Per- & Polyfluoroalkyl Substances (Day 2)

EMEP CEC Workshop 8th – 10th Nov 2023

The climate and environmental research institute NILU
A part of the research alliance NORIN

Flyplassen skjuler en miljøbombe - må rydde opp for over hundre millioner

Svalbard lufthavn er kraftig forurenset av miljøgiften PFAS. Nå får Avinor pålegg om å fjerne de forurensede massene.

Avinor må nå fjerne miljøgiften PFAS ved flyplassen i Longyearbyen på Svalbard.
FOTO: RUNE NORDGÅRD ANDREASSEN / NRK

Rune N. Andreassen
Journalist

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Cost: 114 million NOK

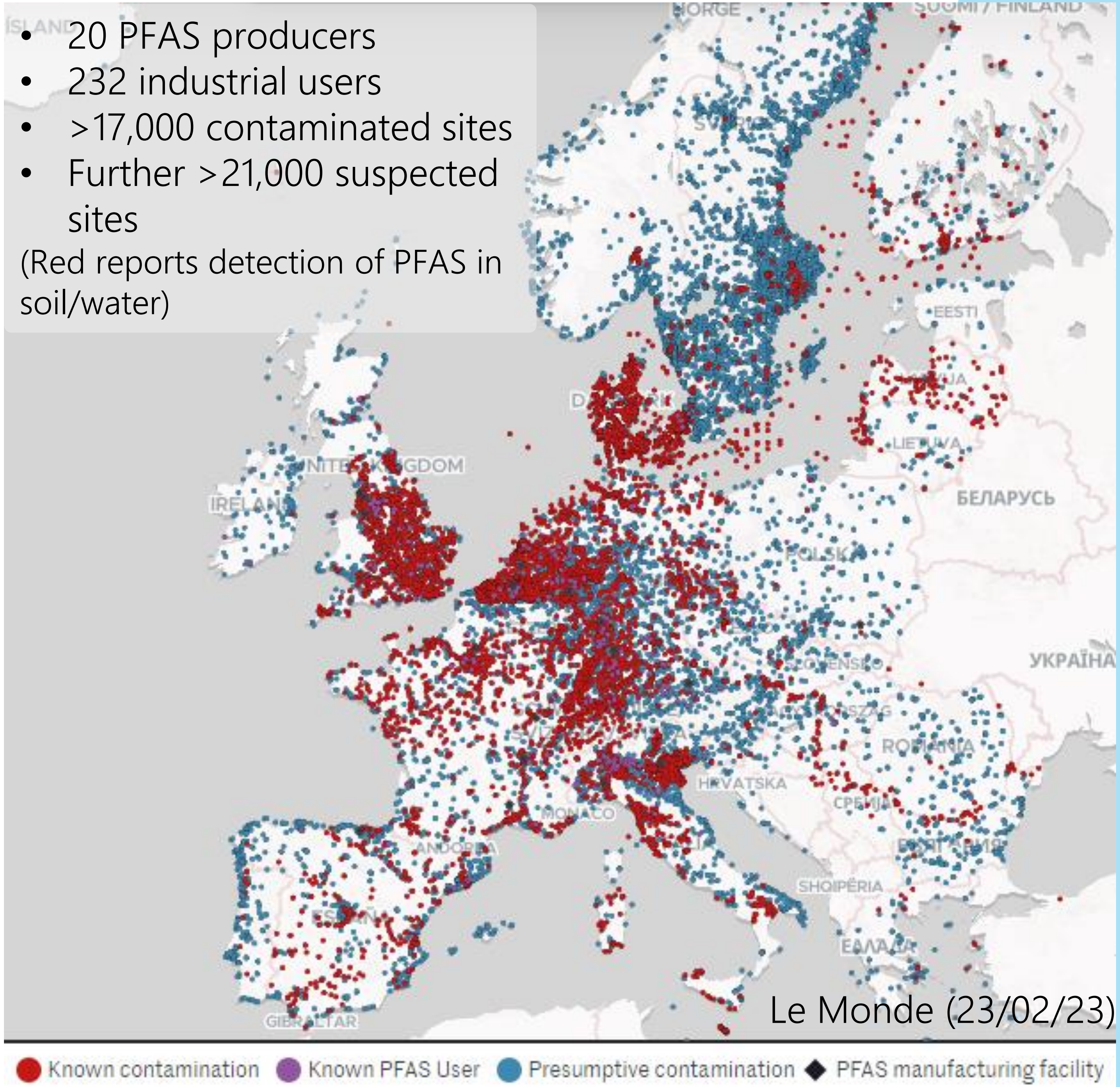
EU considers ban on 'forever chemicals', urges search for alternatives

By Ludwig Burger

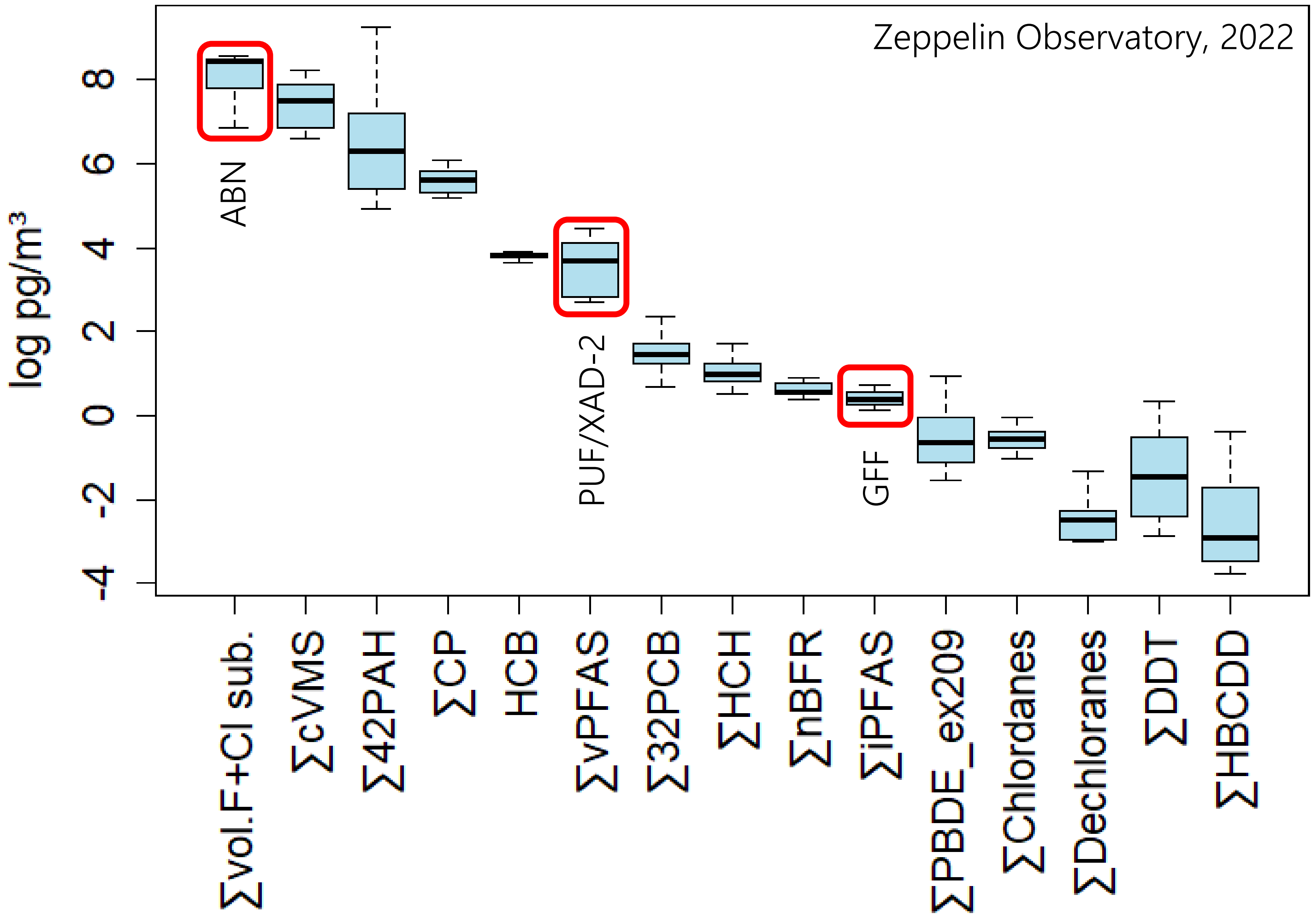
European Union flags flutter outside the EU Commission headquarters, in Brussels, Belgium, February 1, 2023 REUTERS/Yves Herman/File Photo

