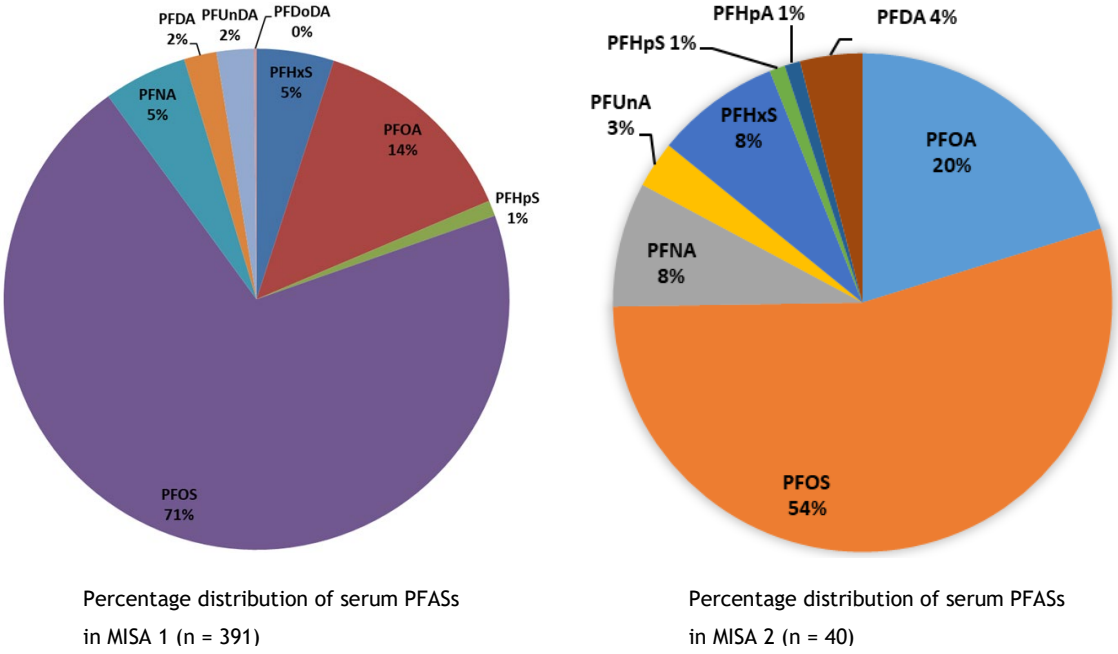


Figure 3. Geometric means with 95% confidence interval of PFASs concentration (ng/mL) from MISA 1 and MISA 2.

Table 3 and Figure 3 show the most important findings in this study so far. The geometric mean of sum PFOS level in the pregnant women is going down from 7.7 ng/mL to 2.3 ng/mL in the trend period. More studies are urgently needed to analyse the background for these extensive changes.



Percentage distribution of serum PFASs in MISA 1 (n = 391)

Percentage distribution of serum PFASs in MISA 2 (n = 40)

Figure 4. Distribution of PFASs in serum from MISA 1 and MISA 2.

In another study, the team at UiT/UNN also analysed comparable blood samples from Argentina (Data not published, Odland personal communication). Descriptive statistics of the dominating PFASs in maternal serum concentrations (ng/mL) are shown in Table 4.
The levels are very low compared to the MISA levels. There is a significant gradient against the northern hemisphere. The sequence of different PFASs were: PFOS > PFBA > PFOA > PFHxS > PFHxA > PFNA > PFDA > PFHpS (Table 4). The laboratory in Quebec has raised the question about possible contamination in the relatively high GM for PFBA.

