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NILU report 24/2025

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Monitoring of environmental contaminants in air and precipitation
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Overvåkning av langtransporterte atmosfæriske miljøgifter i luft og nedbør
Årsrapport 2024

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Short summary (English)
This report presents air monitoring data from 2024 for the Norwegian monitoring programme "Atmospheric contaminants". The results cover 16 groups comprising of 260 organic compounds (regulated and non-regulated) as well as 14 heavy metals, and a selection of organic chemicals of emerging concern.

Short summary (Norwegian)
Denne rapporten inkluderer miljøovervåkningsdata fra 2024 for overvåkningsprogrammet Atmosfæriske miljøgifter. Resultatene omfatter 260 organiske miljøgifter (regulerte og ennå ikke regulerte), 14 tungmetaller og et utvalg organiske forbindelser som er av mulig bekymring for miljøet.

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Contents

Summary

This report presents environmental monitoring data for a total of 260 organic compounds across 16 compound groups, as well as 14 heavy metals, in air and precipitation for 2024. The organic compounds include regulated persistent organic pollutants (POPs) and non-regulated organic chemicals of emerging concern (CECs). The heavy metals (HMs) include mercury (Hg) in both gas and particulate phase. The data is collected at background monitoring stations on mainland Norway and Svalbard in the Arctic, and at an urban monitoring station located in the city of Oslo. Data was collected using active sampling techniques for contaminants in air and bulk deposition samplers for contaminants in precipitation.

The monitoring is performed on behalf of the Norwegian Environment Agency and is part of the Government's environmental monitoring in Norway. This report covers findings from the monitoring programme "*Atmospheric contaminants".* As for previous years, the programme in 2024 covered POPs, HMs and CECs in air at Zeppelin (in the Arctic), Birkenes (southern Norway) and Sofienbergparken (city of Oslo) (Figure 1). Polycyclic aromatic hydrocarbons (PAHs) in air at Zeppelin were also covered, while PAHs in air at Birkenes were funded internally by NILU. Since 2022, HMs in air at Svanvik (eastern Finnmark in northern Norway) have also been included in the present monitoring programme. The programme also covered POPs and HMs in precipitation at Birkenes and HMs in precipitation at Hurdal, Kårvatn and Svanvik.

In 2024, the concentrations of the organic contaminants ranged over eight orders of magnitude, from below the method detection limits (<MDL) of 0.001 pg/m^3 to detected concentrations of several hundred thousand pg/m^3. The highest concentrations were found for the compounds unregulated or newly regulated, e.g. cyclic- and linear volatile methyl siloxanes (cVMS/lVMS), the climate relevant volatile fluorinated and/or chlorinated substances (vol. F+Cl substances), some polycyclic aromatic hydrocarbons (PAH) and short/medium chain chlorinated paraffins (SCCPs, MCCPs). On the other hand, the lowest concentrations were generally found for the regulated compounds. The concentrations of the organic contaminants measured in Sofienbergparken in the city of Oslo were generally higher than the concentrations measured at the two background stations Birkenes and Zeppelin.

For the HMs, the highest concentrations in air were detected at the urban station Sofienbergparken in Oslo, where the presence of local sources is likely. Still, the concentrations are below the air quality criteria for metals as set by the National Institute for Public Health (NIPH). The lowest concentrations of HMs in air were measured at Zeppelin in the Arctic, followed by Birkenes. The higher concentrations at Birkenes than Zeppelin is due to Birkenes being closer to the emission sources at the European continent. In precipitation, all the targeted HMs were detected at all stations. For As, Pb, Cd, Cu and Hg, the concentrations are highest at Birkenes and Hurdal followed by Kårvatn, reflecting the decreasing distances to the main emission sources in continental Europe (EMEP, 2021). Elevated concentrations and deposition levels were also observed at Svanvik, in particular for As, Ni, V, Cu and Co. The results are in line with those of 2023.

Sammendrag

Denne rapporten presenterer norske miljøovervåkningsdata for totalt 260 organiske forbindelser og 16 grupper, samt 14 tungmetaller, i luft og nedbør i 2024. De organiske forbindelsene inkluderer regulerte persistente organiske miljøgifter (POP-er) og ikke-regulerte organiske forbindelser som er av mulig bekymring (CEC-er). Tungmetallene inkluderer kvikksølv (Hg) i både gass- og partikkelfase. Dataene ble samlet inn fra bakgrunnsstasjoner på Fastlands-Norge og Svalbard i Arktis, og fra en urban overvåkningsstasjon i Oslo, Sofienbergparken. Dataene ble samlet inn ved bruk av aktiv luftprøvetaking samt bulk nedbørsprøvetaking.

Overvåkningen utføres på oppdrag fra Miljødirektoratet og er en del av regjeringens miljøovervåkning i Norge. Rapporten omfatter funn fra overvåkningsprogrammet «Atmosfæriske miljøgifter». I 2024 inkluderte programmet POP-er, tungmetaller og CEC-er i luft ved Zeppelin (Arktis), Birkenes (Sør-Norge) og Sofienbergparken (Oslo) (Figur 1). PAH i luft ved Zeppelin ble også dekket av Miljødirektoratets bevilgning, mens PAH i luft ved Birkenes var dekket av NILUs «interne overvåkningsprogram». Siden 2022 har tungmetaller ved Svanvik (Øst-Finnmark i Nord-Norge) vært inkludert i overvåkningsprogrammet, med finansiering fra Utenriksdepartementet. POP-er og tungmetaller i nedbør fra Birkenes, samt tungmetaller i nedbør fra Hurdal, Kårvatn og Svanvik, inngår også i programmet.

Luftkonsentrasjonene av de organiske forbindelsene i overvåkningsprogrammet i 2024 ble målt over et stort konsentrasjonsområde; fra under metodens deteksjonsgrense (< MDL) på 0,001 pg/m^3 til detekterte konsentrasjoner på hundretusenvis av pg/m^3. Som i de siste årene så ble de høyeste konsentrasjonene i luft funnet for de nylig regulerte eller ikke-regulerte forbindelsene, dvs. siloksaner (cVMS/lVMS), klimarelevante fluor- og klororganiske forbindelser (Vol. F+Cl forbindelser), noen polysykliske aromatiske hydrokarboner (PAH), og kort- og mellomkjedete klorparafiner (SCCP/MCCP) (se figur 2 nedenfor og Appendix A for detaljer). Lavest konsentrasjoner ble målt for de regulerte forbindelsene. Konsentrasjonene for de organiske forbindelsene var generelt høyere ved Sofienbergparken enn de to bakgrunnsstasjonene Zeppelin og Birkenes.

Tilsvarende de organiske forbindelsene, ble de høyeste konsentrasjonene for tungmetaller i luft observert ved den urbane bakgrunnsstasjonen i Sofienbergparken. Dette antas å skyldes lokale kilder, men konsentrasjonene var likevel innenfor luftkvalitetskriteriene som er fastsatt av Folkehelseinstituttet (FHI). De laveste konsentrasjonene i luft ble funnet ved Zeppelin i Arktis, etterfulgt av Birkenes. Høyere konsentrasjoner ved Birkenes enn ved Zeppelin skyldes at Birkenes er nærmere utslippskildene på det europeiske kontinentet. De observerte konsentrasjonene av As, Pb, Cd, Cu og Hg i nedbør var høyest ved Birkenes og Hurdal, etterfulgt av Kårvatn, igjen som følge av økende avstand til det europeiske kontinentet (EMEP, 2021). Høye konsentrasjoner i nedbør ble også observert på Svanvik, spesielt for As, Ni, V, Cu og Co. Konsentrasjonene målt i 2024 samsvarer med de fra 2023.

Abbreviations

ABN: Evolute ABN, an adsorbent (modified polystyrene divinylbenzene polymer) from Biotage

AMAP: Arctic Monitoring and Assessment Programme, https://www.amap.no

CAMP: Comprehensive Atmospheric Monitoring Programme under OSPAR

CECs: Organic contaminants of emerging concern, a list of compounds included in Table 4

cVMS: Cyclic volatile methyl siloxanes (D4, D5, and D6), organic contaminants

DDTs: Dichlorodiphenyltrichloroethane and its metabolites Dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD), organic contaminants

EMEP: The European Monitoring and Evaluation Programme, https://emep.int

FTOHs: Fluorotelomer alcohols

FTSAs: Fluorotelomer sulfonic acids

GFF: Glass fibre filter

GMP: The Global Monitoring Programme of the Stockholm Convention

HBCDD: Hexabromocyclododecane, organic contaminant

HCB: Hexachlorobenzene, organic contaminant

HCBD: Hexachlorobutadiene, organic contaminant

HCHs: Hexachlorocyclohexane (α, β, γ), organic contaminants

HM: Heavy Metals, i.e. a metal with a density greater than about 5.0 g/cm^3

LRTAP: (Convention on) Long-range Transboundary Air Pollution

lVMS: Linear volatile methyl siloxanes (L3, L4, and L5)

MDL: Method Detection Limit, determined from the concentrations of target analytes in the blank samples and the sample volume

nBFRs: novel brominated flame retardants

ng: nanogram, 1 / 1000 000 000 (10^{-9})

OSPAR: the Convention for the Protection of the marine Environment of the North-East Atlantic. OSPAR is so named because of the original Oslo and Paris Conventions ("OS" for Oslo and "PAR" for Paris), http://www.ospar.org.

OPFRs: Organophosphorous flame retardants

PAHs: Polycyclic aromatic hydrocarbons, organic contaminants

PBDEs: Polybrominated diphenyl ethers, organic contaminants

PCB: Polychlorinated biphenyls, organochlorine compounds with the formula $C_{12}H_{10-x}Cl_x$

PCP/PCA: Pentachlorophenol and pentachloroanisole, organic contaminants

PFAAs: Perfluoroalkyl acids

PFAS: Per- and polyfluoroalkyl substances, including both ionic (iPFAS) and volatile (vPFAS)

PFCAs: Perfluoroalkyl carboxylic acids

PFSAs: Perfluoroalkyl sulfonic acids

pg: picogram, 1 / 1000 000 000 000 (10^{-12})

POPs: Persistent Organic Pollutants

PUF: Polyurethane foam

S/MCCPs: Short-chain chlorinated paraffins (C10-C13) and medium-chain chlorinated paraffins (C14-C17), organic contaminants

TVOC: Total level of Volatile Organic Compounds

UNECE: United Nations Economic Commission for Europe. It is one of five regional commissions of the United Nations.

UV-substances: Organic ultraviolet absorber chemicals commonly used to protect against UV/sunlight, in sunscreens, paints and coatings, and as an additive in a wide variety of plastics.

µg: microgram, 1 / 1000 000 (10^{-6})

XAD: Amberlite XAD-2, an adsorbent (polystyrene divinylbenzene polymer) from Sigma-Aldrich

Monitoring of environmental contaminants in air and precipitation

1 Background

Persistent organic pollutants (POPs) and heavy metals (HMs) are toxic, bioaccumulative and persistent in the environment, and can undergo long-range environmental transport. Long-range transport via air is often the major source of pollution in remote areas, such as the Arctic. The presence of environmental contaminants in Arctic air has contributed to regulation of the use and emission of several POPs and heavy metals both on a regional and global scale. Norway implements obligations under the UNECE Convention on Long-range Transboundary Air Pollution (UNECE, 1998a, 1998b), the Stockholm- and Minamata Conventions (UNEP, 2001, 2013) and associated EU regulations.

The monitoring programme *"Atmospheric contaminants"* supports policy makers with information on the contaminants' concentrations in air at background sites across Norway, including the Arctic. The programme is performed on behalf of the Norwegian Environment Agency and is part of the Government's environmental monitoring in Norway. The overall purposes of the monitoring are to i) assess long-term temporal trends of atmospheric contaminants in Norway and evaluate the effectiveness of regulatory actions, ii) increase the understanding of occurrence and distribution of organic contaminants of emerging concern (CECs) for future regulations, iii) increase the understanding of the contaminants' potential for long-range transport, iv) assess spatial variabilities of atmospheric contaminants in Norway, including differences between background and urban air, and v) provide data for international conventions, programmes and networks, e.g. The Global Monitoring Programme (GMP) of the Stockholm Convention on POPs and the European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-range Transboundary Air Pollution (LRTAP).

The monitoring in 2024 included 16 different contaminant groups consisting of 260 organic compounds, as well as 14 heavy metals, measured in air and precipitation at background monitoring stations on mainland Norway and Svalbard in the Arctic, and at an urban monitoring station located in the city of Oslo. The organic compounds include POPs, PAHs and non-regulated CECs, and the heavy metals include mercury (Hg). Data was collected using active sampling techniques for contaminants in air and a bulk deposition sampler for contaminants in precipitation.

2 Overview of monitoring sites

The location of the monitoring sites included in this monitoring programme is illustrated in Figure 1, whereas more detailed information about each site can be found in Appendix C. The monitoring sites in this monitoring programme are also used within the national monitoring programme for "*long-range transboundary air pollutants"* (Aas et al., 2025).

To document the long-range transport of the environmental contaminants, the background monitoring stations/observatories have been placed, as far as possible, in areas that are not influenced by local sources. The locations have been selected to represent different parts of Norway, which receives air masses from different source regions globally. For example, the occurrence of organic anthropogenic contaminants in the Arctic region has been attributed to long-range transport from industrial, agricultural, and populated areas.