- 20 PFAS producers
- 232 industrial users
- >17,000 contaminated sites
- Further >21,000 suspected sites

(Red reports detection of PFAS in soil/water)



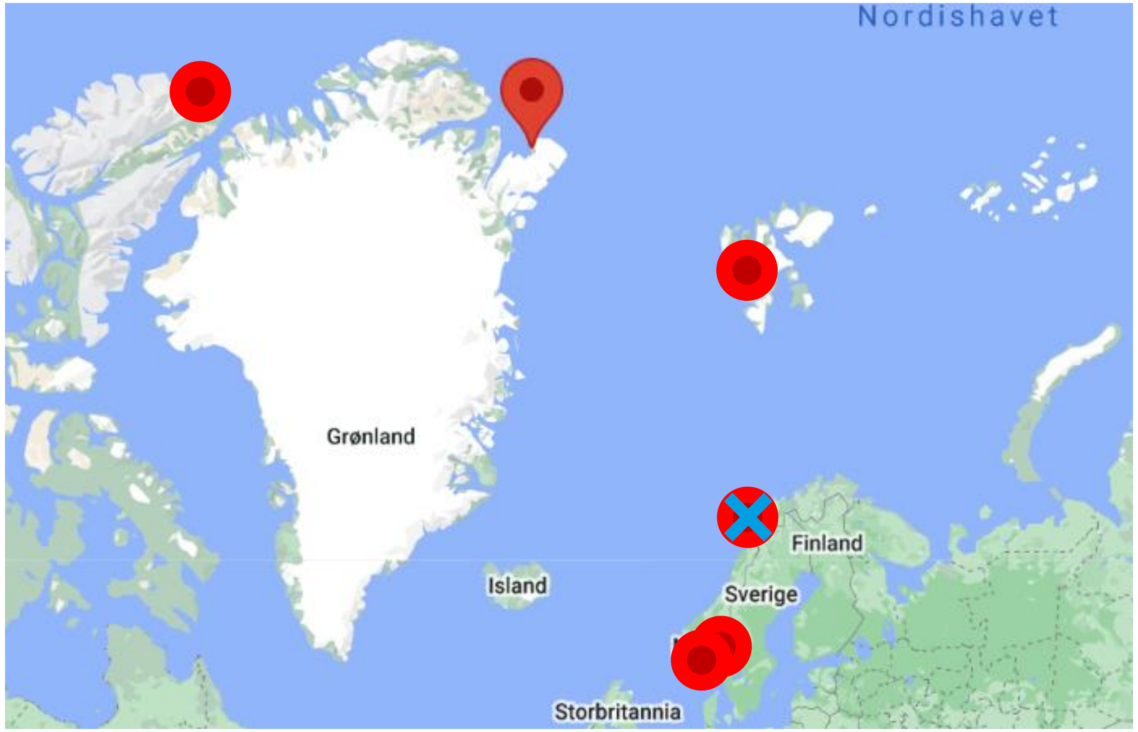
Le Monde (23/02/23)



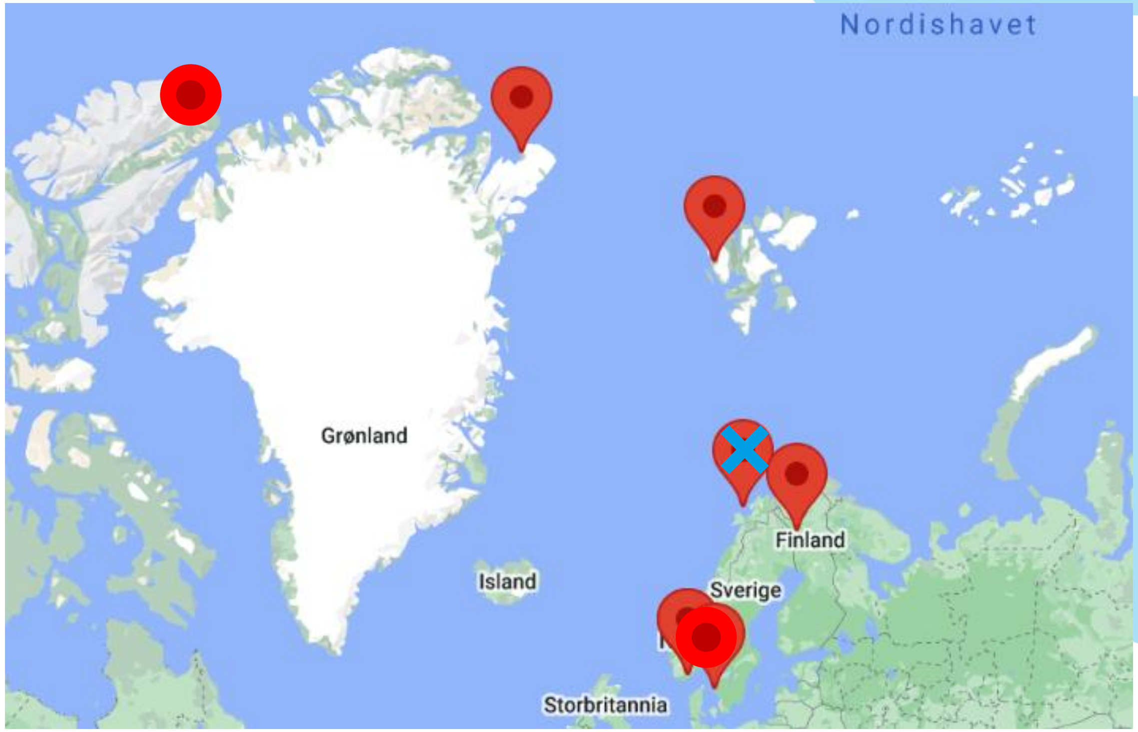
The concentrations of all compound groups measured at the Zeppelin observatory in 2022.

Where are we measuring right now (northern Europe)?

Neutrals (e.g. FTOHs)