Table 4. Maternal serum concentrations (ng/mL) of PFASs in the EMASAR study from Argentina (n = 689)

PFASs	DF (%)[a]	Geometric mean	Minimum	25th percentile	Median	75th percentile	Maximum
PFBA	79	0.57	0.36	0.52	0.57	0.63	0.87
PFOA	94	0.26	0.11	0.20	0.24	0.32	3.02
PFOS	100	0.74	0.11	0.52	0.74	0.99	59.79
PFNA	95	0.04	0.01	0.03	0.04	0.06	1.14
PFDA	84	0.03	0.01	0.02	0.03	0.04	0.55
PFHxS	98	0.21	0.04	0.14	0.21	0.32	3.30
PFHxA	86	0.08	0.01	0.05	0.08	0.12	0.47
PFHpS	34	0.02	0.02	0.02	0.03	0.04	0.53

[a] **Detection Frequency, % of samples above the method detection**

3.5 Pooled samples for emerging contaminants.

In total, 100 samples from MISA 1 and 2 were included in the assessment for dioxins furans, planar PCBs, SCCP and MCCP. 62 samples were from MISA 1 and 38 samples from MISA 2. These samples were divided into 10 sample pools for chemical analysis, in which MISA 1 samples constitute 6 pools (M1D, M1E, M1F, M1G, M1H and M1I) while MISA 2 made up for 4 sample pools (M2A, M2B, M2C and M2NP). The pooled samples concentrations based on serum volume and pool used to show lipids content normalized around 6 g/L. Table 5 shows the blood levels of dioxins furans and planar PCBs in 10 sampling pools. The blood dioxins furans and PCBs levels in MISA 2 were lower than those in MISA 1. The pooled sample M1F has the highest the levels pf dioxins furans and planar PCBs compare to other sample pools (total concentration = 1272 pg/mL). Generally, the compounds of dioxins furans and planar PCBs concentrations in MISA study were lower than these from Canadian samples (Table 5, Figure 5).

PCDD/F normal concentrations have readily declined in Canada between Canadian Health Measures Survey[11] (CHMS) normal concentration in 2007-2009 compared to Inuit in 2017 (Table 5). Thanks to global legislation over decades for these types of compounds. In Table 5, the main PCDD/F levels are lower in MISA 1 but more comparable levels to CHMS, and MISA 2 are more comparable to Inuit 2017 with the exception that Inuit still have higher planar PCBs levels due to their traditional food consumption.

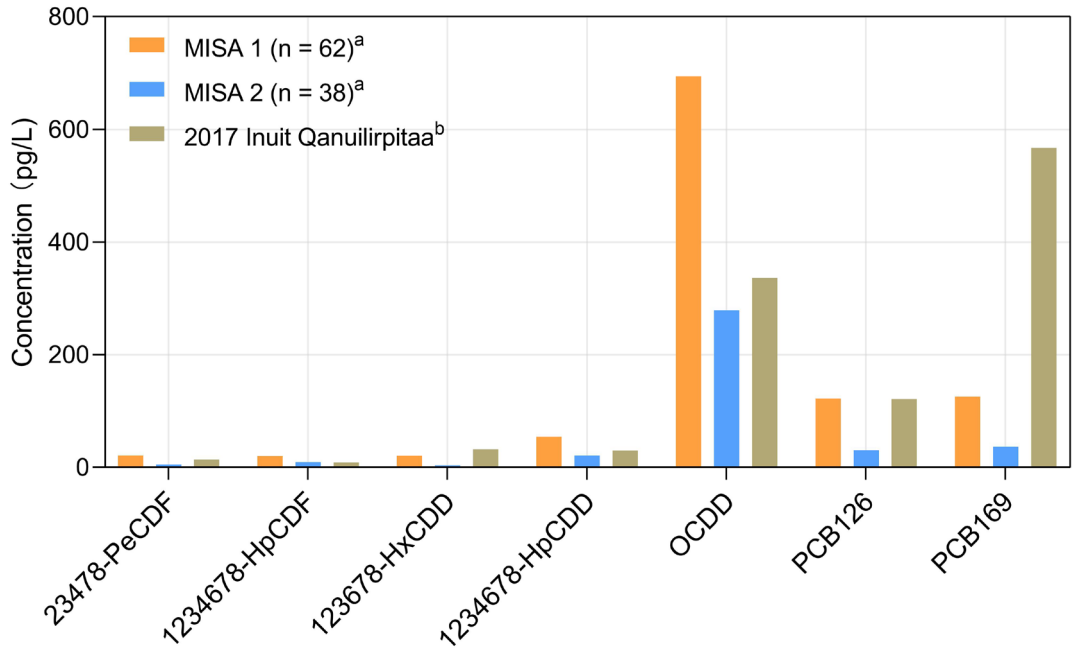


***Figure 5**. The bar chats plot the average pooled levels of contaminants from MISA 1 and MISA and compared with Canadian Inuit levels in 2017. a Arithmetic mean levels of the pooled samples; b Geometric mean.*