A list of contaminants measured at each station in 2024 is given in Table C.2. For the monitoring of POPs and heavy metals in background air, one observatory (i.e. Birkenes) located in southern Norway, and one

observatory (i.e. Zeppelin) located on Svalbard in the Arctic, are used (Figure 1, Table C.2). The programme also covers PAHs in air at Zeppelin, while PAHs in air at Birkenes are funded internally by NILU. In 2022, HMs in air at Svanvik (eastern Finnmark in Northern Norway) was included in the monitoring programme[1], with measurements funded by the Ministry of Foreign Affairs. In 2024, it should be noted that the Zeppelin Observatory needed renovation and the observatory was not operative for six weeks during October and November.

For the monitoring of heavy metals in precipitation, four regional background stations distributed across Norway are included; Birkenes, Hurdal, Kårvatn and Svanvik (Figure 1, Table C.2), while POPs in precipitation are only monitored at Birkenes.

In addition, CECs, selected POPs and heavy metals are monitored in urban air. This monitoring station is located in the city of Oslo (i.e. Sofienbergparken) and is expected to be more influenced by local sources, especially for the CECs that are still in use and present in materials and products. This enables us to compare the atmospheric concentrations of environmental contaminants in background areas with concentrations in an urban area.

Figure 1: Norwegian background stations measuring environmental contaminants in 2024.

[1] Previously this report also included results from "The Norway-Russia measurement programme", covering heavy metals in air and precipitation at Karpdalen in eastern Finnmark. The smelter in Nikel (Russia) ceased operation in December 2020. In January 2022, the monitoring station in Karpdalen was closed, and the monitoring of heavy metals at Svanvik was included in the present programme "Atmospheric contaminants". Also, the monitoring of inorganic components in precipitation was moved from Karpbukt to Svanvik in January 2022.

3 Overview of sampling and analysis

Air samples for organic contaminants and heavy metals (excluding mercury) are collected using active air samplers at Birkenes, Zeppelin, Svanvik and Sofienbergparken. The number of samples per year and the sampling times are compound and site specific (i.e. 12 to 52 samples per year, Table A.3.4). The sampling methodologies have been optimized to achieve maximum detection while minimizing the influence of possible sampling artefacts, such as breakthrough and degradation. Mercury in air is measured continuously using a Tekran Hg monitor. The precipitation samples are collected on a weekly basis using bulk precipitation samplers. Active air samples and precipitation samples for POPs and heavy metals are extracted, analysed and quantified at NILU under strict quality control using accredited methods (details in Appendix B). For the CECs, the sampling and analytical methodologies are associated with a larger degree of uncertainty than for the well-established methods (e.g. PCBs). Details about the sampling and analytical methodologies are given in Appendix B. POPs, selected CECs and heavy metal data presented in this report are available at http://ebas.nilu.no/.

Data and results are reported to various international programmes and all POP, PAH and HM data are openly available in EBAS. In 2025, also data of CECs will be available in EBAS. The 2024 data from EBAS used in this report are associated to Digital Object Identifiers (DOIs), which are presented in Table C.1 in Appendix C.

3.1 Organic contaminants

The monitoring programme for 2024 included eight regulated classes of organic contaminants and one individually regulated compound (Table 1). All of these, except PAHs, are classified as POPs according to the Stockholm Convention.

Organic contaminants that are not yet regulated but have been identified as contaminants of emerging concern (i.e CECs) in, for example, environmental screening programmes in Norway (Schlabach et al., 2017; Schlabach et al., 2018), are also included in the monitoring programme (Table 2). The purpose of the monitoring of these emerging contaminants is to obtain data in air that can be used to inform possible future regulations at national, EU- and/ or global level. Another aspect is that if monitoring is initiated before a regulation/measure enters into force it may also be possible to get a more complete picture of the time trends, and the effect of the regulations. Most of the target iPFAS are non-regulated and therefore fall under the category of CECs in this monitoring programme.

Two classes of CECs; cVMS and S/MCCPs, have been monitored in air as part of this programme since 2013 at Zeppelin, and since 2017 at Birkenes. In addition, volatile PFAS (vPFAS) have been measured at both stations since 2017. At Zeppelin, also novel brominated flame retardants (nBFRs) and OPFRs were included in the monitoring programme in 2017 (OPFRs not measured in 2023-2024), and dechloranes were included in 2019. This year (2024), climate relevant volatile fluorinated and/or chlorinated substances (vol. F+Cl sub.) have been measured at all stations.

At the monitoring station in Sofienbergparken, a number of CECs have been included in addition to the CECs included in the basic programme at Zeppelin (mentioned above); i.e. extra PFAS, extra siloxanes (e.g. lVMS), extra brominated- and chlorinated flame retardants, chlorophenols and UV compounds. A complete list of all organic contaminants of emerging concern included in the monitoring programme in 2024 is given in Table 3.

Details on the sampling strategies (sampling times, sampler type, adsorbents etc.) of all compounds are given in Appendix B. The custom-made NILU sampler for POPs, PAHs and BFRs used at the Zeppelin Observatory, are planned to be replaced by the conventional Digitel Hi-vol in 2025, and a comparative study was therefore conducted in 2024 (Appendix E). Most of the regulated organic contaminants are measured once per week at Birkenes and Zeppelin with some exceptions. Since 2017, the measurements of HCHs and DDTs at Birkenes have been done once per month. Air samples for the PFAS at both Birkenes and Zeppelin are collected two times per month (every second week). The two samples are combined in the lab to give an aggregated monthly concentration. Combining two samples in the lab improves the detection of compounds, which otherwise may have been below detection limit. While air samples for PBDEs are collected weekly at Zeppelin, air samples for PBDEs have been collected twice per month at Birkenes since 2017. For Birkenes, the two samples are combined in the lab and measured for both PBDEs and HBCDDs (i.e. monthly aggregated concentration). Also at Zeppelin, two samples are collected monthly, combined in the lab and measured for HBCDDs. On the other hand, at Sofienbergparken, air samples for PBDEs, HBCDDs, PFAS and OPFRs are collected once per month.

Data from the air measurements are presented as bulk concentrations (i.e. sum of gas- and particle phase) for most of the compounds (Table 1 and 2). Exceptions are the ionic PFAS which are covering the particle phase only, and the most volatile substances (cVMS, vol. F+Cl sub. and vPFAS) which are covering the gas phase only).

Due to many CECs being ubiquitous, it is important to continuously evaluate possible influences of local sources at the background monitoring stations. For example, elevated levels of some CECs have been found near Arctic settlements (Carlsson et al., 2018; Warner et al., 2010). Consequently, measures to remove specific materials and products are taken both at sampling stations and in the analytical laboratories when such are identified and can be replaced. In 2023, dust samples taken inside the Zeppelin station, uncovered high concentrations of some CECs which may lead to occasional local contribution. In 2024, further investigation was done on selected materials inside the station and a potential source was identified and removed (in June). Dust samples were also taken inside the Birkenes station in 2024, uncovering high concentrations of some CECs also at this site. Further measures (e.g. weekly dust cleaning) to reduce the potential for local contribution of the samples are under implementation at both Zeppelin and Birkenes.

Table 1: Monitoring programme for regulated organic contaminants (e.g. POPs) in 2024.

		Sofienbergparken		Birkenes		Zeppelin	
POP class/ compound	**Matrix**	**Start year**	**Sampling frequency**	**Start year**	**Sampling frequency**	**Start year**	**Sampling frequency**
HCB – air	Gas+particle phase			1993	weekly	1993	weekly
HCB - precipitation	Precipitation			1992	weekly	-	-
HCHs	Gas+particle phase			1991	monthly*	1993	weekly
HCHs - precipitation	Precipitation			1992	weekly	-	-
DDTs	Gas+particle phase			2010	monthly*	1994	weekly
Chlordanes	Gas+particle phase			2010-2016**	-	1993	weekly
PCBs	Gas+particle phase			2004	weekly	2001***	weekly
PCB_7 - precipitation	Precipitation			2006	weekly	-	-
PBDEs	Gas+particle phase	2022	monthly	2008	monthly*	2006	weekly
HBCDDs	Gas+particle phase	2022	monthly	2006	monthly*	2006	monthly*
PAHs	Gas+particle phase			2009	weekly	1994	weekly
iPFAS**	Particle phase	2022	monthly	2006	monthly*	2006	monthly*

*Sampling frequency since 2017

**Not included in the new monitoring programme from 2017.

***Data available before 2001 are classified as uncertain due to possible local contamination.

**** Only PFHxS, PFOS and PFOA are internationally regulated

Table 2: Organic contaminants of emerging concern included in this monitoring programme in 2024, year of first monitoring, sampling frequency and sample matrix at the different observatories.

		Zeppelin		Birkenes		Sofienbergparken	
Organic contaminants of emerging concern	**Matrix**	**Start year**	**Sampling frequency**	**Start year**	**Sampling frequency**	**Start year**	**Sampling frequency**
S/MCCPs	Gas+particle phase	2013	weekly	2017	monthly	2022	monthly
cVMS	Gas phase	2013	weekly*	2017	monthly	2022	monthly
lVMS	Gas phase	2021	campaign			2022	monthly
vPFAS	Gas phase	2017	monthly**	2017	monthly**	2022	monthly
Other iPFAS	Particle phase	2021	monthly**			2022	monthly
nBFRs	Gas+particle phase	2017	monthly**			2022	monthly
Other brominated FR	Gas+particle phase					2022	monthly
OPFRs	Gas+particle phase	2017***	monthly**			2022	monthly
Dechloranes	Gas+particle phase	2019	monthly			2022	monthly
Volatile fluorinated and/or chlorinated substances	Gas phase	2020, 2024	monthly (campaign in 2020)	2024	monthly	2022, 2024	monthly
Chlorophenols and UV substances	Gas+particle phase					2022	monthly

*New sampling frequency from 2017.
**Two samples per month

****Not included in 2023-2024*

Table 3:Full names and abbreviations of the organic contaminants of emerging concern included in the monitoring programme in 2024.

Full name	Abbreviation	CAS
Chlorinated paraffins		
Short-chain chlorinated paraffins (C10-C13)	SCCPs	85535-84-8
Medium-chain chlorinated paraffins (C14-C17)	MCCPs	85535-85-9
Siloxanes		
Octamethylcyclotetrasiloxane	D4	556-67-2
Decamethylcyclopentasiloxane	D5	541-02-6
Dodecamethylcyclohexasiloxane	D6	540-97-6
Octamethyltrisiloxane	L3	107-51-7
Decamethyltetrasiloxane	L4	141-62-8
Dodecamethylpentasiloxane	L5	141-63-9
Tris(trimethylsiloxy)phenylsilane	M3T(Ph)	2116-84-9
2,4,6,8-tetramethyl-2,4,6,8-tetrakis (3,3,3-trifluoropropyl)-cyclotetrasiloxane	F4-Sil	429-67-4
2,4,6-trimethyl-2,4,6-tris(3,3,3-trifluoropropyl)cyclotrisiloxane	F3-Sil	2374-14-3
Heptamethylphenylcyclotetrasiloxane	Ph-D4	10448-09-6
Other Ionic PFAS		
Trifluoroacetic acid	TFA	76-05-1
Pentafluoropropanoic acid	PFPrA	422-64-0
Trifluoromethane sulfonic acid	TFMS	1493-13-6
Perfluoroethane sulfonic acid	PFEtS	354-88-1
Perfluoropropane sulfonic acid	PFPrS	423-41-6
Perfluorooctanoic acid, branched isomers	br-PFOA	
Perfluorooctanesulfonic acid, branched isomers	br-PFOS	
10:2 Fluorotelomer sulfonic acid	10:2 FTSA	120226-60-0
12:2 Fluorotelomer sulfonic acid	12:2 FTSA	149246-64-0
Perfluorohexadecanoic acid	PFHxDA	67905-19-5
Perfluorooctadecanoic acid	PFOcDA	16517-11-6
7H-perfluoroheptanoic acid**	1H-PFHpA	1546-95-8
Perfluoro-3,7-dimethyloctanoic acid	PF-3,7-DMOA	172155-07-6
7:3 Fluorotelomer acrylate	7:3 FTCA	812-70-4
Hexafluoropropylene oxide dimer acid	HFPO-DA (GenX)	13252-13-6
Perfluorooctanesulfonamidoacetic acid	FOSAA	2806-24-8
N-Methylperfluorooctane sulfonamido-acetic acid	MeFOSAA	2355-31-9
N-ethyl-N-[(heptadecafluorooctyl)-sulfonyl]glycine	EtFOSAA	2991-50-6
9-chlorohexadeca-fluoro-3-oxanonane-1-sulfonate	6:2 F53B	73606-19-6