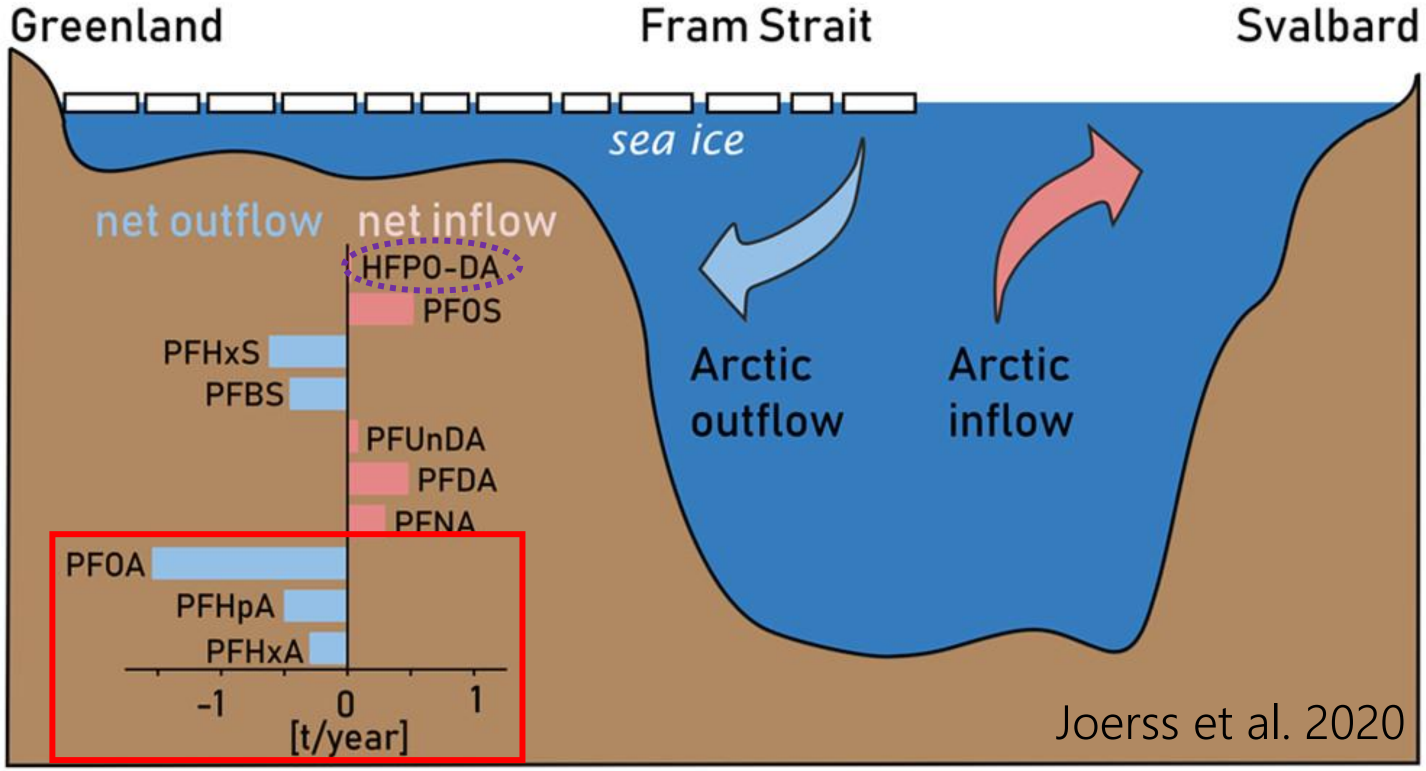


Ionics (e.g. PFOA, PFOS etc)

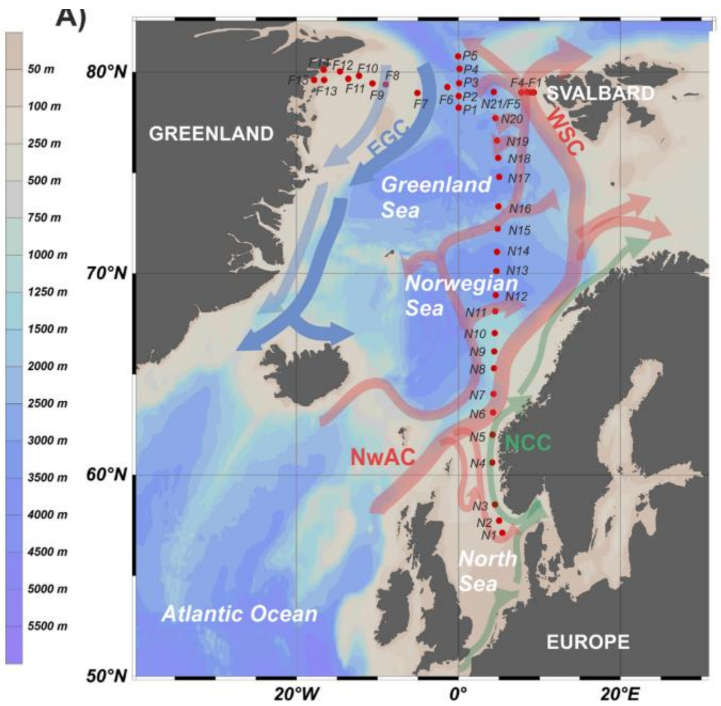


What do we know so far (in the Arctic)?

- Atmospheric deposition enables:
  - Ubiquitous detection of PFAS in Arctic ocean surface water, including emerging PFAS like GenX (HFPO-DA)
  - Export of some PFAS from the Arctic (!?)



Joerss et al. 2020



What should we measure?

Current active air sampling measures:

Ionic PFAS: i.e. C4 – C11 PFCAs

Neutral PFAS: i.e. FTOHs, FASAs, FASEs

PFAS are persistent, some also bioaccumulative and toxic

Some PFAS also relevant to climate forcing (high GWP) (Ozone depleting?)

What do we know so far (in the Arctic)?

	Neutral PFAS (e.g. FTOHs)	Ionic PFAS (e.g. PFOA)
Alert (Canada - ECCC)	2006 – ongoing (GFF + PUF/XAD-2)	2006 – ongoing (GFF + PUF/XAD-2)
Villum (Greenland - Aarhus)	2014 – ongoing (GFF + PUF/XAD-2)	2021 – ongoing (GFF only)
Zeppelin (Svalbard - NILU)	2017 – ongoing (PUF/XAD-2)	2006 – ongoing (GFF only)
Andøya (dicscon. - NILU)	2017 – 2021 (PUF/XAD-2)	2010 – 2021 (GFF only)

XAD-2/PUF Sandwich

Abbreviation	Name	Structure
-	**Perfluorosulfo**	
FBSA	Perfluorobutan	$CF_3(CF_2)_3SO_2NH_2$
FHxSA	Perfluorohexane Sulfonamide	$CF_3(CF_2)_5SO_2NH_2$
FOSA	Perfluorooctane Sulfonamide	$CF_3(CF_2)_7SO_2NH_2$
FASAs	N-alkyl perfluoroalkane sulfonamide	
MeFBSA	N-Methyl Perfluorobutane Sulfonamide	$CF_3(CF_2)_3SO_2NH_2$
MeFHxSA	N-Methyl Perfluorohexane Sulfonamide	$CF_3(CF_2)_5SO_2NH_2$
MeFOSA	N-Methyl Perfluorooctane Sulfonamide	$CF_3(CF_2)_7SO_2NH_2$
EtFOSA	N-Ethyl Perfluorooctane Sulfonamide	$CF_3(CF_2)_7SO_2NH_2$
FOSEs	**N-alkyl perfluoroalkane sulfonamido ethanols**	
MeFBSE	N-Methyl Perfluorobutane Sulfonamidoethanol	$CF_3(CF_2)_3SO_2N(CH_3)(CH_2CH_2OH)$
MeFOSE	N-Methyl Perfluorooctane Sulfonamidoethanol	$CF_3(CF_2)_7SO_2N(CH_3)(CH_2CH_2OH)$
EtFOSE	N-Ethyl Perfluorooctane Sulfonamidoethanol	$CF_3(CF_2)_7SO_2N(CH_3)(CH_2CH_2OH)$
FTOHs	**Fluorotelomer alcohols**	
4:2 FTOH	4:2 Fluorotelomer Alcohol	$CF_3(CF_2)_3(CH_2)_2OH$
6:2 FTOH	6:2 Fluorotelomer Alcohol	$CF_3(CF_2)_5(CH_2)_2OH$
8:2 FTOH	8:2 Fluorotelomer Alcohol	$CF_3(CF_2)_7(CH_2)_2OH$
10:2 FTOH	10:2 Fluorotelomer Alcohol	$CF_3(CF_2)_9(CH_2)_2OH$
12:2 FTOH	12:2 Fluorotelomer Alcohol	$CF_3(CF_2)_{11}(CH_2)_2OH$
FTAs	**Fluorotelomer acrylate**	
6:2 FTA	6:2 Fluorotelomer Acrylate	$CF_3(CF_2)_5(CH_2)_2OC(O)CHCH_2$
8:2 FTA	8:2 Fluorotelomer Acrylate	$CF_3(CF_2)_7(CH_2)_2OC(O)CHCH_2$
Other		
POSF	Perfluorooct	$_3(CF_2)_7SO_2F$