[11] The Canadian Health Measures Survey: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/environmental-contaminants/human-biomonitoring-environmental-chemicals/canadian-health-measures-survey.html.

Table 5. Concentration of dioxins furans and planar PCBs in serum (pg/L)

Compounds	LOD	Sample pool										Average pooled levels		Canadian Normal Levels	
		Pool M1D	Pool M1E	Pool M1F	Pool M1G	Pool M1H	Pool M1I	Pool M2A	Pool M2B	Pool M2C	Pool M2NP	MISA 1	MISA 2	2007-2009 Canadian CHMS GM (Range)	2017 Inuit Qanuilirpitaa GM (Range)
2378-TCDF	6	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 6 (< 6-12)	< 6 (< 6-9)
12378-PeCDF	5	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 4 (< 4-7)	< 5
23478-PeCDF	6	23	28	31	14	14	18	7	7	< LOD	6	21	7	20 (< 3-53)	14 (< 6-46)
123478-HxCDF	8	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	NR	< LOD	< LOD	< LOD	-[a]	-[a]	< 5 (< 5-96)	(< 8-10)
123678-HxCDF	6	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	7	-[a]	-[a]	15 (1-37)	(< 6-10)
234678-HxCDF	7	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	8 (2-13)	< 7
123789-HxCDF	5	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 4 (< 4-7)	< 5
1234678-HpCDF	9	27	21	28	14	16	13	0	16	11	10	20	9	26 (1-126)	9 (< 9-18)
1234789-HpCDF	4	< LOD	< LOD	NR	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	6 (0-29)	< 4
OCDF	10	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 5 (< 5-14)	< 8
2378-TCDD	8	< LOD	< LOD	NR	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 6 (< 6-13)	(< 8-21)
12378-PeCDD	6	7	7	NR	8	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	7	-[a]	19 (5-47)	12 (< 6-43)
123478-HxCDD	8	NR	< LOD	NR	0	NR	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	15 (2-37)	(< 8-35)
123678-HxCDD	4	19	21	21	19	17	25	5	0	4	5	20	4	130 (18-306)	32 (< 4-89)
123789-HxCDD	6	< LOD	< LOD	< LOD	6	9	< LOD	< LOD	< LOD	< LOD	< LOD	8	-[a]	16 (1-43)	(< 6-13)
1234678-HpCDD	11	40	64	80	56	34	52	17	38	15	13	55	21	135 (20-276)	30 (15-57)
OCDD	10	664	809	819	640	655	579	247	350	345	175	694	279	900 (14-2160)	336 (185-784)
PCB81	5	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 50	(< 5-11)
PCB77	10	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	< 60 (<60-240)	< 10
PCB126	8	131	176	140	99	66	122	35	36	26	23	122	30	100 (< 60-240)	121 (17-456)
PCB169	12	137	125	153	105	91	142	45	40	34	27	125	36	100 (< 60-240)	567 (69-2200)
∑Dioxins Furans and planar PCBs		1048	1251	1272	963	902	951	355	487	435	267				

N.R. Not Reported due to analytical difficulties (interferences or recovery lower than 50%)

[a] Detection frequency < 30%; the limit of detection (LOD)

Table 6. Concentration of dioxins furans and planar PCBs pg-TEQ/L in serum (WHO TEF 2005)