Full name	Abbreviation	CAS
1,1,2,2-tetrafluoro-2-(perfluorohexyloxy)ethane sulfonate**	F53	754925-54-7
8-chloroperfluoro-1-octane-sulfonate	8Cl-PFOS	777011-38-8
Volatile PFAS		
4:2 fluorotelomer alcohol	4:2 FTOH	2043-47-2
6:2 fluorotelomer alcohol	6:2 FTOH	647-42-7
8:2 fluorotelomer alcohol	8:2 FTOH	678-39-7
10:2 fluorotelomer alcohol	10:2 FTOH	865-86-1
12:2 fluorotelomer alcohol	12:2 FTOH	39239-77-5
N-ethyl perfluorooctanesulfonamide	N-EtFOSA	4151-50-2
N-ethyl perfluorooctanesulfonamido-ethanol	N-EtFOSE	1691-99-2
N-methylperfluorooctansulfonamide	N-MeFOSA	31506-32-8
N-Methylperfluorooctanesulfonamido-ethanol	N-MeFOSE	24448-09-7
Other Volatile PFAS		
N-Methylperfluorooctanesulfonamidoethyl acrylate	N-MeFOSEA	25268-77-3
Perfluorobutane sulfonamide	FBSA	30334-69-1
N-Methyl perfluorobutane-sulfonamide	N-MeFBSA	68298-12-4
N-Ethylperfluorobutane-sulfonamide	N-EtFBSA	40630-67-9
Novel brominated flame retardants – nBFRs		
Allyl 2,4,6-tribromophenyl ether	ATE (TBP-AE)*	3278-89-5
α-Tetrabromoethylcyclohexane	α-TBECH (DBE-DBCH)	1232836-48-4, 3322-93-8
β-Tetrabromoethylcyclohexane	β-TBECH (DBE-DBCH)	1232836-49-5, 3322-93-8
γ/δ-Tetrabromoethylcyclohexane	γ/δ-TBECH (DBE-DBCH)	
2-Bromoallyl-2,4,6-tribromophenyl ether	BATE (TBP-BAE)*	99717-56-3
Pentabromotoluene	PBT	87-83-2
Pentabromoethylbenzene	PBEB	85-22-3
1,2,3,4,5-pentabromobenzene	PBBZ	608-90-2
Tetrabromo-p-xylene	pTBX	23488-38-2
Hexabromobenzene	HBB	87-82-1
2,3-dibromopropyl-2,4,6-tribromophenyl ether	DPTE (TBP-DBPE)	35109-60-5
2-ethylhexyl-2,3,4,5-tetrabromobenzoate	EHTBB	183658-27-7
1,2-bis(2,4,6-tribromophenoxy)ethane	BTBPE	37853-59-1
Bis(2-ethylhexyl)tetrabromophthalate	TBPH (BEH-TBP)	26040-51-7
Decabromodiphenylethane	DBDPE	84852-53-9
Tetrabromobisphenol A	TBBPA	79-94-7
Other nBFRs		
2,2-dimethylpropan-1-ol, tribromo derivative		36483-57-5
2,3,4,5-Tetrabromo-6-chlorotoluene	TBCT	39569-21-6
2,3,5,6-Tetrabromo-*p*-xylene	TBX	23488-38-2
Organophosphorous flame retardants – OPFRs		

Full name	Abbreviation	CAS
Triethylphosphate	TEP	78-40-0
Tris(2-chloroethyl)phosphate	TCEP	115-96-8
Tris(2-chloroisopropyl)phosphate	TCPP (TClPP)	13674-84-5
Tripropylphosphate	TPrP (TPP)	513-08-6
Tris(1,3-dichloro-2-propyl)phosphate	TDClPP (TDCPP)	13674-87-8
Triphenylphosphate	TPhP (TPP)	115-86-6
Triisobutylphosphate	TiBP (TBP)	126-71-6
Tributylphosphate	TnBP	126-73-8
Tris(2-butoxyethyl)phosphate	TBOEP (TBEP)	78-51-3
Dibutylphenylphosphate	DBPhP	2528-36-1
Tricresylphosphate	TCP (TMPP)	1330-78-5
Butyldiphenylphosphate	BdPhP	2752-95-6
2-ethylhexyldiphenylphosphate	EHDP (EHDPP)	1241-94-7
Trixylylphosphate	TXP	25155-23-1
Tris(4-isopropylphenyl)phosphate	TIPPP	68937-41-7
Tris(4-tert-butylphenyl)phosphate	TTBPP	78-33-1
Tris(2-ethylhexyl)phosphate	TEHP	78-42-2
Tris(2,3-dibromopropyl)phosphate	TDBPP	126-72-7
Tris(2-bromo-4-methylphenyl)phosphate**	T2B4MP4	871320-61-5
Tris(4-bromo-3-methylphenyl)phosphate**	T4B3MP4	127580-00-1
Tris(3-bromo-4-methylphenyl)phosphate**	T3B4MP4	35656-01-0
2,2-bis(chloromethyl_propane-1,3-diyl tetrakis(2-chloroethyl)bis(phosphate)	V6	38051-10-4
Dechloranes and other chlorinated FRs		
Dechlorane plus, *syn-*	syn-DP	135821-03-3
Dechlorane plus, *anti-*	anti-DP	135821-74-8
Dechlorane 601	Dec-601	13560-90-2
Dechlorane 602	Dec-602	31107-44-5
Dechlorane 603	Dec-603	13560-92-4
Dechlorane 604	Dec-604	34571-16-9
Dibromoaldrin	Dba	20389-65-5
Chlordene plus		1356-91-3
Chlorendic anhydride*		115-27-5
Dechlorane plus Cl10		
Dechlorane plus axx Cl10		
Dechlorane plus ax Cl11		
Dechlorane plus Cl11		
Volatile fluorinated and/or chlorinated substances		
Perfluorotributylamine	PFTBA	311-89-7
Tetrachlorohexafluorobutane	TCPFB	375-45-1
Perfluorotripentylamine	PFTPeA	338-84-1
Hexachlorobutadiene	HCBD	87-68-3

Full name	Abbreviation	CAS
Perfluoroperhydrophenanthrene	PFPHP	306-91-2
Dichlorotrifluoropyridene	DCTFP	1737-93-5
Pentachlorotoluene	PCTol	877-11-2
Dichloroperfluorocyclohexene	DCPFcH	336-19-6
Pentafluorobromobenzene	PFBB	344-04-7
3,5-bis-(trifluoromethyl)-bromobenzene	bTFMBB	328-70-1
2,3- dichlorobenzotrichloride	2,3-DCBTC	84613-97-8
3,4- dichlorobenzotrichloride	3,4-DCBTC	13014-24-9
Perfluorobutylcyclohexane	PFBCH	374-60-7
Hexachlorocyclobutene	HCcBen	6130-82-1
Hexachlorobicyclobutane	HCBcB	-
Chlorophenols		
Pentachlorophenol	PCP	87-86-5
Pentachloroanisole	PCA	1825-21-4
UV – substances		
2-Ethylhexyl-3-methoxycinnamate	OctylMethoxyCinnamate	5466-77-3
Octocrylene	Parsol 340	6197-30-4
Oxybenzone		131-57-7
N-Cyclohexyl-2-benzothiazolesulfenamide	Accelerator CZ	95-33-0
Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylethyl)-	UV-320 (tBu2)	3846-71-7
Bumetrizole	UV-326 (Me,tBu,Cl)	3896-11-5
Phenol, 2-(5-chloro-2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylethyl)-	UV-327 (tBu2,Cl)	3864-99-1
2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol	UV-328 (tAm2)	25973-55-1
2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol	Octrizole / UV-329 (tOct)	3147-75-9
methyl-1H-benzotriazole	Tolyltriazole	29385-43-1

*Possible degradation during analytical clean-up steps. Results uncertain.

**No standards available, not analysed (n.a.)

***Method under development/no recovery of internal standard (n.d.)

3.2 Heavy metals and mercury

Heavy metals in precipitation have been monitored at Norwegian observatories as part of government funded monitoring programmes since 1980 (Table 4).

Mercury in air has been monitored since 1990 to support the evaluation of the effectiveness of the Minamata Convention (entered into force in 2017). Norwegian monitoring follows the Guidance on monitoring of mercury and mercury compounds (UNEP, 2021) in order to maintain harmonized and comparable information on mercury levels in the environment. From 2021, measurements of Hg in precipitation were included at Hurdal and Kårvatn, in addition to Birkenes, and sampling frequency was increased from monthly to weekly sampling. Hg speciation measurements in air were also included in the programme at Zeppelin in 2021. This enabled reporting Hg in both the gas and particulate phase, i.e. as gaseous elemental mercury (GEM), particulate bound mercury (PBM) and gaseous oxidized mercury (GOM). The data series

however dates back to 2007, when the Norwegian University of Science and Technology (NTNU) started to monitor Hg species at Zeppelin. Data obtained by NTNU are published in Platt et al. (2022) and references therein, and data are available at http://ebas.nilu.no/. Hg speciation measurements, in concert with trajectory modelling and chemical profiling, will help us to better understand the contribution from different source categories in different source regions. This is a relevant contribution to Article 22 of the Minamata Convention (the Effectiveness Evaluation), that requires an estimation of the influence of different regulatory measures to the observed mercury concentrations.

Table 4: Monitoring programme for heavy metals in 2024.

	Matrix	Birkenes	Zeppelin	Hurdal	Kårvatn	Svanvik	Sofienberg-parken
Heavy metals – air	Particle phase	weekly	weekly	-	-	weekly	monthly
Heavy metals – precipitation	Precipi-tation	weekly	-	weekly	weekly	weekly	-
Hg – air	Gas phase	continuously	continuously	-	-	-	continuously
Hg species – air	Gas and particles	-	semi-continuously				-
Hg - precipitation	Precipi-tation	weekly	-	weekly	weekly	-	-

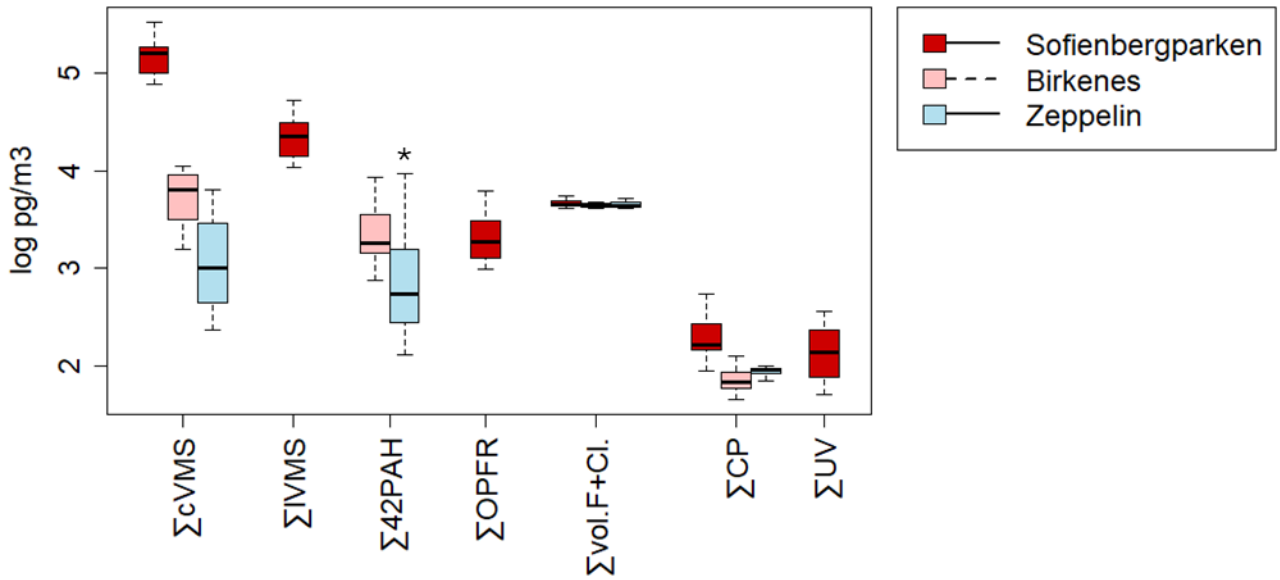
4 Key findings

4.1 Measured concentrations and spatial variability

4.1.1 Organic contaminants

Similar to previous years, the concentrations of the organic contaminants ranged over eight orders of magnitude, from below the method detection limits (<MDL) of 0.001 pg/m^3 to detected concentrations of several hundred thousand pg/m^3. The highest concentrations were found for the unregulated or newly regulated compounds, e.g. cyclic- and linear volatile methyl siloxanes (cVMS/lVMS), organophosphorus flame retardants (OPFRs), UV substances and short/medium chain chlorinated paraffins (SCCPs, MCCPs) (see Figure 2 below and Appendix A for details). These compound groups have been discussed in more detail below. Some polycyclic aromatic hydrocarbons (PAHs) and the climate relevant volatile fluorinated and chlorinated substances (vol. F+Cl substances) were also found at high concentrations. On the other hand, the lowest concentrations and lowest detection frequencies were generally found for the regulated compounds, including hexabromocyclododecane (HBCDD), the polybrominated diphenyl ethers (PBDEs), chlordanes (CHL), DDTs, hexachlorcyclohexanes (HCHs) and polychlorinated biphenyls (PCBs).

a)



b)