Online GC-MS (Medusa)

Abbreviation	Name	Generic Formula Example	Example
HFCs	Hydrofluorocarbons	$C_nF_{2n+1}(CHF)_xCH_yF_z$ $C_nF_{2n+1}(CHF)_x(CF_2)_yF$ $(x = 0 – 2, y = 0 – 3, z = 0 – 3)$	HFC-134a (CF_3CH_2F)
HCFCs	Hydrochlorofluorocarbons	$C_nF_{2n+1}CHFCl$ $C_nF_{2n+1}CH_xCl_y$ $(x = 1 – 2, y = 1 – 2)$	HCFC-123 (CF_3CCl_2H)
HFEs	Hydrofluoroethers	$C_nF_{2n+1}O(CH_2)_xH$ $(x = 1 – 2)$	HFE-236ea2 ($CF_3CFHOCF_2H$)
HFOs	Hydrofluoroolefins	$C_nF_{2n+1}CF{=}CH_xF_y$ $(x = 0 – 2, y = 0 – 2)$	HFO-1234yf ($CF_3CF{=}CH_2$)

GFF

Abbreviation	Name	Structure
PFCAs	**Perfluoroalkyl carboxylic a**	
TFA	Trifluoroacetic Acid	CF_3CO_2H
PFPrA	Perfluoropropanoic Acid	$CF_3CF_2CO_2H$
PFBA	Perfluorobutanoic Acid	$CF_3(CF_2)_2CO_2H$
PFPeA	Perfluoropentanoic Acid	$CF_3(CF_2)_3CO_2H$
PFHxA	Perfluorohexanoic Acid	$CF_3(CF_2)_4CO_2H$
PFHpA	Perfluoroheptanoic Acid	$CF_3(CF_2)_5CO_2H$
PFOA	Perfluorooctanoic Acid	$CF_3(CF_2)_6CO_2H$
PFNA	Perfluorononanoic Acid	$CF_3(CF_2)_7CO_2H$
PFDA	Perfluorodecanoic Acid	$CF_3(CF_2)_8CO_2H$
PFUnDA	Perfluoroundecanoic Acid	$CF_3(CF_2)_9CO_2H$
PFDoDA	Perfluorododecanoic Acid	$CF_3(CF_2)_{10}CO_2H$
PFTrDA	Perfluorotridecanoic Acid	$CF_3(CF_2)_{11}CO_2H$
PFTeDA	Perfluorotetradecanoic Acid	$CF_3(CF_2)_{12}CO_2H$
PFHxDA	Perfluorohexadecanoic Acid	$CF_3(CF_2)_{14}CO_2H$
PFOcDA	Perfluorooctadecanoic Acid	$CF_3(CF_2)_{18}CO_2H$
PFSAs	**Perfluoroalkyl sulfonic acids**	
TFMS	Trifluoromethane Sulfonic Acid	CF_3SO_3H
PFEtS	Perfluoroethane Sulfonic Acid	$CF_3CF_2SO_3H$
PFPrS	Perfluoropropane Sulfonic Acid	$CF_3(CF_2)_2SO_3H$
PFBS	Perfluorobutane Sulfonic Acid	$CF_3(CF_2)_3SO_3H$
PFPeS	Perfluoropentane Sulfonic Acid	$CF_3(CF_2)_4SO_3H$
PFHxS	Perfluorohexane Sulfonic Acid	$CF_3(CF_2)_5SO_3H$
PFHpS	Perfluoroheptane Sulfonic Acid	$CF_3(CF_2)_6SO_3H$
PFOS	Perfluorooctane Sulfonic Acid	$CF_3(CF_2)_7SO_3H$
PFNS	Perfluorononane Sulfonic Acid	$CF_3(CF_2)_8SO_3H$
PFDS	Perfluorodecane Sulfonic Acid	$CF_3(CF_2)_9SO_3H$
PFDoDS	Perfluorododecane Sulfonic Acid	$CF_3(CF_2)_{12}SO_3H$
PFECHS	Perfluoroethylcyclohexane Sulfonic Acid	$(CF_3CF_2)C_6F_{10}SO_3H$
PFECAs	**Perfluoroalkyl ether carboxylic acids**	
HFPO-DA (GenX)	Hexafluoropropylene Oxide Dimer Acid	$CF_3(CF_2)_2OCH(CF_3)CO_2H$
ADONA	3H-Perfluoro-3-[(3-Methoxy-Propoxy)Propanoic Acid]	$CF_3O(CF_2)_3OCHFCF_2CO_2H$
PFESAs	**Perfluoroalkyl ether sulfonic acids**	
6:2 Cl-PFESA	6:2 Chlorinated Polyfluorinated Ether Sulfonic Acid	$ClCF_2(CF_2)_5O(CF_2)_2SO_3H$
8:2 Cl-PFESA	8:2 Chlorinated Polyfluorinated Ether Sulfonic Acid	$ClCF_2(CF_2)_7O(CF_2)_2SO_3H$
FTSAs	**Fluorotelomer sulfonic acids**	
4:2 FTSA	4:2 Fluorotelomer Sulfonic Acid	$CF_3(CF_2)_3(CH_2)_2SO_3H$
6:2 FTSA	6:2 Fluorotelomer Sulfonic Acid	$CF_3(CF_2)_5(CH_2)_2SO_3H$
8:2 FTSA	8:2 Fluorotelomer Sulfonic Acid	$CF_3(CF_2)_7(CH_2)_2SO_3H$
FTUCAs	**Fluorotelomer Unsaturated Carboxylic Acid**	
6:2 FTUCA	6:2 Fluorotelomer Unsaturated Carboxylic Acid	$CF_3(CF_2)_4CFCHCO_2H$
8:2 FTUCA	8:2 Fluorotelomer Unsaturated Carboxylic Acid	$CF_3(CF_2)_6CFCHCO_2H$
FTCAs	**Fluorotelomer Carboxylic Acid**	
6:2 FTCA	6:2 Fluorotelomer Carboxylic Acid	$CF_3(CF_2)_5CH_2CO_2H$
8:2 FTCA	8:2 Fluorotelomer Carboxylic Acid	$CF_3(CF_2)_7CH_2CO_2H$