Compounds	LOD	Sample pools										Average pooled levels		WHO TEF
		Pool M1D	Pool M1E	Pool M1F	Pool M1G	Pool M1H	Pool M1I	Pool M2A	Pool M2B	Pool M2C	Pool M2NP	MISA 1	MISA 2	
2378-TCDF	0.64	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.1
12378-PeCDF	0.15	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.03
23478-PeCDF	1.73	6.9	8.4	9.2	4.2	4.2	5.4	2.1	2.0	0.0	1.7	5.7	2.0	0.3
123478-HxCDF	0.79	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	NR	< LOD	< LOD	< LOD	-[a]	-[a]	0.1
123678-HxCDF	0.58	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.7	-[a]	-[a]	0.1
234678-HxCDF	0.71	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.1
123789-HxCDF	0.52	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.1
1234678-HpCDF	0.09	0.3	0.2	0.3	0.1	0.2	0.1	< LOD	0.2	0.1	0.1	0.2	0.1	0.01
1234789-HpCDF	0.04	< LOD	< LOD	NR	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.01
OCDF	0.003	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.0003
2378-TCDD	7.83	< LOD	< LOD	NR	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	1
12378-PeCDD	5.65	6.7	6.5	NR	7.7	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	7.0	-[a]	1
123478-HxCDD	0.81	NR	< LOD	NR	< LOD	NR	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.1
123678-HxCDD	0.41	1.9	2.1	2.1	1.9	1.7	2.5	0.5	< LOD	0.4	0.5	2.0	0.5	0.1
123789-HxCDD	0.60	< LOD	< LOD	< LOD	0.6	0.9	< LOD	< LOD	< LOD	< LOD	< LOD	0.8	-[a]	0.1
1234678-HpCDD	0.11	0.4	0.6	0.8	0.6	0.3	0.5	0.2	0.4	0.2	0.1	0.5	0.2	0.01
OCDD	0.00	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.0003
PCB81	0.002	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.0003
PCB77	0.001	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]	0.0001
PCB126	0.77	13.1	17.6	14.0	9.9	6.6	12.2	3.5	3.6	2.6	2.3	12.2	3.0	0.1
PCB169	0.36	4.1	3.8	4.6	3.1	2.7	4.2	1.4	1.2	1.0	0.8	3.8	1.1	0.03
∑Dioxins Furans and planar PCBs		33.7	39.4	31.2	28.4	16.8	25.2	7.6	7.5	4.5	6.3			

N.R. Not Reported due to analytical difficulties (interferences or recovery lower than 50%)

[a] Detection frequency < 30%; the limit of detection (LOD)

The concentrations of dioxin like furans and planar PCBs with WHO Toxic Equivalency (TEQ) are shown in Table 6. The toxic equivalency of a mixture is defined by the sum of the concentrations of individual compounds multiplied by their relative toxicity (TEF)[12]. Pool M1E in MISA 1has the highest levels of dioxins furans and planar PCBs (sum concentration = 39.4 pg-TEQ/L). Overall, the toxic equivalents of dioxins furans and planar PCBs is higher in MISA 1 than the MISA 2 (Table 6).

Table 7. Blood concentration of SCCP (µg/L)

Congeners Group	LOD	Sample pool										Average SCCP levels	
		Pool M1D	Pool M1E	Pool M1F	Pool M1G	Pool M1H	Pool M1I	Pool M2A	Pool M2B	Pool M2C	Pool M2NP	MISA 1	MISA 2
C10H17Cl5	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	0.03	-[a]	0.03
C10H16Cl6	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	0.01	-[a]	0.01
C10H15Cl7	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C10H14Cl8	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C10H13Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C10H12Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C11H19Cl5	0.01	< LOD	0.02	< LOD	< LOD	0.02	< LOD	0.01	0.02	< LOD	0.02	0.02	0.02
C11H18Cl6	0.01	0.03	0.03	< LOD	0.01	0.03	0.01	0.03	0.02	< LOD	0.03	0.02	0.03
C11H17Cl7	0.01	< LOD	< LOD	< LOD	< LOD	0.01	0.01	0.02	< LOD	< LOD	< LOD	0.01	-[a]
C11H16Cl8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
C11H15Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C11H14Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C12H21Cl5	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C12H20Cl6	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	0.02	-[a]	0.02
C12H19Cl7	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.03	< LOD	< LOD	0.01	-[a]	0.02
C12H18Cl8	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	-[a]	-[a]
C12H17Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C12H16Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C13H23Cl5	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C13H22Cl6	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C13H21Cl7	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	-[a]	-[a]
C13H20Cl8	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	< LOD	-[a]	-[a]
C13H19Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C13H18Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
ΣSCCP		0.03	0.05	< LOD	0.01	0.06	0.02	0.19	0.04	< LOD	0.12		