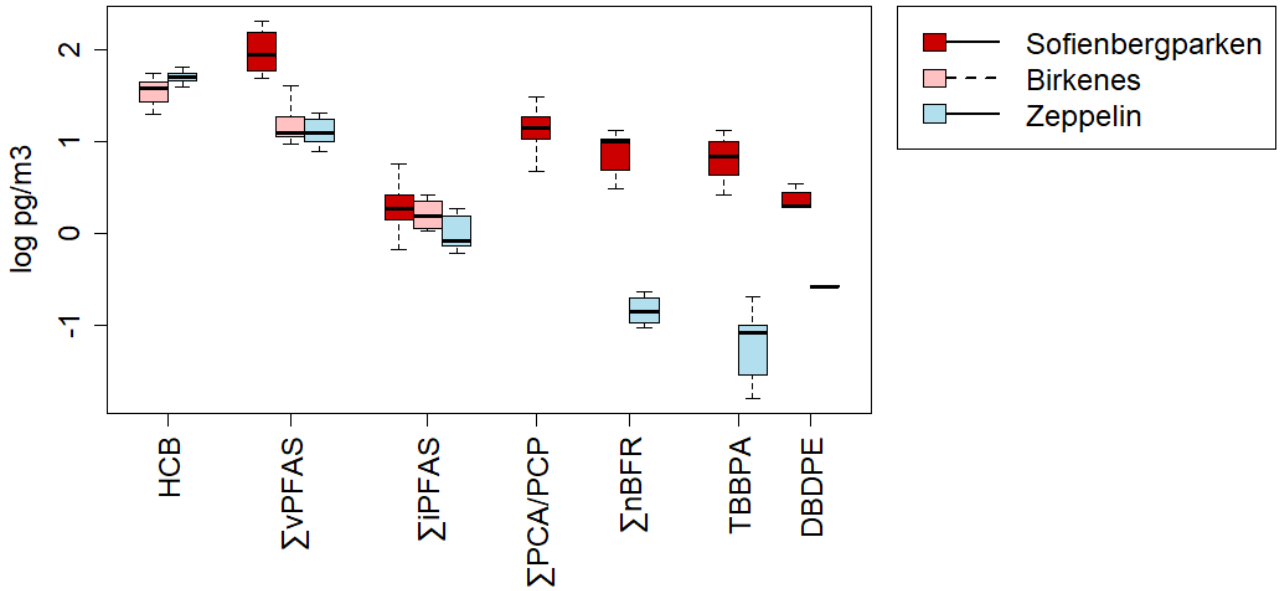


*Figure 2a-b: Boxplot of the logarithmic measured concentrations (pg/m³) of the organic compound groups in air at the respective monitoring stations in 2024. The highest concentrations are presented in the upper figure (a) and the medium concentrations in the lower figure (b). The boxes represent the range from 25 to 75 percentile with the center line representing the median value. The whiskers represent the 1 and 99 percentiles. Concentrations below MDL are set to MDL/2. *Due to low detection frequency for many PAHs at Zeppelin, the sum 42 PAH is highly affected by MDLs*

c)

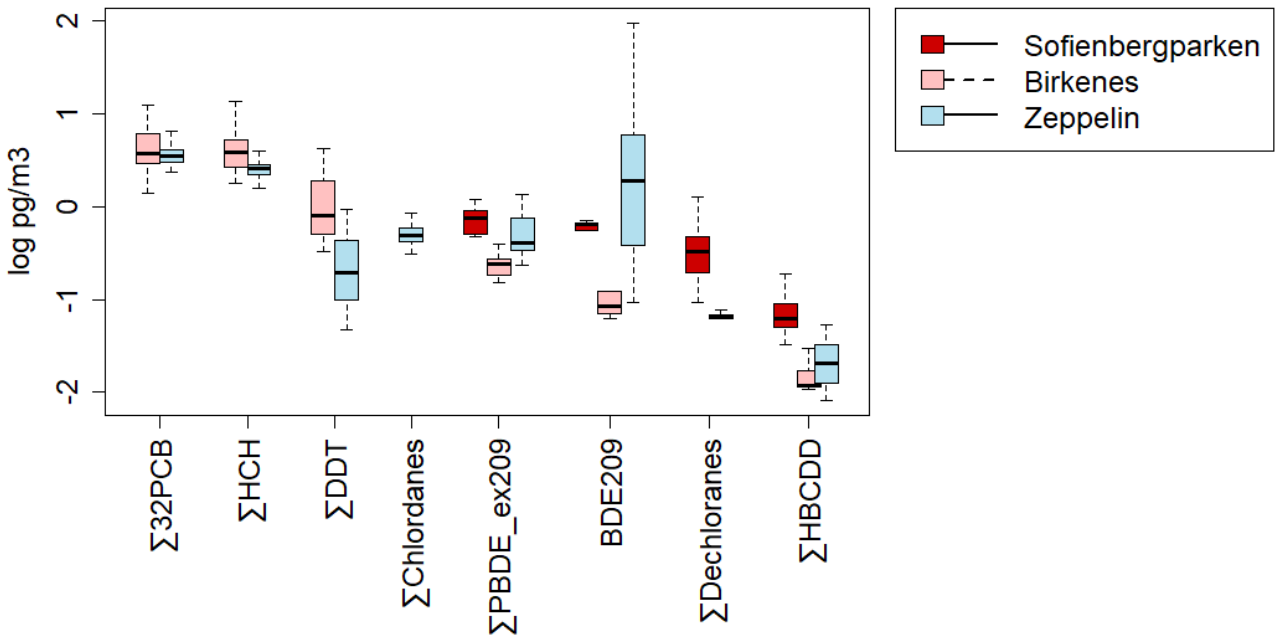


Figure 2c: *Boxplot of the lowest measured concentrations of the organic compound groups in air at the respective monitoring stations in 2024. The boxes represent the range from 25 to 75 percentile with the center line representing the median value. The whiskers represent the 1 and 99 percentiles. Concentrations below MDL are set to MDL/2.*

The concentrations of the organic contaminants measured in Sofienbergparken in Oslo were generally higher than the concentrations measured at the two background stations. The largest differences in concentrations between Sofienbergparken and Zeppelin, in the Arctic, were found for cVMS, nBFRs (incl. TBBPA and DBDPE), dechloranes and CPs (Figure 2). This may suggest that there are existing sources of these contaminants in urban environments. For other compounds with potential urban sources, like OPFRs, UV-compounds and chlorophenols, measurements were only done at Sofienbergparken and a comparison to remote sites are not possible. Furthermore, the concentrations of cVMS and the regulated compounds (not measured at Sofienbergparken); PAHs and DDTs, were significantly higher at the background station at Birkenes, located in southern Norway, than at Zeppelin. The higher concentrations likely reflect that Birkenes may be more influenced by long-range transport from source regions in central and eastern Europe, than Zeppelin (Lunder Halvorsen et al., 2021). In contrast to the other regulated organic contaminants, the median concentration of HCB on the other hand, was 32% higher at Zeppelin than at Birkenes, similar to previous years.

Siloxanes

High concentrations of sum cVMS (sum D4, D5 and D6) were found in Sofienbergparken, with a median of 160 000 pg/m^3. Concentrations were lower at Birkenes, with a median sum cVMS of 6 400 pg/m^3, and lower again at Zeppelin where median sum cVMS was 1 000 pg/m^3. This spatial pattern reflects that Sofienbergparken is located in an urban area, i.e. within a source region for cVMS, and that Birkenes and Zeppelin are located with increasing distance away from source regions.

At both Sofienbergparken and Birkenes, the highest concentrations of cVMS were measured for D5, followed by D4 and D6. At Zeppelin, the concentrations of D4 and D5 were comparable. In 2022 and 2023, the detection frequencies of D4, D5 and D6 at Zeppelin were low compared to previous years, due to comparatively high MDLs. In 2024, MDLs were back at a lower level, giving much higher detection frequencies compared to 2022 and 2023. D4 and D5 were detected in all samples at Zeppelin, while D6 was detected in 98% of samples. The higher detection frequency does not imply an increase in air concentrations at Zeppelin. D4 and D5 concentrations at Zeppelin in 2024 were comparable to, or slightly lower compared to 2023.

At Sofienbergparken, three linear VMS (lVMS: L3, L4 and L5), M3T(Ph), F3 and F4 were analysed in addition to the cVMS. As in 2022 and 2023, the three lVMS were found at high concentrations (median 8 400 pg/m^3, 7 100 pg/m^3, and 6 200 pg/m^3 for L3, L4 and L5 in 2024 respectively). M3T(Ph) was also detected in all samples, but at much lower concentrations (median 620 pg/m^3). F3 and F4 were not detected in any sample. These siloxanes were not measured at the other stations (Zeppelin and Birkenes).

Siloxane analysis is associated with potential analytical challenges such as the potential for sample contamination in the field and laboratory (Gerhards et al., 2022). All siloxane results are therefore classified under uncertainty category 3 (Appendix B4).

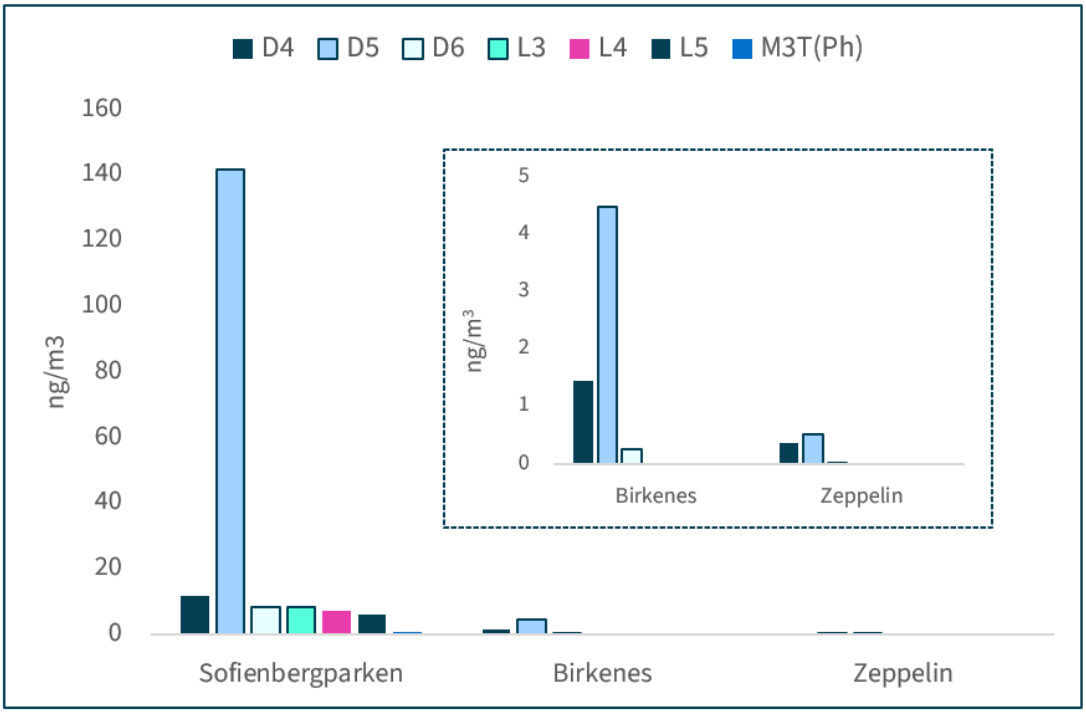


Figure 3: Annual median concentrations of targeted siloxanes in air (ng/m^3) at Sofienbergparken, Birkenes and Zeppelin in 2024. Concentrations < MDL are set to MDL/2. The inset graph shows the median concentrations at Birkenes and Zeppelin. The median concentrations for the cyclic oligomers D4-D6 are based on weekly samples at Zeppelin and monthly samples at Birkenes and Sofienbergparken. Linear oligomers L3-L5 and M3T(Ph) were only measured at Sofienbergparken.

Chlorinated paraffins

The highest median concentrations of sum CPs were found at Sofienbergparken (Figure 4), followed by Zeppelin and Birkenes with approximately two-times lower concentrations respectively. As in 2023, MCCPs concentrations exceeded SCCP concentrations at Sofienbergparken in 2024. At Birkenes, MCCPs concentrations were comparable to SCCPs concentrations. The relative concentrations of SCCPs and MCCPs at Zeppelin should be interpreted with caution, as the MCCPs are highly affected by low detection frequency and relatively high MDL.

At Sofienbergparken both SCCPs and MCCPs were detected in all samples. SCCPs were detected in 92% and 98% of the samples at Birkenes and Zeppelin, respectively. This is in contrast to 2023, where SCCPs were detected in only 15% and 29% of samples at Birkenes and Zeppelin, respectively. However, this is a consequence of improved MDLs for SCCPs, not increasing concentrations. MCCPs were, in 2024, detected in 33% and 7% of the samples at Birkenes and Zeppelin compared to 46% at both sites in 2023. This may be caused by a combination of decreasing concentrations and higher MDLs for MCCPs for Zeppelin in 2024 compared to 2023. Investigations into the indoor environment and materials used at the Zeppelin station have shown notable concentrations of MCCPs. We have taken these results, and elevated MCCP concentrations in two field blanks into account to set the Zeppelin MDL for MCCPs, which is higher in 2024 compared to previous years. It should be noted that the measured concentrations after the renovation at the Zeppelin observatory were similar to the rest of the year.

CPs are associated with analytical challenges related to instrumental analysis/quantification, and potential for sample contamination from materials and indoor environments in the field and in the laboratory (Mézière et al., 2020; van Mourik et al., 2020) and are classified under uncertainty category 3 (Appendix B4).