Measured at Zeppelin

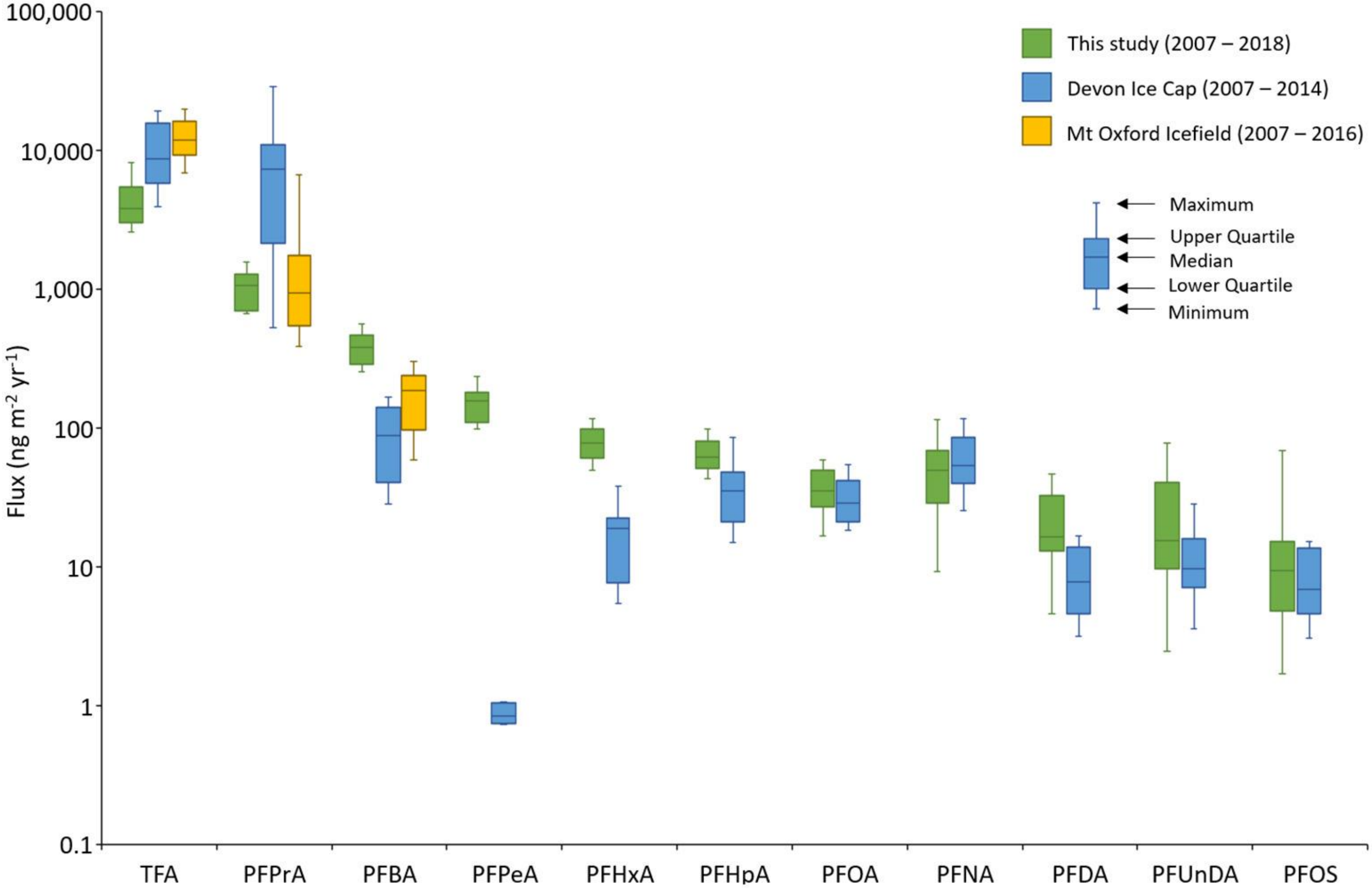
ZEPPELIN – Air 2022

Ionic and volatile PFAS (pg/m3)
Class of uncertainty:2

Compound	Matrix	No. of samples	MDL*	DF (%)	Concentration range	Annual mean	Annual median
FTS 4:2	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
FTS 6:2	Particle phase	12	0.940	8	<0.940-1.26	<0.940	<0.940
FTS 8:2	Particle phase	12	0.022	0	<0.022-<0.022	<0.022	<0.022
PFBA	Particle phase	12	0.250	0	<0.250-<0.250	<0.250	<0.250
PFPeA	Particle phase	12	0.044	50	<0.044-0.104	0.048	<0.044
PFHxA	Particle phase	12	0.088	42	<0.088-0.204	<0.088	<0.088
PFHpA	Particle phase	12	0.033	75	<0.033-0.298	0.116	0.099
PFOA	Particle phase	12	0.022	58	<0.011-0.297	0.124	0.130
PFNA	Particle phase	12	0.022	50	<0.022-0.165	0.0401	0.021
PFDA	Particle phase	12	0.022	33	<0.022-0.119	0.031	<0.022
PFUnA	Particle phase	12	0.033	0	<0.033-<0.033	<0.033	<0.033
PFDoA	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFTrA	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
PFTeA	Particle phase	12	0.022	0	<0.022-<0.022	<0.022	<0.022
PFBS	Particle phase	12	0.022	0	<0.022-<0.022	<0.022	<0.022
PFPS	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFHxS	Particle phase	12	0.022	0	<0.022-<0.022	<0.022	<0.022
PFHpS	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFOS	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFNS	Particle phase	12	0.066	0	<0.066-<0.066	<0.066	<0.066
PFDS	Particle phase	12	0.066	0	<0.066-<0.066	<0.066	<0.066
PFUnS	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
PFDoS	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
PFTrS	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
PFTS	Particle phase	12	0.100	0	<0.100-<0.100	<0.100	<0.100
PFOSA	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
sum ionic PFAS		12			1.145-2.036	1.54	1.46
4:2 FTOH	Gas phase	12	0.680	0	<0.68-<0.68	<0.68	<0.68
6:2 FTOH	Gas phase	12	1.96	100	5.30-42.1	14.0	9.53
8:2 FTOH	Gas phase	12	1.04	100	5.79-49.2	19.4	17.0
10:2 FTOH	Gas phase	12	0.780	100	1.12-17.6	6.20	5.38
12:2 FTOH	Gas phase	12	0.390	100	0.56-7.46	2.64	2.58
N-Me-FOSA	Gas phase	12	0.780	20	<0.78-0.86	<0.78	<0.78
N-Et-FOSA	Gas phase	12	0.440	30	<0.44-0.67	<0.44	<0.44
N-Me-FOSE	Gas phase	12	0.280	30	<0.28-0.85	0.29	<0.28
N-Et-FOSE	Gas phase	12	0.340	10	<0.34-0.52	<0.34	<0.34
Sum Vol PFAS		12			14.6-85.8	43.9	40.4

Halvorsen, H. L., Pfaffhuber, K. A., Nipen, M., Bohlin-Nizzetto, P., Berglen, T. F., Nikiforov, V., & Hartz, W. F. (2023). Monitoring of environmental contaminants in air and precipitation. Annual report 2022. *NILU rapport*.


North Pacific Ocean
Bering Sea
ALEUTIAN TRENCH
ALEUTIAN ISLANDS
KURIL TRENCH
JAPAN
Sea of Okhotsk
Petropavlovsk-Kamchatskiy
Kodiak
Bethel
Anchorage
Nome
Valdez
Juneau
Whitehorse
Fairbanks
UNITED STATES
Provideniya
Anadyr'
Magadan
Okhotsk
Khabarovsk
KOLYMSKOYE NAGOR'YE
ALDANSKOYE NAGOR'YE
Prince George
Dawson
ROCKY MOUNTAINS
BROOKS RANGE
MACKENZIE MOUNTAINS
Fort Nelson
Chukchi Sea
Wrangel Island
Peyek
Cherskiy
Oymyakon
Yakutsk
Verkhoyansk
VERKHOYANSKIY KHREBET
Barrow
Prudhoe Bay
Inuvik
Beaufort Sea
East Siberian Sea
sea ice extent summer average 2000-2006
Fort McMurray
Yellowknife
Great Slave Lake
Great Bear Lake
Tiksi
NEW SIBERIAN ISLANDS
Banks Island
Victoria Island
Cambridge Bay
Arctic Ocean
Laptev Sea
CANADA
QUEEN ELIZABETH ISLANDS
Churchill
Arviat
Gjoa Haven
Resolute
Rankin Inlet
SEVERNAYA ZEMLYA
RUSSIA
North Pole
Noril'sk
Hudson Bay
Repulse Bay
Ellesmere Island
Pond Inlet
Qaanaaq (Thule)
Kara Sea
Dikson
FRANZ JOSEF LAND
Baffin Island
Baffin Bay
Nord
Iqaluit
Svalbard (NORWAY)
Longyearbyen
NOVAYA ZEMLYA
Molloy Deep (deepest point of Arctic Ocean, -5607 m)
Greenland (DENMARK)
Kuujjuaq
Davis Strait
Ilulissat (Jakobshavn)
Sisimiut (Holsteinsborg)
Nuuk (Godthåb)
Barents Sea
Bjørnøya (NORWAY)
URAL MOUNTAINS
Yekaterinburg
Greenland Sea
Ittoqqortoormiit (Scoresbysund)
Jan Mayen (NORWAY)
Labrador Sea
Qaqortoq (Julianehåb)
Tasiilaq
Murmansk
Arkhangel'sk
Perm'
Denmark Strait
Norwegian Sea
Arctic Circle
Kazan'
Samara
ICELAND
Reykjavik
NORWAY
FINLAND
Nizhniy Novgorod
Faroe Islands (DENMARK)
SWEDEN
Helsinki
Saint Petersburg
Moscow
Saratov
North Atlantic Ocean
Tórshavn
Stockholm
Tallinn
EST.
SHETLAND ISLANDS
Oslo
LATVIA
Volgograd
Voronezh
Riga
LITH.
Vilnius
Minsk
Scale 1:39,000,000
Lambert Azimuthal Equal-Area Projection
Baltic Sea
BELARUS
Kharkiv
Rostov
North Sea
Copenhagen
DENMARK
Kaliningrad
Belfast
Warsaw
Kyiv
UKRAINE
Krasnodar
Dublin
IRE.
U.K.
Berlin
POLAND
Sochi
500 Kilometers
500 Miles
Amsterdam
London
GERMANY
Prague
Chisinau
Black Sea
Brussels
ROMANIA
TURKEY