N.A. Not Available

[a] Detection frequency < 30%; the limit of detection (LOD)

Table 7 and Table 8 present the concentrations of SCCP and MCCP. The SCCP and MCCP concentrations are very low, and the majority of the congeners are barely detected in different sampling pools, with DF < 30%. Pool M2A in MISA 2 has the highest SCCP and MCCP levels compared to other pools, with the sum SCCP and MCCP concentration at 0.19 µg/L and 0.13 µg/L, respectively. As SCCP were globally banned since MISA 1 study, SCCP in MISA 1 pools should be as for other POPs higher than MISA 2. However, this is not the case rising important questions. One reason for this may be related to stability. Since analytical methods for SCCP have only recently become available, this possible instability has still not been studied. We are questioning the very low levels of SCCP and MCCP found in humans in our study but also other studies. We begin to think that they may not be as biopersistent as PCBs or PCDD/F and they may degrade or be metabolized faster than other POPs. Further internal studies at Institut national de santé publique du Québec (INSPQ) are undergoing regarding this important aspect of low detectable concentrations.

[12] Van den Berg, Martin, et al. "The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds." Toxicological sciences 93.2 (2006): 223-241.

Table 8. Blood concentration of MCCP (µg/L)

Congeners Group	LOD	Sample pool										Average MCCP levels	
		Pool M1D	Pool M1E	Pool M1F	Pool M1G	Pool M1H	Pool M1I	Pool M2A	Pool M2B	Pool M2C	Pool M2NP	MISA 1	MISA 2
C14H25Cl5	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C14H24Cl6	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	0.02	-[a]	0.02
C14H23Cl7	0.01	0.02	< LOD	< LOD	0.01	< LOD	0.01	0.02	0.02	0.01	0.08	0.01	0.03
C14H22Cl8	0.01	0.01	0.01	0.01	0.01	< LOD	< LOD	0.03	0.02	0.02	0.09	0.01	0.04
C14H21Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD	< LOD	0.03	-[a]	0.03
C14H20Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C15H27Cl5	0.01	0.02	< LOD	< LOD	< LOD	0.00	< LOD	0.01	< LOD	< LOD	< LOD	-[a]	-[a]
C15H26Cl6	0.01	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	0.02	< LOD	< LOD	0.01	-[a]	0.02
C15H25Cl7	0.01	0.01	0.01	< LOD	< LOD	< LOD	0.01	0.01	0.01	< LOD	0.04	0.01	0.02
C15H24Cl8	0.01	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	0.01	< LOD	< LOD	0.04	-[a]	0.03
C15H23Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C15H22Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C16H29Cl5	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	-[a]	-[a]
C16H28Cl6	0.01	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C16H27Cl7	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C16H26Cl8	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C16H25Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C16H24Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C17H31Cl5	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C17H30Cl6	0.01	0.01	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	-[a]
C17H29Cl7	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C17H28Cl8	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C17H27Cl9	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
C17H26Cl10	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	-[a]	-[a]
ΣMCCP		0.08	0.02	0.01	0.04	0.01	0.02	0.13	0.05	0.03	0.32		

N.A. Not Available

[a] Detection frequency < 30%; the limit of detection (LOD)

Table 9. Concentration of different contaminants in pooled samples from MISA 1 and MISA 2 (µg/L)