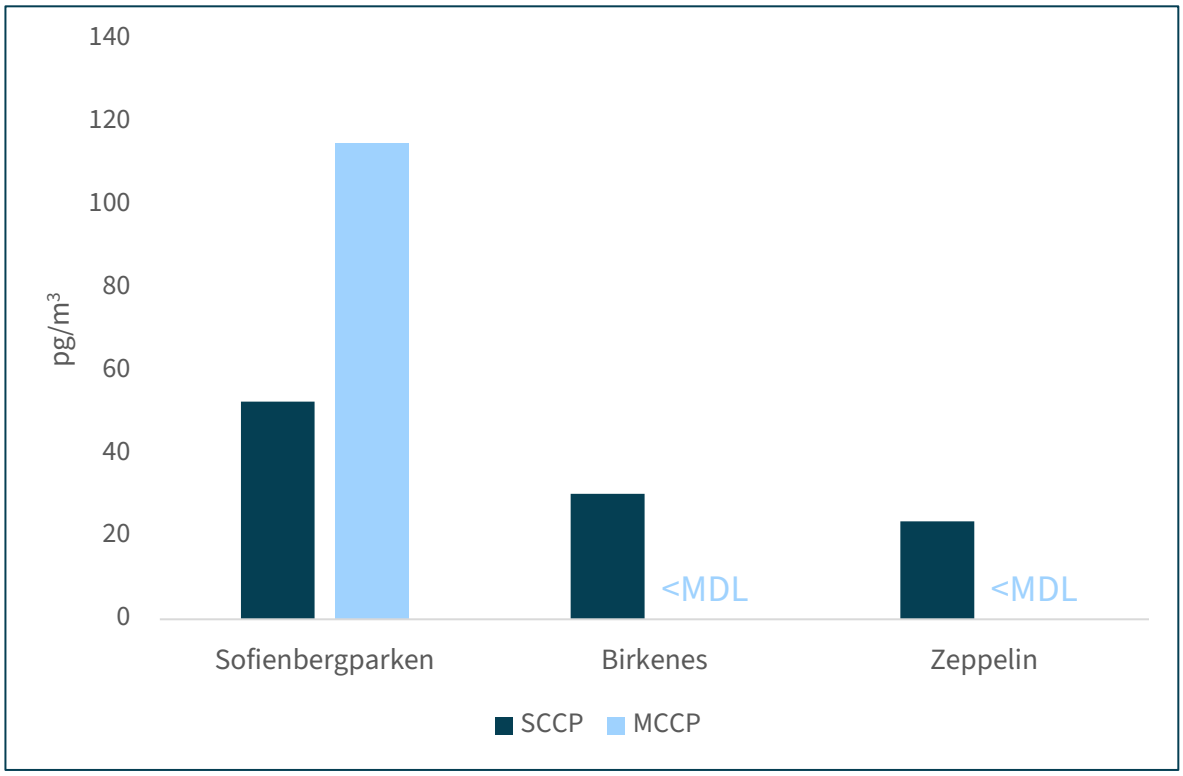


Figure 4: Annual median concentrations of short and medium chain chlorinated paraffins (SCCP, MCCP) in air (pg/m³) at Sofienbergparken, Birkenes and Zeppelin in 2024, based on weekly samples at Zeppelin and monthly samples at Birkenes and Sofienbergparken.

UV compounds

The gas and particle phase were combined (i.e. filters+ABN) for the analysis of UV compounds at Sofienbergparken, similar to 2023. In 2024, the detection limits were high compared to 2023 and 2022, and lower detection frequency of some of the UV compounds (e.g. UV-320 and UV-327) were observed. It should be noted that due to the lower sensitivity of the instrument, the compound-specific isotope-labelled internal standards could not be measured quantitatively for all analytes in every sample, and the quantification of all compounds were instead based on UV-328. Also, this year, no reliable results were possible to achieve for neither 2-EthylHexyl-4-MethoxyCinnamate nor tolyltriazol.

The overall results confirmed the findings from previous years, indicating that significant sources of UV compounds exist in the urban environment. As for 2023, octocrylene is dominating (Figure 5, median 78 pg/m^3), with the highest concentrations observed during summer. However, the peak concentration (260 pg/m^3) was significantly lower compared to the peak concentration for octocrylene in 2023 (1174 pg/m^3). Oxybenzone was also found in significant levels (14 pg/m^3).

The median concentration of UV-328 (1.6 pg/m^3), which was listed as POP in 2023, was lower compared to the median in 2023 (17.5 pg/m^3), but further monitoring is needed before any trend can be concluded. On the other hand, the peak concentrations for UV-328 (103 pg/m^3 in November) and UV-329 (72 pg/m^3 in January and 31 pg/m^3 in December) exceeded the maximum concentrations in 2023 (83 pg/m^3 and 5.5 pg/m^3 respectively). It is also noticeable that these high concentrations are observed during winter.

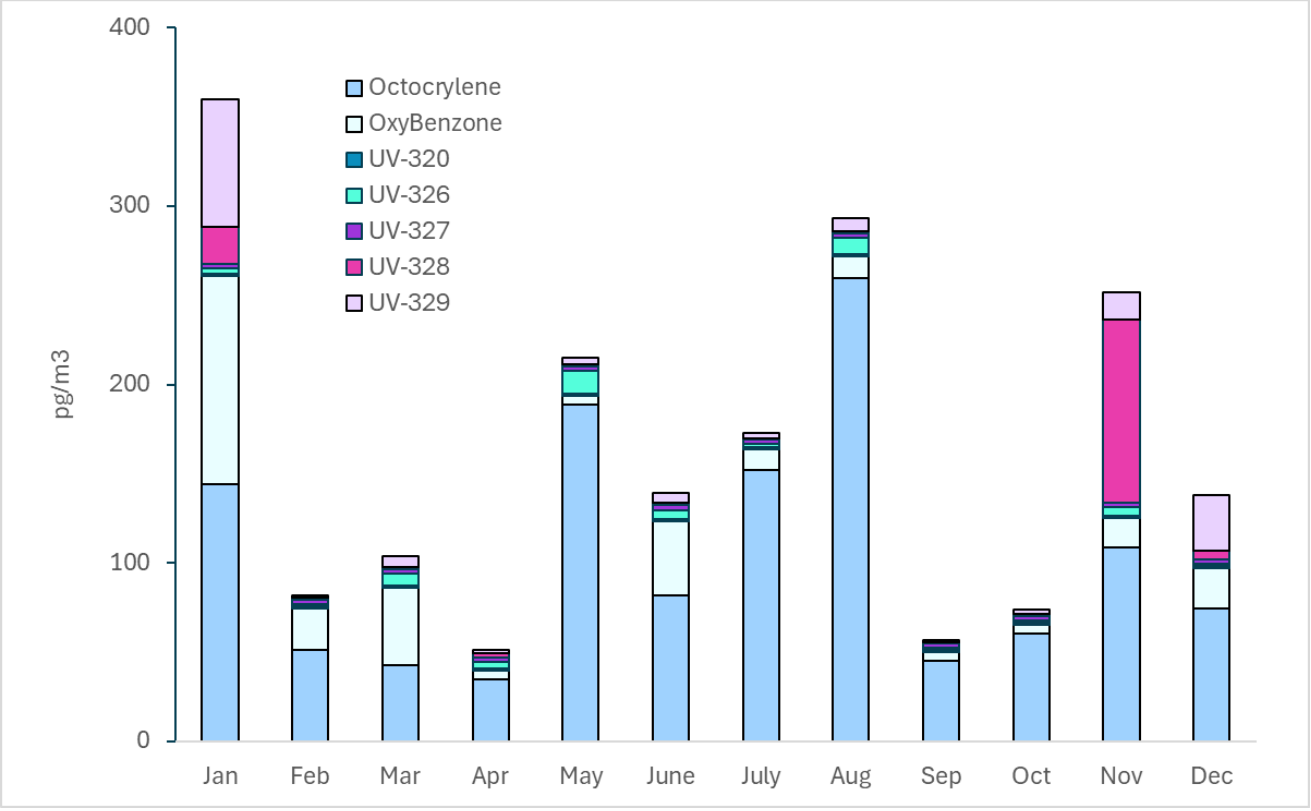


Figure 5: UV-substances in air (pg/m^3) at Sofienbergparken in 2024.

Flame retardants

Of the flame retardants, the highest concentrations are found for the OPFRs (measured at Sofienbergparken only). In 2024, the same nine OPFRs as in 2023 were detected in more than 60% of the samples, with the highest concentrations found for TCPP (573 - 4756 pg/m^3). It should be noted that TDCPP was possible to detect this year due to improvements in the analytical method. Challenges still remain for the analysis of TEP (no recovery of the internal standard).

Of the brominated flame retardants, the concentrations of the regulated PBDEs and HBCDD are generally lower than the replacement BFRs (Figure 2b-c). The concentrations of all BFRs (except BDE-209) are higher at Sofienbergparken, compared to the background stations. At Zeppelin and Birkenes, the concentrations of PBDEs and HBCDD are below or close to the method detection limits, with concentrations of sum PBDEs and HBCDD at Zeppelin being approximately two times higher than at Birkenes. It has been detected high concentrations of HBCDD in indoor dust at the Zeppelin station, which may cause occasional local contribution. A potential source was removed in June, but further investigations may still be needed to explain the slightly higher concentrations at Zeppelin.

Similar to previous years, BDE-209 was measured in much higher concentrations than the other BDEs and was excluded from the sum in Figure 2c. The blank contribution of BDE-209 during laboratory analysis are significant and higher uncertainty is expected. The median concentration of BDE-209 at Zeppelin observatory was lower in 2024 compared to 2023, most likely as a consequence of more regular dust cleaning (section 3.1), but still the median concentration was higher compared to Sofienbergparken. Further investigations may therefore still be needed to reduce the potential for blank contribution at the Zeppelin station.

Similar to 2023, the concentrations of nBFRs at Sofienbergparken were much higher compared to Zeppelin, with a/b-TBECH dominating (55% of the sum nBFR). As the concentrations of DBDPE are uncertain due to high influence by contamination, it was excluded from the sum of nBFRs in Figure 2c. TBBPA was also excluded from the sum nBFRs, due to much higher concentrations than the other nBFRs and the high uncertainty of this compound due to low recovery of internal standard. It should be noted that TBBPA and DBDPE were detected in much higher concentrations at Zeppelin in December, after the renovation was finished, and these results have therefore been omitted.

Of the chlorinated FRs, only syn-DP and anti-DP were detected at Sofienbergparken, with comparable concentrations with 2023. However, in contrast to 2023, neither syn-DP or anti-DP were detected at Zeppelin in 2024.

Brominated/Chlorinated Methanes

For the first time we measured bromoform ($CHBr_3$, all stations) and bromodichloromethane ($CHBrCl_2$, Sofienbergparken only). $CHBr_3$ was detected at all stations ubiquitously. $CHBr_3$ has both anthropogenic and natural sources, such as water treatment works and marine phytoplankton. Median levels increased from Sofienbergparken, to Birkenes, to Zeppelin (825, 1460, 4310 pg/m^3, respectively). This is possibly due to the closer proximity of Zeppelin (and lesser so Birkenes) to the open ocean, compared to Sofienbergparken. $CHBrCl_2$ was not detected at Sofienbergparken (<10 pg/m^3). Further method development is required to measure bromochloromethane (CH_2ClBr).

PFAS

Per- and polyfluoroalkyl Substances (PFAS), in the context of this report, refer to those compounds listed as volatile/ionic PFAS in Appendix A.

As in previous years, fluorotelomer alcohols (FTOHs) were still the dominant PFAS in the monitoring programme, and the atmospheric levels of FTOHs were significantly higher than the fluorotelomer sulfonic acids (FTSAs) and perfluoroalkyl acids (PFAAs, Figure 6). 6:2 FTOH, 8:2 FTOH and 10:2 FTOH were the most frequently detected at all stations (80 – 100%), while none of the four C_8 sulfonamides targeted (MeFOSA, EtFOSA, MeFOSE and EtFOSE) were detected at any station.

Of the PFAAs, C_5 – C_{10} perfluoroalkyl carboxylic acids (PFCAs) were detected at all stations (11 – 100%). PFCAs with chain lengths C_{12} or greater were seldom detected at any station. The detection of perfluoroalkyl sulfonic acids (PFSAs) was largely isolated to PFOS, with other C_4 – C_{12} PFSAs having widespread non-detection. Similar to most PFCAs, the detection frequency and median levels of PFOS were highest at Sofienbergparken (92%, 0.044 pg/m^3) compared to at Birkenes (92%, 0.019 pg/m^3), and then Zeppelin (33%, <0.009 pg/m^3) which was lower still (Figure 6).

This year, improvements to the analytical method have allowed for the inclusion of PFBA whose detection frequencies (92 – 100%) and median concentrations remain relatively consistent between all three stations (Sofienbergparken = 0.602 pg/m^3, Birkenes = 0.864 pg/m^3 and Zeppelin = 0.552 pg/m^3). This is in contrast to, for example, PFOS (described above) and PFOA, whose levels indicated that source proximity was important to the median concentrations observed (Sofienbergparken = 0.121 pg/m^3, Birkenes = 0.073 pg/m^3 and Zeppelin = <0.014 pg/m^3). The consistent levels observed for PFBA (see Figure 6) might be explained by precursors in the atmosphere which have sufficiently long atmospheric lifetimes to become well mixed in the troposphere (i.e. between urban, rural and Arctic sites). Further investigation is required to confirm this. No clear seasonality in the PFBA atmospheric levels was observed, unlike what was previously observed for surface snow in the Arctic (Hartz et al., 2024) and as found for C_6 – C_{11} PFCAs in last year's report.