NILU

Hartz, William F., et al. "Levels and distribution profiles of Per-and Polyfluoroalkyl Substances (PFAS) in a high Arctic Svalbard ice core." *Science of the Total Environment* 871 (2023): 161830.

ZEPPELIN – Air							
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Compound	**Matrix**	**No. of samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
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PFHpS	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFOS	Particle phase	12	0.044	0	<0.044-<0.044	<0.044	<0.044
PFNS	Particle phase	12	0.066	0	<0.066-<0.066	<0.066	<0.066
PFDS	Particle phase	12	0.066	0	<0.066-<0.066	<0.066	<0.066
PFUnS	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
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PFTrS	Particle phase	12	0.088	0	<0.088-<0.088	<0.088	<0.088
PFTS	Particle phase	12	0.100	0	<0.100-<0.100	<0.100	<0.100
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Sum Vol PFAS		12			14.6-85.8	43.9	40.4

Ultrashort-chain

FTUCAs

PFECHS, GenX, ADONA +

C4 PFAS

	UNIS, Longyearbyen	**Foxfonna**	**Reference sites**	**Svalbard Ice Core (Lomo)**
TFA	**100%**	**100%**	**100%**	**100%**
PFPrA	**100%**	**100%**	**100%**	**100%**
PFBA	**100%**	**90%**	**100%**	**100%**
PFPeA				**100%**
PFHxA				**100%**
PFHpA				**100%**
PFOA				**100%**
PFNA				**100%**
PFDA				**100%**
PFUnDA				**100%**
PFDoDA				**82%**
PFTrDA				**88%**
PFTDA				18%
PFHxDA				12%
PFOcDA				0%
TFMS	**100%**	**100%**	**100%**	n/a
PFEtS	**100%**	0%	0%	0%
PFPrS	0%	0%	0%	0%
PFBS	63%	10%	0%	24%
PFPeS				6%
PFHxS				65%
PFHpS				0%
PFOS				**82%**
PFNS				0%
PFDS				0%
PFDoDS				0%
4:2 FTSA				0%
6:2 FTSA				41%
8:2 FTSA				0%
6:2 FTUCA				35%
8:2 FTUCA				6%
PFECHS				0%
6:2 Cl-PFESA				0%
8:2 Cl-PFESA				0%
HFPO-DA (GenX)				0%
ADONA				0%
FBSA				**82%**
MeFBSA				29%
FHxSA				6%
MeFHxSA				0%
FOSA				59%
MeFOSA				0%
EtFOSA				6%
MeFOSE				24%
EtFOSE				35%

Blue data *in review.*

Hartz, William F., et al. "Levels and Seasonal Variations of Per- and Polyfluoroalkyl Substances (PFAS) in Surface Snow in the Arctic." *In review.* Submitted 2023

Other data references:

Björnsdotter, Maria K., et al. "Levels and seasonal trends of C1–C4 perfluoroalkyl acids and the discovery of trifluoromethane sulfonic acid in surface snow in the Arctic." *Environmental Science & Technology* 55.23 (2021): 15853-15861.

Hartz, William F., et al. "Levels and distribution profiles of Per-and Polyfluoroalkyl Substances (PFAS) in a high Arctic Svalbard ice core." *Science of the Total Environment* 871 (2023): 161830.

Zeppelin data from 2022:

Halvorsen, Helene Lunder, et al. "Monitoring of environmental contaminants in air and precipitation. Annual report 2022." *NILU rapport* (2023).

What should we measure?

Current active air sampling measures:

- Ionic PFAS: i.e. C4 – C11 PFCAs
- Neutral PFAS: FTOHs, FASAs, FASEs

Future?

- Ultrashort chain PFAAs (e.g. TFA, TFMS)
- Emerging PFAS (e.g. GenX, PFECHS)
- FTUCAs (FTOH degradation product)
- C4 replacement compounds (e.g. FBSA, MeFBSA, MeFBSE, MeFBSAA)
- Other compounds?

Volatile Fluorinated & Chlorinated Substances

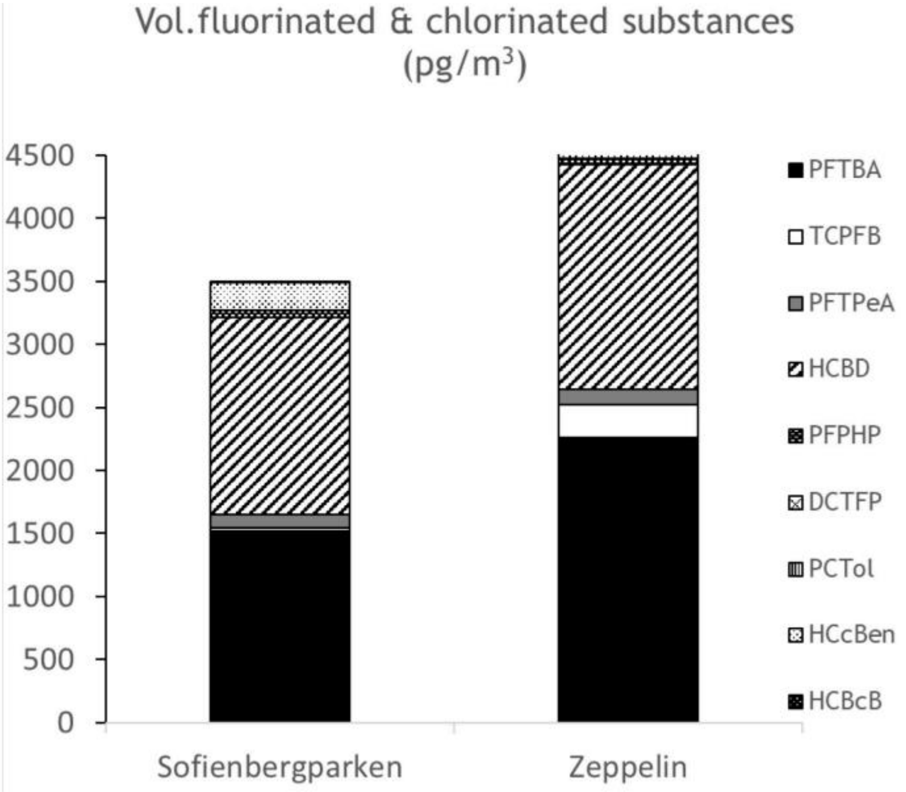


Figure 4: Annual median concentrations of the detected volatile fluorinated and chlorinated substances in air (pg/m^3) at Sofienbergparken and Zeppelin in 2022. The annual median concentration at Zeppelin is based on weekly samples, while Sofienbergparken is based on monthly samples.