Compounds	Sample pools										Average pooled levels	
	Pool M1D	Pool M1E	Pool M1F	Pool M1G	Pool M1H	Pool M1I	Pool M2A	Pool M2B	Pool M2C	Pool M2NP	MISA 1	MISA 2
Aldrin	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
α-Endosulfan	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
ß-Endosulfan	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
Dieldrin	< LOD	< LOD	< LOD	< LOD	< LOD	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
Endrin	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
Hexachlorobenzene	0.10	0.10	0.09	0.08	0.07	0.08	0.05	0.05	0.05	0.05	0.09	0.05
PBB, IUPAC # 153	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
PBDE, IUPAC # 209	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.02	< LOD
PBDE, IUPAC # 47	< LOD	< LOD	0.01	0.55	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.28	< LOD
PCB, IUPAC # 153	0.22	0.20	0.25	0.16	0.13	0.21	0.05	0.07	0.05	0.04	0.20	0.05
p,p'-DDE	0.27	0.38	0.29	0.24	0.15	0.28	0.11	0.11	0.08	0.06	0.27	0.09
Total Lipids	9.20	8.80	11.00	8.50	8.80	8.00	7.00	7.10	6.80	6.50	9.05	6.85
Toxaphene, Parlar No. 26	0.01	0.01	0.01	< LOD	0.01	0.01	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
Toxaphene, Parlar No. 50	0.01	0.02	0.01	0.01	0.01	0.02	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD
Sum	9.83	9.50	11.66	9.54	9.16	8.61	7.21	7.32	6.98	6.64		

LOD: the limit of detection

Table 9 shows the levels of different emerging contaminants in pooled samples from MISA 1 and MISA 2.

The concentrations are mostly at or below limit of detection (LOD). The old POP pesticides, Aldrin and, Endrin were not detected in any of the pooled samples and Dieldrin was only detected in one of 5 pooled samples from MISA 1. Toxaphene was detected at low levels in MISA 1 pools but were below detection limits in MISA 2. Endosulfan was not detected in any of the pooled samples. Levels of pp-DDE in the pooled samples corresponded well with the levels found by UiT presented in Table 2. Levels of PCB-153 was slightly higher in the pooled samples from MISA 1 than in the individual samples analyzed by UiT presented in Figure 1, but levels in the pooled samples from MISA 2 was more similar with those in Figure 1. PBDE-209 was only detected at low level in one of five pooled MISA 1 samples, and PBDE-47 in two of five pooled samples from MISA 1 only. PBB-153 was below detection limit in both MISA 1 and 2. Hexachlorobenzene was detected in all samples with average pooled levels of 0.09 and 0.05 ug/L for MISA1 and MISA 2, respectively.

4. Conclusions

Most analytes demonstrate a significant reduction in POPs levels in human blood between the MISA 1 and 2, i.e., between the years 2007 and 2019. Also the legacy POPs,such as PCBs, show significant reduction, despite their long half-life in nature.

As for the pesticides the same development is showing up in the analyses, where the degradation products and metabolites have taken the bulk of the exposure.

One interesting finding is the significant reduction in the levels of PFOS, PFHxS and PFOA. This might be due to the successful international regulation of PFOS and PFOA through the Stockholm Convention and other agreements which are reflecting already a decrease in these concentrations over the last decade.

As for the emerging compounds concentrations are very low, and the majority of the congeners are barely detected. SCCP has been globally banned since the MISA 1 study, SCCP in MISA 1 pools should be as for the other POPs higher than MISA 2. However, this is not the case rising important questions. One reason for this may be related to stability. Since analytical methods for SCCP have only recently become available, possible instability has still not been studied. We are questioning the very low levels of SCCP and MCCP found in human serum in our study but also other studies. We begin to think that they may not be as biopersistent as PCBs or PCDD/F and they may degrade or be metabolized faster than other POPs.

5. References are inserted as foot notes

Norwegian Environment Agency
Telephone: +47 73 58 05 00 | Fax: +47 73 58 05 01
E-mail: post@miljodir.no
Web: www.miljødirektoratet.no
Postal address: Postboks 5672 Torgarden, N-7485 Trondheim
Visiting address Trondheim: Brattørkaia 15, 7010 Trondheim
Visiting address Oslo: Grensesvingen 7, 0661 Oslo

The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are a government agency under the Ministry of Climate and Environment and have 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.