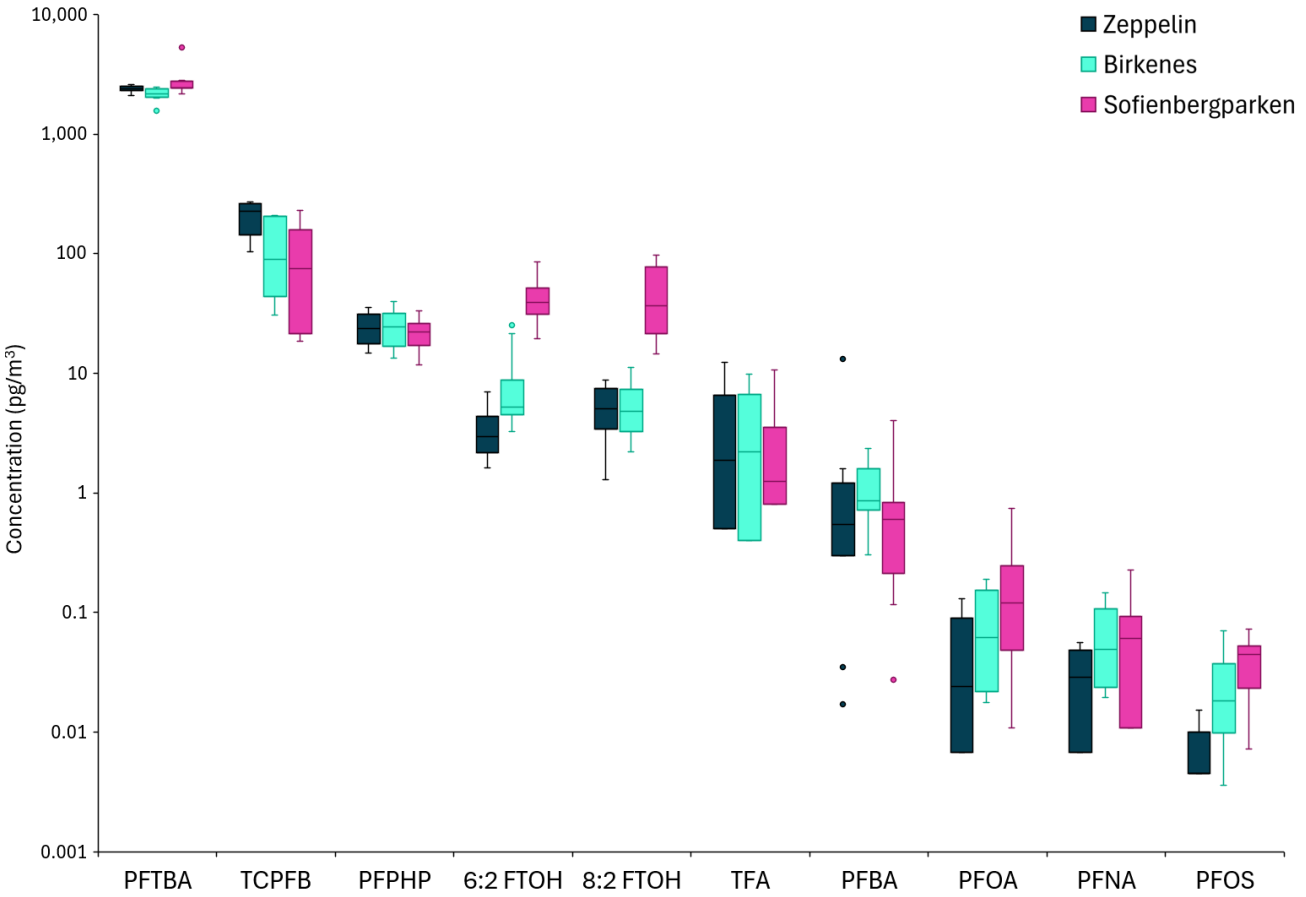


Figure 6. The levels of selected volatile/ionic PFAS and VFCs (pg/m³). Boxes indicate the interquartile range, the horizontal line indicates the median and the whiskers the maximum/minimum values within 1.5x the interquartile range. Points indicate values outside 1.5x the interquartile range. TFA, PFBA, PFOA, PFNA and PFOS have been sampled using a GFF with high volume air sampling. 6:2 FTOH and 8:2 FTOH have been sampled using a PUF/XAD-2 sandwich with high volume air sampling. PFTBA, TCPFB and PFPHP have been sampled using ABN and low volume sampling.

Of the FTSAs, 6:2 FTSA had relatively high detection frequencies at Sofienbergparken (50%) and Birkenes (67%), similar to 2023 (but not at Zeppelin, 9%). The levels of 6:2 FTSA at Sofienbergparken (<0.036 - 0.230 pg/m³) and Birkenes (<0.018 - 0.063 pg/m³) were similar to that of PFOS (<0.015 - 0.073 pg/m³ and <0.007 - 0.071 pg/m³, respectively). This indicates the importance of 6:2 FTSA as an active replacement for other PFAS, and its ongoing presence in urban and rural air in mainland Norway.

In 2024, the extra ionic PFAS required for monitoring at Sofienbergparken, were analysed at all stations (on glass fibre filter, GFF). This year, PFPrS and PFPrA have been measured for the first time as well. TFMS and PFEtS have also been analysed additionally. Of the extra PFAS, only TFA, PFPrA and TFMS were detected. TFA and PFPrA were detected at all stations (50 – 89%), with average levels 14 – 190 (for TFA), and 1.2 – 15 (for PFPrA) times higher when compared to PFOA. TFA and PFPrA are known to be the degradation products of CFC replacement products such as hydrofluorocarbons (Björnsdotter et al., 2021). Like PFBA, TFA and PFPrA had similar levels at all three stations (Figure 6). This report also presents the most comprehensive follow up on the ubiquitous detection of TFMS in Arctic surface snow by Björnsdotter et al. 2021. However, TFMS was conversely not detected in any of the air samples (sampled using GFF) from Zeppelin or Birkenes, and only in one sample from Sofienbergparken.

There is still uncertainty surrounding the partitioning of TFA in air between particle bound and gas phase components, but the gas phase is thought to be a major part of its atmospheric partitioning (Zhang et al.,

2018). In 2024, an additional campaign to measure TFA with ABN was undertaken at Sofienbergparken. For those samples >MDL (Table 5), TFA concentrations measured on ABN were 5.3 – 190 times higher than on GFF. This suggests that ABN is able to capture more atmospheric TFA, despite the lesser volume of air sampled, possibly due to a larger proportion of gas phase TFA being captured by the ABN. Furthermore, results for TFA on ABN show a characteristic seasonal trend, with atmospheric levels on average 5.2 times higher during May – September compared to the rest of the year. These are the first results for the measurement of TFA on ABN, and further work is required to fully validate this method.

Table 5: Concentrations of TFA (pg/m³) detected using GFF and ABN sampling at Sofienbergparken in 2024.

Sampling Method	Sampling Month:	Jan		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sampling with GFF (high-volume)	Sampling dates	01/01 – 03/01	-	01/02 – 03/02	01/03 – 03/03	01/04 – 03/04	01/05 – 03/05	01/06 – 03/06	01/07 – 03/07	01/08 – 03/08	01/09 – 03/09	01/10 – 03/10	01/11 – 03/11	01/12 – 03/12
	Concentration (pg/m³)	<1.61	-	2.73	<1.61	10.6	1.93	<1.61	3.83	<1.61	<1.61	2.01	5.69	<1.61
Sampling with ABN (low-volume)	Sampling dates	08/01 – 11/01	24/01 – 27/01	09/02 – 12/02	05/03 – 07/03	08/04 – 10/04	01/05 – 03/05	06/06 – 08/06	15/07 – 17/07	12/08 – 14/08	10/09 – 12/09	07/10 – 09/10	18/11 – 20/11	16/12 – 18/12
	Concentration (pg/m³)	104	33.9	260	26.1	55.7	373	175	133	346	155	15.2	54.1	46.3

Volatile fluorinated and/or chlorinated substances

In 2024, measurements of 15 volatile fluorinated and/or chlorinated substances (vol. F+Cl sub.) were undertaken at all three stations for the first time. A summary of the results from the last four years of monitoring is shown in Table 6.

Considering all compounds, the levels were in general consistent between all three stations in 2024, which reflects the results from 2021 and 2022. This is expected given that these compounds are well mixed in the atmosphere and typically have long atmospheric lifetimes. For example, PFTBA, TCPFB and PFPHP are known to have atmospheric lifetimes 100 – 3650 years.

Results from monitoring during 2021 – 2024 has shown consistently higher levels of PFTBA and HCBD within this group of compounds, with median levels ranging 1541 – 2390 pg/m³ and 1523 – 1930 pg/m³. A small proportion of HCBD exists as structural isomers; hexachlorocyclobutene (HCcBen) and hexachlorobicyclobutane (HCBcB), which together make up <15% of the mass for these three compounds.

Relatively high levels of TCPFB, PFTPeA and PFPHP have also been observed during monitoring in 2021, 2022 and 2024. Median levels of TCPFB (see Figure 6) remained quite consistent (221 – 255 pg/m³) at Zeppelin during these three years, but it is unclear why median levels were lower at Sofienbergparken (42 and 75 pg/m³ in 2022 and 2024, respectively) and Birkenes (90 pg/m³ in 2024). PFTPeA is a longer chain version of PFTBA and had levels 55 – 118 pg/m³ during the three years of monitoring, which was less than PFTBA. Median levels of PFPHP at Zeppelin appeared to decrease during 2021, 2022 and 2024 (47, 39, 24 pg/m³). But it can't be ruled out that variations in the analytical methods could have contributed to this.

Table 6: Median levels in pg/m³ (and detection frequency, %) of vol. F+Cl substances for monitoring during 2020, 2021 and 2024.

Name	Compound	2021	2022		2024		
		Zeppelin	Sofienbergparken	Zeppelin	Sofienbergparken	Birkenes	Zeppelin
Perfluorotributylamine	PFTBA	1960 (82)	1540 (100)	2090 (77)	2430 (100)	2150 (100)	2390 (100)
Tetrachlorohexafluorobutane	TCPFB	255 (82)	42 (100)	221 (100)	75.0 (100)	90.2 (100)	226 (100)
Perfluorotripentylamine	PFTPeA	110 (82)	92 (100)	118 (70)	55.2 (100)	81.1 (100)	62.4 (100)
Hexachlorobutadiene	HCBD	1630 (100)	1520 (100)	1750 (100)	1850 (100)	1930 (100)	1740 (100)
Perfluoroperhydrophenanthrene	PFPHP	47 (82)	60 (100)	39 (70)	22.2 (100)	24.3 (100)	23.6 (100)
Dichlorotrifluoropyridene	DCTFP	5.6 (93)	2.3 (100)	5.0 (98)	<1.00 (9.1)	<1.00 (0)	1.3 (55)
Pentachlorotoluene	PCTol	1.3 (100)	0.9 (79)	1.0 (84)	<5.00 (18.2)	5.59 (64)	<5.00 (0)
Dichloroperfluorocyclohexene	DCPFcH	<1.0 (0)	<1.0 (0)	<1.0 (0)	<10.0 (0)	<10.0 (0)	<10.0 (0)
Pentafluorobromobenzene	PFBB	<5.0 (0)	<5.0 (0)	<5.0 (0)	<0.200 (0)	<0.200 (0)	<0.200 (0)
3,5-bis-(trifluoromethyl)bromobenzene	bTFMBB	<1.0 (0)	<1.0 (0)	<1.0 (0)	<1.00 (0)	<1.00 (0)	<1.00 (0)
2,3-dichlorobenzotrichloride	2,3-DCBTC	<0.5 (0)	<0.5 (0)	<0.5 (0)	<10.0 (0)	<10.0 (0)	<10.0 (0)
3,4-dichlorobenzotrichloride	3,4-DCBTC				<10.0 (0)	<10.0 (0)	<10.0 (0)
Perfluorobutylcyclohexane	PFBCH	n.a.	n.a.	n.a.	<100 (0)	<100 (0)	<100 (0)
Hexachlorocyclobutene	HCcBen	242 (100)	214 (100)	196 (100)	n.a.	n.a.	n.a.
Hexachlorobicyclobutane	HCBcB	7.7 (93)	6.0 (100)	4.0 (100)	n.a.	n.a.	n.a.

Only HCBD was measured at Solfienbergparken in 2023, for which the median was 1700 (detection frequency 100%). In 2024, the analysis of DCBTC has been able to distinguish its positional isomers (2,3-DCBTC and 3,4-DCBTC). n.a. = not analysed.

Across the three years of monitoring DCPFcH, PFBB, bTFMBB, 2,3-DCBTC and 3,4-DCBTC were never detected (MDLs: 0.2 – 10 pg/m³). In addition, PFBCH was not detected in 2024 at any station (MDL: 100 pg/m³).

The atmospheric levels of the most routinely detected vol. F+Cl substances (e.g. PFTBA, TCPFB and PFPHP) were often higher than the PFAS discussed in the previous section (Figure 6). Generally speaking, vol. F+Cl substances are a group of contaminants typically concerned with radiative forcing and/or stratospheric ozone depletion. This contrasts with PFAS that often have toxic and/or bioaccumulative properties (or as a precursor of such a compound), and therefore associated with impact on human and environmental health.

4.1.2 Heavy metals and mercury

For heavy metals (HM) in precipitation, all the targeted HMs (Al, As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn and Hg) are detected at all stations (Figure 7). Generally, the observed concentrations and deposition levels of most HM's are higher at Birkenes and Hurdal compared to Kårvatn. This difference reflects the distance to the main emission sources in continental Europe (Ilyin et al., 2022). Elevated concentrations and deposition levels are still observed at Svanvik in eastern Finnmark for a few elements associated with emissions from smelter activity close to the Ru-No border. This applies to Ni, V, and Co, in particular. The influence from the Russian smelters on the environment in eastern Finnmark has been repeatedly demonstrated through moss surveys (Berglen et al., 2025). The smelter in Nikel closed down in December 2020, but there is still production at the briquetting facility in Zapolyarny (Berglen et al., 2022). However, very little is known about the emissions from Zapolyarny and there has been no contact with our former Russian colleagues. The results from Svanvik in 2024 confirm the 2 to 10-fold decrease in HM in precipitation compared to 2020 when the smelters in Nikel were still in operation (Bohlin-Nizzetto et al., 2021).