Halvorsen, H. L., Pfaffhuber, K. A., Nipen, M., Bohlin-Nizzetto, P., Berglen, T. F., Nikiforov, V., & Hartz, W. F. (2023). Monitoring of environmental contaminants in air and precipitation. Annual report 2022. *NILU rapport*.

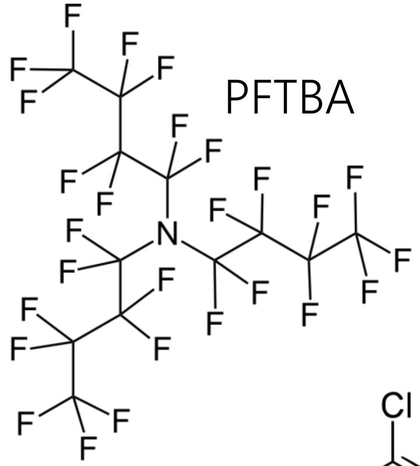
Volatile Fluorinated & Chlorinated Substances

Volatile fluorinated and chlorinated substances (pg/m3) Class of uncertainty:2							
PFTBA	Gas phase	24	50	77	59-2529	2085	2264
TCPFB	Gas phase	24	1	100	36-299	221	260.5
PFTPeA	Gas phase	24	10	70	44-183	118	116
HCBD	Gas phase	24	5	100	851-2100	1745	1789
PFPHP	Gas phase	24	5	70	13-53	39	40
DCTFP	Gas phase	24	0.2	98	0.6-7.3	5.0	4.6
PCTol	Gas phase	24	0.2	84	0.4-3.3	1.0	1.2
DCPFcH	Gas phase	24	1	0	n.d.-n.d.	n.d.	n.d.
PFBB	Gas phase	24	5	0	n.d.-n.d.	n.d.	n.d.
bTFMBB	Gas phase	24	1	0	n.d.-n.d.	n.d.	n.d.
DCBTC	Gas phase	24	0.5	0	n.d.-n.d.	n.d.	n.d.
HCcBen	Gas phase	24	1	100	80-247	196	208
HCBcB	Gas phase	10	1	100	1.5-6.8	4.0	4.1

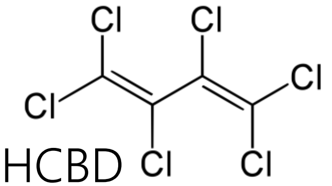
Halvorsen, H. L., Pfaffhuber, K. A., Nipen, M., Bohlin-Nizzetto, P., Berglen, T. F., Nikiforov, V., & Hartz, W. F. (2023). Monitoring of environmental contaminants in air and precipitation. Annual report 2022. *NILU rapport*.

Volatile Fluorinated & Chlorinated Substances

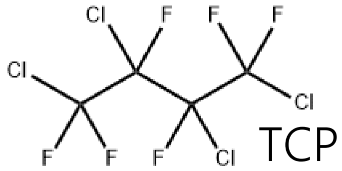
Volatile fluorinated and chlorinated substances		
Perfluorotributylamine	PFTBA	311-89-7
Tetrachlorohexafluorobutane	TCPFB	375-45-1
Perfluorotripentylamine	PFTPeA	338-84-1
Hexachlorobutadiene	HCBD	87-68-3
Perfluoroperhydrophenanthrene	PFPHP	306-91-2
Dichlorotrifluoropyridene	DCTFP	1737-93-5
~~**Dichlorobenzotrichloride, 2,3**~~ ~~**Dichlorobenzotrichloride, 3,4-**~~	~~DCBTC~~	~~13014-24-9~~ ~~84613-97-8~~
~~**Dichloroperfluorocyclohexene**~~	~~DCPFcH~~	~~336-19-6~~
~~**Pentafluorobromobenzene**~~	~~PFBB~~	~~344-04-7~~
~~**3,5-bis-(trifluoromethyl)-bromobenzene**~~	~~bisTFMBB~~	~~328-70-1~~
Pentachlorotoluene	PCTol	877-11-2
Hexachlorocyclobutene	HCcBen	6130-82-1
HexaChlorobicyclobutane	HCBcB	-