For HMs in air, the concentrations are mostly comparable to 2023 and well below the air quality criteria for metals as set by the National Institute for Public Health (Table 7), which also applies to the urban monitoring station Sofienbergparken.

Overall, the lowest HM concentrations in air are measured at Zeppelin in the Arctic, while the highest concentrations for all HM's were observed at Sofienbergparken in Oslo. Birkenes experiences higher concentrations than Zeppelin, because Birkenes is closer to the emission sources at the European continent (Ilyin et al., 2022), while in Sofienbergparken local sources, such as non-exhaust emissions from vehicles, road dust and wood burning, contribute considerably to the concentrations observed. Historically, and similar to the reported HM levels in precipitation, the concentrations in air samples at Svanvik were about ten times higher than those observed at Birkenes depending on element (Berglen et al., 2022). However, since the close-down of the smelter in Nikel close to the Norwegian border, the concentrations of most heavy metals in air are dramatically reduced, and in 2024 the concentrations are comparable to Birkenes (Figure 7). The annual mean concentration of gaseous elemental mercury (GEM) is similar at Zeppelin, Birkenes and Sofienberparken, and at the same level as the northern hemispheric mean concentration (Sprovieri et al., 2016). The concentration is lower at the Norwegian monitoring station Trollhaugen in Antarctica (Table A.4). The concentration of mercury in air at background sites in the southern hemisphere is expected to be lower than the northern hemisphere, because most emission sources are located in the northern hemisphere, and the atmospheric lifetime of mercury is not long enough for inter-hemispheric mixing.

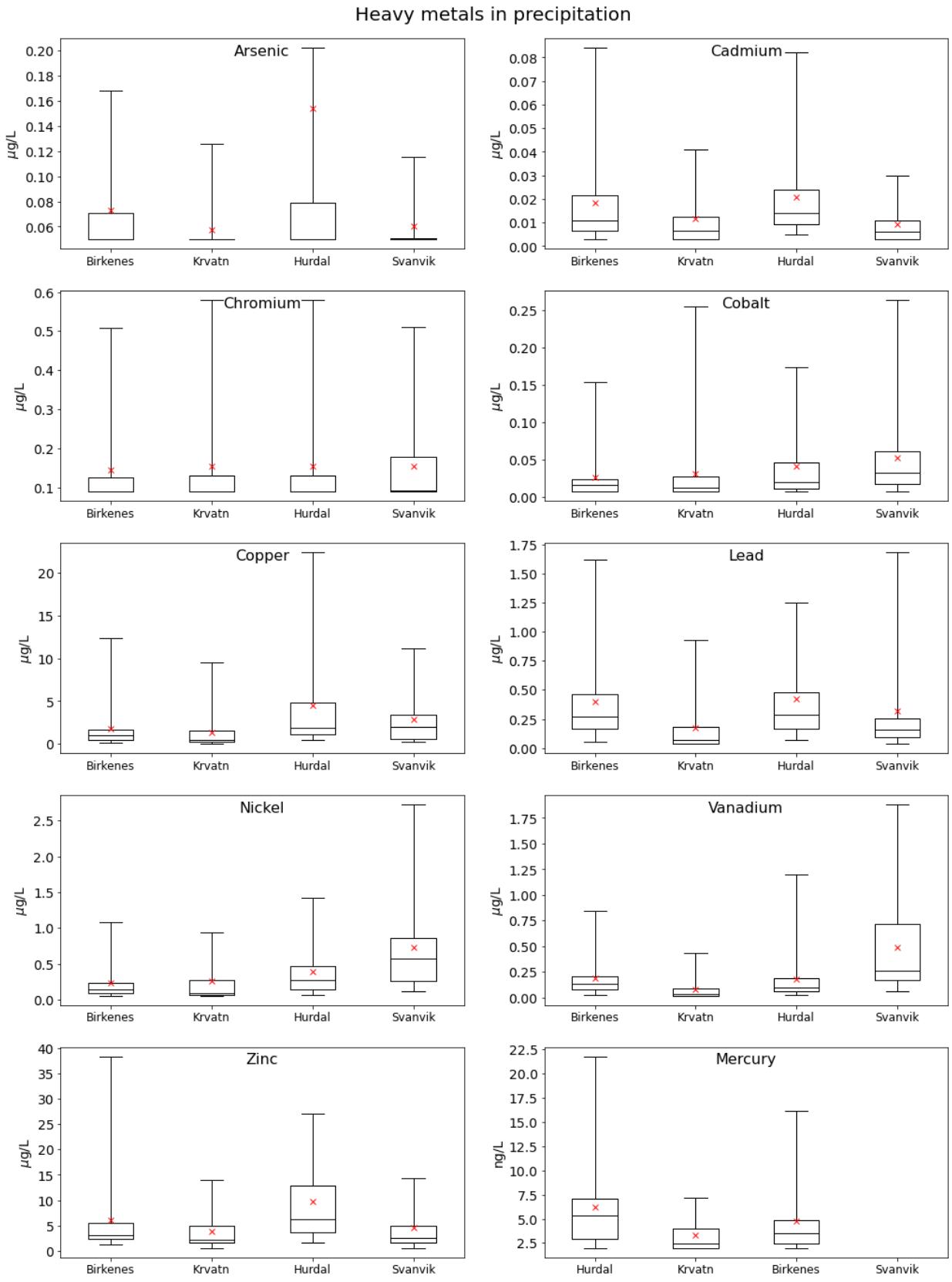
The mean and median concentrations of mercury species (GOM and PHg) measured at Zeppelin in 2024 are in the same range as previously (Figure 8). The mean concentration of GOM and PHg is strongly influenced by a few extreme high values occurring in spring at the time when GEM is subject to oxidation chemistry and converted into GOM and PHg. More on the seasonality of mercury species is described below.

Table 7: Annual mean concentrations of all heavy metals measured on PM_{10} in air (ng/m³) at the Norwegian monitoring stations in 2024, compared to target values in regulations related to pollution control (Forurensingsforskriften kap 7) and National Institute for Public Health Air Quality Criteria (FHI's luftkvalitetskriterier).

Compound	Norwegian Target values [1] ng/m³	NIPH Air Quality Criteria [2] ng/m³	Birkenes	Zeppelin	Svanvik	Sofienberg parken
			ng/m³	ng/m³	ng/m³	ng/m³
Al	n.a.	n.a.	34.8	52.7	36.4	308
As	6	2	0.097	0.061	0.0897	0.337
Cd	5	2.5	0.027	0.063	0.0128	0.292
Cr	n.a.	n.a.	0.290	0.186	0.285	1.32
Co	n.a.	n.a.	0.018	0.011	0.0373	0.162
Cu	n.a.	n.a.	0.323	0.192	0.382	7.30
Fe	n.a.	n.a.	32.2	20.5	126	382
Pb	500	100	0.562	0.253	0.381	0.996
Mn	n.a.	150	1.07	0.519	0.636	7.08
Ni	20	10	0.17	0.092	0.809	0.854
Ag	n.a.	n.a.	n.a.	n.a.	n.a.	0.015
Ti	n.a.	n.a.	2.24	1.55	1.97	17.3
V	n.a.	200	0.313	0.07	1.62	1.49
Zn	n.a.	n.a.	2.21	1.78	1.30	15.0
Hg	n.a.	200	1.46	1.53	n.a.	1.50

1) https://lovdata.no/forskrift/2004-06-01-931/§7-10 [URL 13-05-2024], in Norwegian. Pb is given as limit value 0.5 µg/m³.

2) https://www.fhi.no/en/cl/air-pollution/outdoor-air-handbook---air-quality-criteria/summary-and-background-information/summary/?term= [URL 13-05-2024].


Heavy metals in precipitation
Arsenic
Cadmium
Chromium
Cobalt
Copper
Lead
Nickel
Vanadium
Zinc
Mercury
µg/L
ng/L
Birkenes
Krvatn
Hurdal
Svanvik

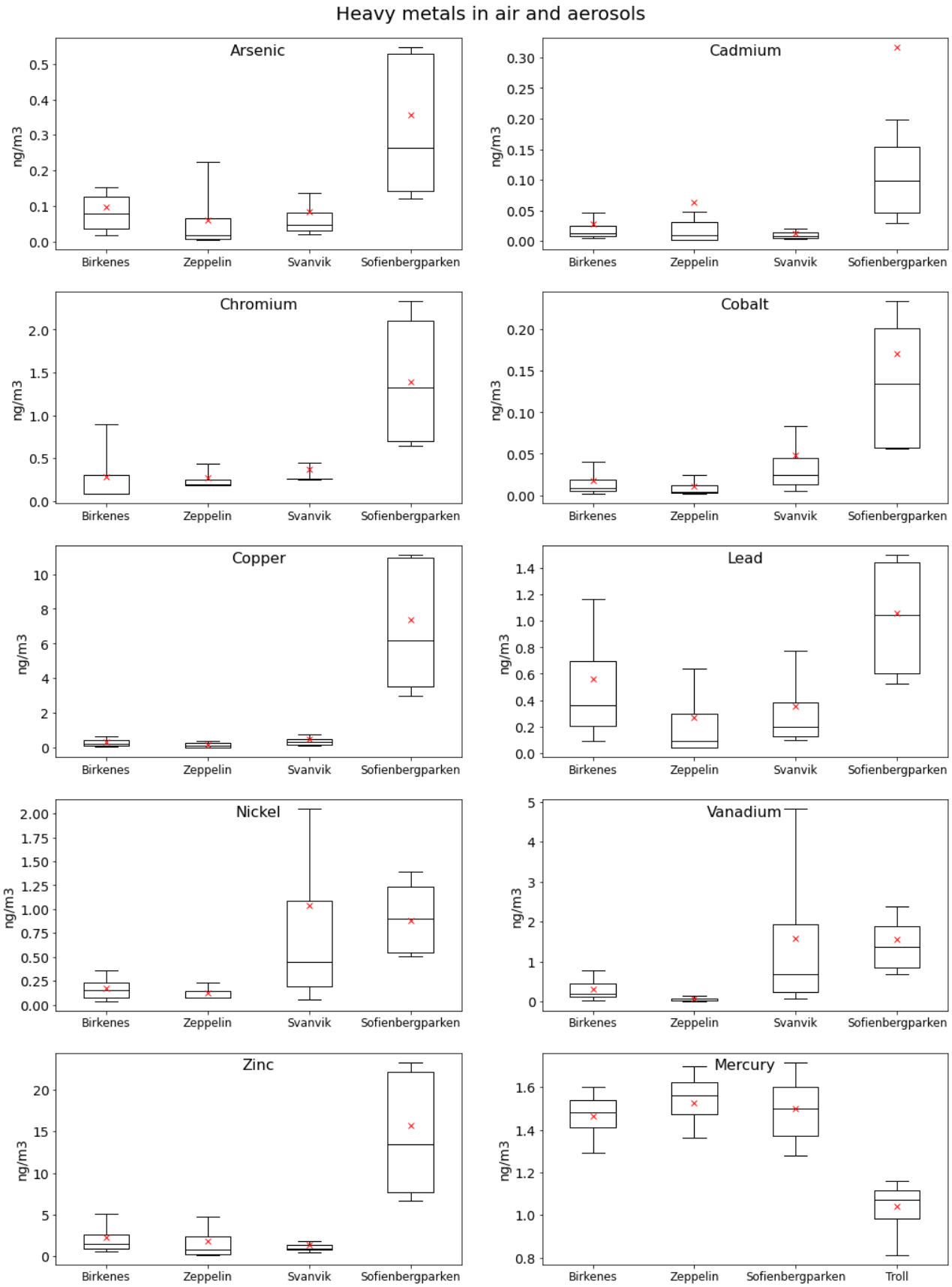


Figure 7: Box plots of measured concentrations of selected heavy metals in precipitation and aerosols in 2024. The box represents the 50th, 25th, and 75th percentiles and the whiskers represent the 1 and 99 percentiles. The red crosses indicate annual means.

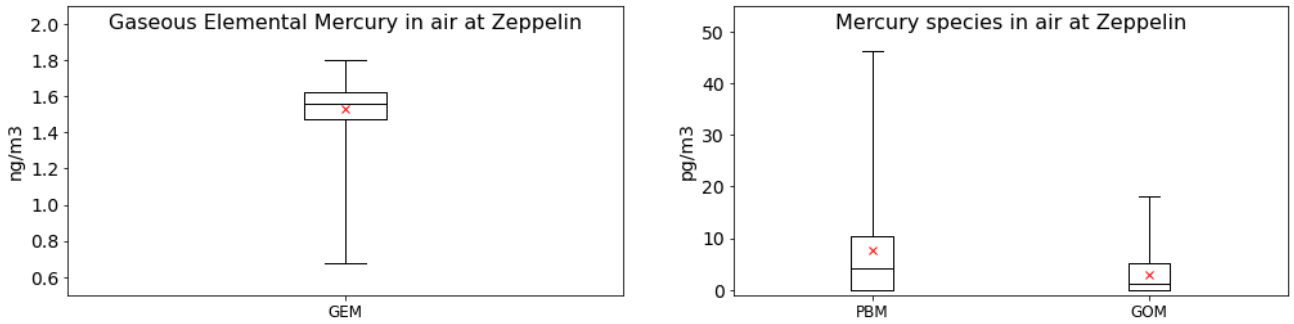


Figure 8: Box plots of Hg species (GEM in ng/m³, and GOM and PBM in pg/m³) measured in air at Zeppelin in 2024. The box represents the range from 25 to 75 percentile with the center line representing the median value. The whiskers represent the 1 and 99 percentiles, while the red cross represents the mean value.