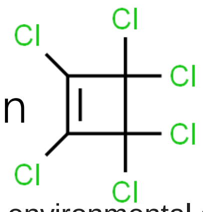
PFTBA



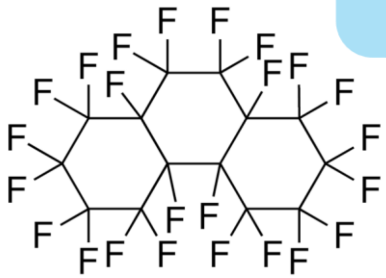
HCBD



TCPFB



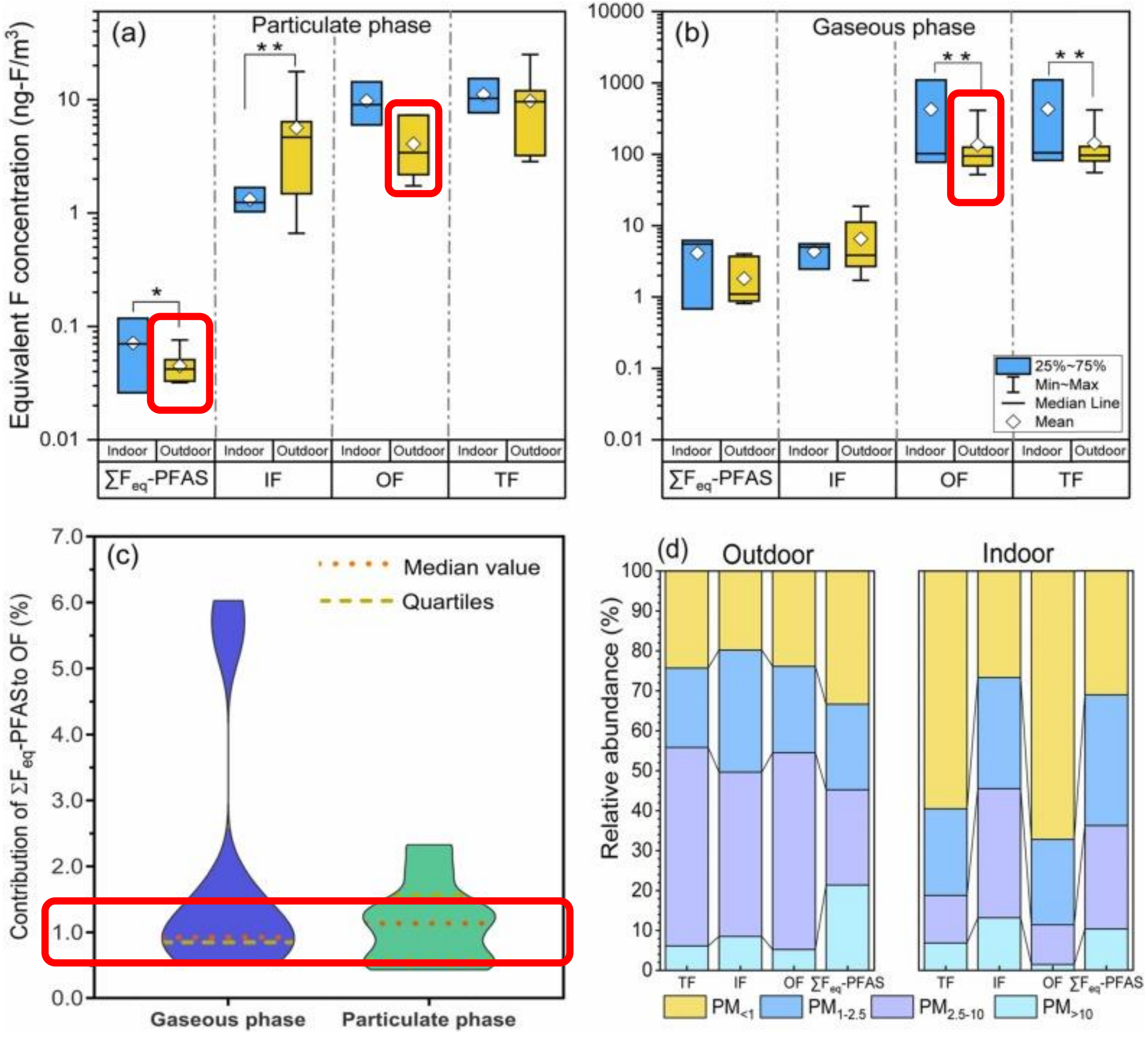
HCcBen



PFPHP

Halvorsen, H. L., Pfaffhuber, K. A., Nipen, M., Bohlin-Nizzetto, P., Berglen, T. F., Nikiforov, V., & Hartz, W. F. (2023). Monitoring of environmental contaminants in air and precipitation. Annual report 2022. *NILU rapport*.

Other measurement approaches?

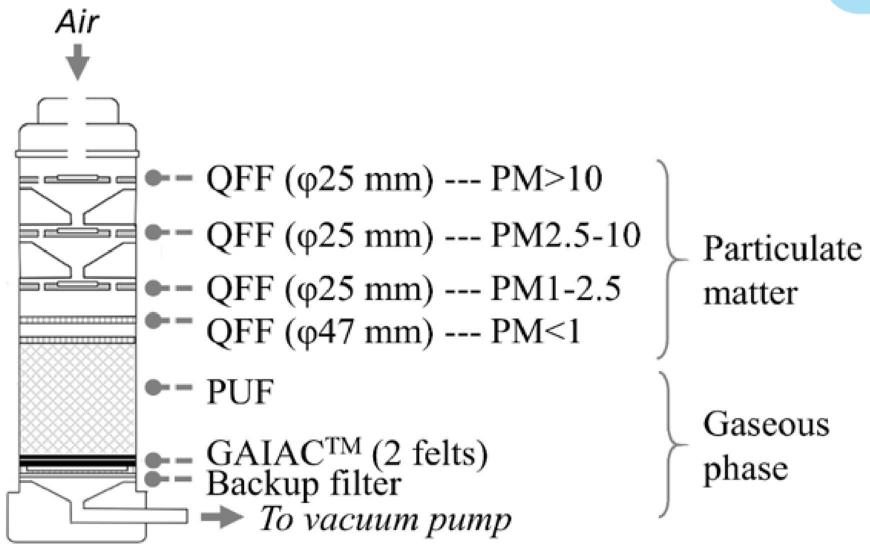


Indoor and outdoor (urban) air measurements in Japan

Approx. 1% could be identified

Role for CIC?

Li et al. 2022



Points for discussion

- Different measurement strategies at different locations vs Harmonisation of measurements
- Current sampling often distinguishes particles vs gas phase
  - Is this important knowledge, or even accurate? Requirement for harmonisation across sites?
- What is relevant to measure? How important are PFAS that don't fulfil all PBT or long-range transport requirements (but are climate forcing / ozone depleting)?
- New role for ABN/online sampling for neutral/ionic PFAS?
- Deposition vs direct air measurement?
- Any QA/QC issues to discuss? Requirement for analytical/sampling method inter-institution comparison?
- For those not measuring PFAS currently – should we expand geographical coverage e.g. with PAS?
- Role of PAS in a field dominated by active sampling - Deploy XAD-2 PAS with EMEP/MONET? EMEP intensive measurement campaign?
- Role of archived filters/XAD-2 sandwich for retrospective investigations?
- Role for Fluorine Mass Balance approach (with CIC) or Total Oxidisable Precursor Assay (TOPA)?
- Anything I have missed?

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PFAS – Outlook (Day 3)

EMEP CEC Workshop 8th – 10th Nov 2023

The climate and environmental research institute NILU
A part of the research alliance NORIN

Summary of monitoring stations

		Neutral PFAS		Ionic PFAS	
Station	Latitude	Time period	Sampling method	Time period	Sampling method
Alert (Canada - ECCC)	82.5 °N	2006 – ongoing	GFF + PUF/XAD-2	2006 – ongoing	GFF + PUF/XAD-2
Villum, Station Nord (Greenland - Aarhus)	81.6 °N	2014 – ongoing	GFF + PUF/XAD-2	2021 – ongoing	GFF
Zeppelin (Svalbard - NILU)	78.9 °N	2017 – ongoing	PUF/XAD-2	2006 – ongoing	GFF
Andøya (Norway - NILU)	69.3 °N	2017 – 2021	PUF/XAD-2	2010 – 2021	GFF
Pallas (Finland - IVL)	68.0 °N	-	-	2017 - ongoing	GFF
Sofienbergparken (Oslo - NILU)	59.9 °N	2022 – ongoing	PUF/XAD-2	2022 - ongoing	GFF
Birkenes (Norway – NILU)	58.4 °N	2017 – ongoing	PUF/XAD-2	2006 – ongoing	GFF
Råö (Sweden – IVL)	57.3 °N	-	-	2009 - ongoing	GFF
Kosetice (Czechia – Masaryk)	49.6 °N	ongoing	QFF + PUF/XAD-2	ongoing	QFF + PUF/XAD-2

Discussion for conclusions, recommendations and outlook - PFAS

- Different measurement strategies at different locations vs Harmonisation of measurements
    - Unable to use GFF and PUF/XAD-2 to distinguish particles-bound and gas phase neutral/ionic PFAS
    - Need for harmonisation, by measuring both GFF and XAD-2/PUF matrices for both individually for ionic and neutral PFAS
    - Also inconsistent sampling time periods, use of pooling, QFF vs GFF
    - High background from PUF for ionic PFAS with LC – use of mesh instead to hold XAD-2
    - How do we achieve this together?
- What new PFAS should we measure (next slide)?
- New role for ABN/online sampling for neutral/ionic PFAS
    - First results coming soon
- Requirement for PAS to expand geographical coverage in Europe (+ N. America and Africa?)
    - Are PAS methods ready for this? EMEP intensive measurement campaign?
    - Deposition vs direct air measurement?
- Role for Fluorine Mass Balance approach (with CIC) or Total Oxidisable Precursor Assay (TOPA)?
    - Potentially has a future role
- Policy makers – need to reduce and remove atmospheric emissions of FTOHs?

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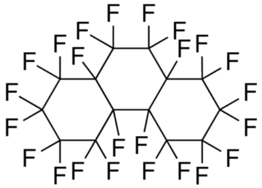
PFPHA



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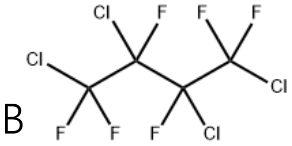
- PFTBA, PFPeTA, PFPHA, TCPFB, (HCBD)
- Other compounds?

TCPFB



Conclusion of Discission (written after the workshop)

- Arctic/established stations should aim to measure both neutral and ionic PFAS on filters and PUF/XAD-2 individually
  - Results should be summed and reported as a combined gas + particle phase concentration
- To increase special coverage, stations already measuring PAHs, can also measure PFAS just on a GFF filter
  - This is to get an indication of regional/local atmospheric levels, owing to lack of established method for passive air sampling for PFAS
- A Europe wide passive air sampling campaign to measure neutral PFAS (with XAD-2) is recommended (e.g. EMEP intensive measurement campaign and/or MONET network)
- All stations should continue to measure existing (neutral and/or ionic) analytes and try to measure as many additional analytes as possible
  - As a minimum, this should include GenX (HFPO-DA)

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