Seasonal variation in mercury and mercury species at Zeppelin

The seasonal variation in GEM at the Zeppelin Observatory displays high concentrations in winter and summer and low concentrations in spring and autumn (Figure 8). This is in contrast to the pattern at temperate northern latitudes with the highest concentrations in winter and lowest concentrations in summer (Sprovieri et al., 2016; Temme et al., 2007) (Sprovieri et al., 2016; Temme et al., 2007), which are mainly attributed to primary anthropogenic mercury emissions from coal combustion for domestic heating (Temme et al., 2007; Weigelt et al., 2015). Global Hg models have so far not been able to test this hypothesis as current anthropogenic mercury emission inventories have no seasonal resolution and are kept constant throughout the year (Holmes et al., 2010; Horowitz et al., 2017; Song et al., 2015). The seasonal pattern at the Zeppelin Observatory is strongly influenced by the so-called atmospheric mercury depletion events (ADMEs) taking place through fast oxidation mechanisms initiated by photochemistry involving halogens derived from heterogeneous reactions on hygroscopic sea salt aerosols (Alexandra Steffen et al., 2015). AMDEs cause the springtime-low GEM concentrations, and the summertime high is caused by either re-emission of previously deposited GEM during spring or GEM volatilization from the ocean (Berg et al., 2013; Hirdman et al., 2010). Concentrations of GOM and PBM at Zeppelin are low for most parts of the year but are elevated during spring and summer (Figure 8), again due to AMDEs, though they are still lower compared to other Arctic sites (Lindberg et al., 2002; A. Steffen et al., 2008). This is likely because Zeppelin is located relatively far from where the AMDEs take place and most of the Hg species have already been deposited before being captured at Zeppelin (Steen et al., 2011). Trends in speciated Hg measurements have been investigated in the most recent AMAP Hg assessment (AMAP, 2021), and it was found that trends for GOM are declining for the months from February through September with no significant trend for the remainder of the year. On the other hand, trends for PBM are increasing for the months January through May and in November and decreasing for September, October, and December. The shift in speciation from GOM to PBM in spring suggests an influence of changing Arctic conditions on AMDEs.

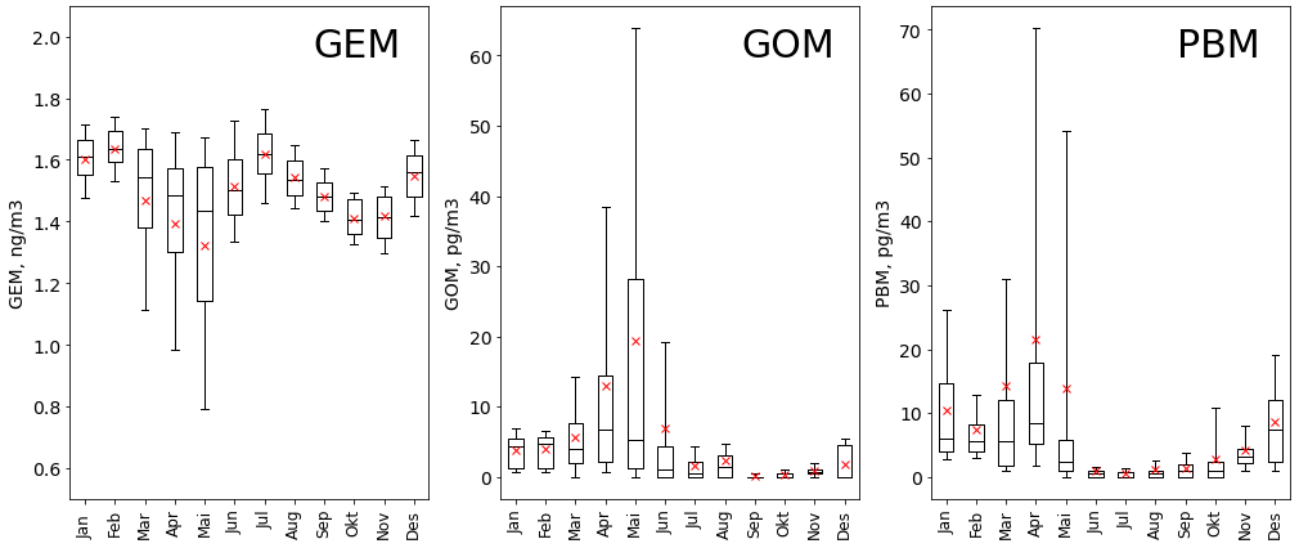


Figure 8. Seasonal variation of GEM, GOM and PBM.

4.2 Measurements at the Zeppelin observatory during renovation

Passive air sampling was conducted at the Zeppelin observatory to assess whether the renovation activities in October/November could influence the station's measurements of organic contaminants. Regular monitoring was paused during the renovation, but the passive sampling provided a means to evaluate potential impacts.

Also, dust samples (wipes) were collected indoors to assess organic contaminants present during renovation.

4.2.1 Organic contaminants in indoor and outdoor air

The passive PUF-samples taken indoors during renovation (Table 8a) revealed high concentrations of brominated flame retardants and chlorinated paraffins relative to outdoor air, with higher concentrations in the NILU-room than the Cleanroom, in accordance with where activity was largest. Remarkably high levels of BDE-47 (13 and 12 pg/m^3 respectively), BDE-99 (10 and 1.4 pg/m^3), BDE-206 (10 and 2.1 pg/m^3), BDE-207 (6.0 and 1.1 pg/m^3) and BDE-209 (108 and 64 pg/m^3), α-HBCD (28 and 2.8 pg/m^3), TBBPA (80 and 11 pg/m^3), PBT (10 and 8 pg/m^3), PBBz (10 and 3.8 pg/m^3), HBB (13 and 6 pg/m^3), DPTE (12 and 2.3 pg/m^3), and DBDPE (92 and 32 pg/m^3) were observed. For these compounds, no similar measurements have been done prior to the renovation that the levels can be compared too. Significant levels of CPs were found, with higher concentrations of MCCP than SCCP, both indoor and outdoor. A passive air sampling campaign was also conducted in 2017 (Bohlin-Nizzetto et al., 2018), which detected approximately 100 times higher concentrations of S/MCCP indoor than outdoor. This is comparative to the indoor/outdoor ratio observed in this year's campaign, which ranged from 21 to 56 for SCCP and from 5 to 13 for MCCP, for the Cleanroom and NILU-room respectively.

The passive PUF-samples taken outdoors (Table 8a) were relatively low and within a factor of 10 of the median concentrations found for the rest of 2024, with some exceptions; PCB-118 (167) and PCB-153 (25), pp-DDE (17), dechloranes plus syn/anti (30/92), naphthalene (24), fluorene (16), HBCDD (106-190), TBBPA (41), EHTBB (57), BEHTBP (90) and DBDPE (741). Passive air sampling gives semi-quantitative concentrations only, but this may indicate that local contribution of these compounds was likely during renovation. No

elevated concentrations were observed for PCBs, PBDEs or CPs for the active air samples from December after the renovation finished. However, for HBCD, TBBPA and nBFRs the samples from December were excluded from the 2024-dataset due to elevated concentrations.

The measured concentrations of cVMS in the passive XAD-samples (Table 8b) were substantially higher than the long-term background levels typically observed at the site (median ΣcVMS ≈ 0.9 ng/m^3). Outdoor passive samples showed ΣcVMS of 8–14 ng/m^3, while indoor samples reached 750–1200 ng/m^3, i.e. one to three orders of magnitude above background. These indoor/outdoor ratios also exceeded the ratios found in 2017 (Bohlin-Nizzetto et al., 2018). Indoors, the D5/D4 ratio (~1.1) was much lower than in typical indoor environments (3–10; Pieri et al. (2013), indicating a D4-enriched profile. Given the timing of the renovation and limited human activity at the station, the elevated concentrations most likely reflect emissions from silicone-based building and technical materials, which can release residual cyclic siloxanes, particularly D4, under ambient conditions (Horii et al., 2020).

Table 8. Concentrations (pg/m^3) of organic contaminants in passive air samples collected on (a) PUFs and (b) XAD, deployed outdoor and indoor (05.11.24-18.12.24) at the Zeppelin Observatory during renovations.

a) Passive PUF (pg/m^3)

	Outdoor	NILU-room	Cleanroom
Sum PAHs	5846		
Sum 7 PCBs	3.6	32	12
Sum DDTs	2.2	1.5	0.3
Sum HCHs	9.5	14	14
Sum Chlordanes	3.5	1.8	0.7
Sum Dechloranes	4.7	13	< MDL
Sum PBDEs ex. BDE209	0.8	46	18
BDE209	11	108	64
Sum HBCDDs	3.8	39	3.8
Sum nBFRs	1.8	58	24
DBDPE	197	92	32
TBBPA	3.4	80	11
Sum CPs	273	4424	1605

b) Passive XAD (pg/m^3)

	Outdoor	NILU-room	Cleanroom
Sum cVMS	12000	1199000	779000
Sum C4-C7 PFCAs	24	4	3
Sum C4-C8 PFSAs	4	1	1
Sum FTOHs	< MDL	5	4

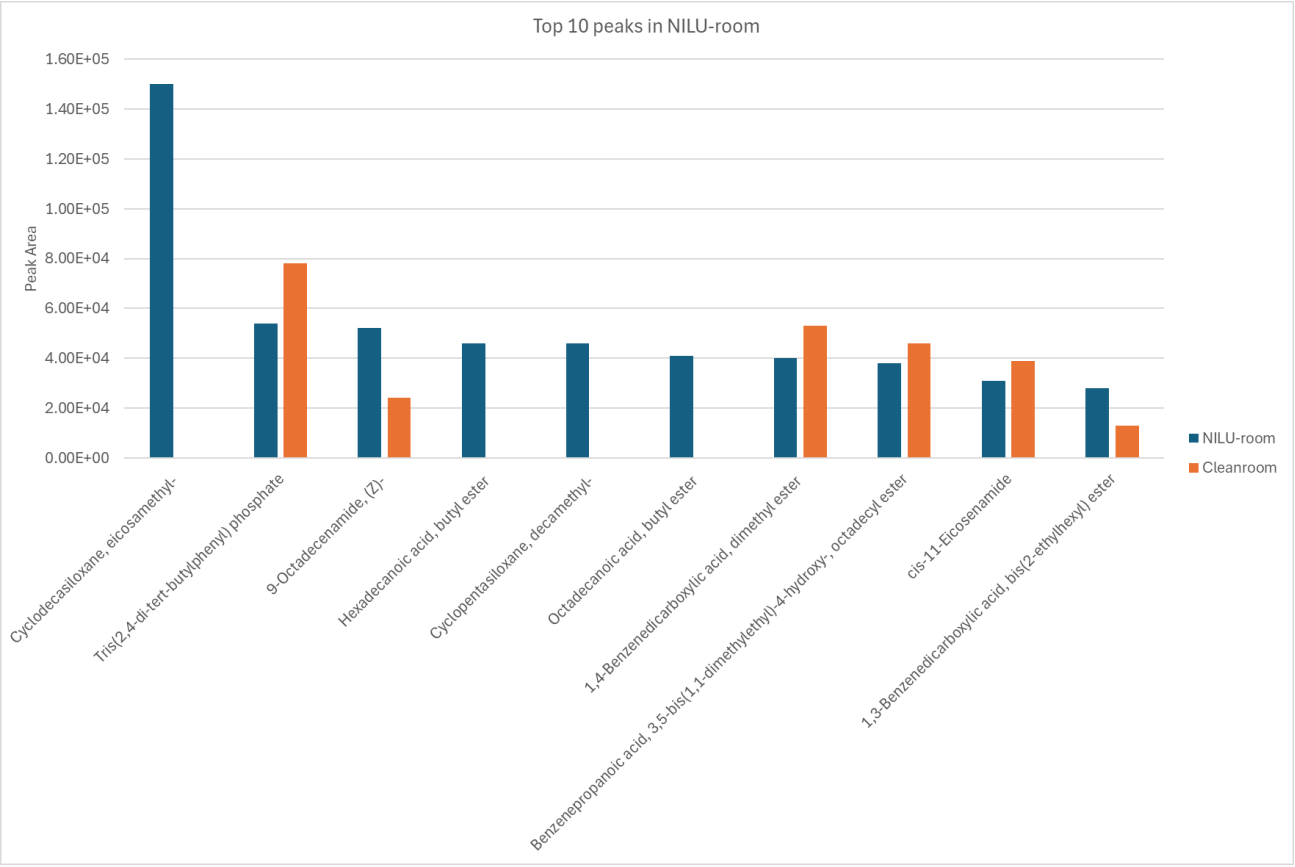
4.2.2 *Organic contaminants in indoor dust*

Generally high concentrations of flame retardants and chlorinated paraffins (Table 9) were found in the samples of indoor dust before cleaning the room after renovation. Figure 9 also shows the top 10 compounds detected by non-target analysis from the NILU-room and Cleanroom. It is recommended that this is followed up with new samples in 2025 to evaluate the concentrations after dust cleaning and the renovation has been completed.

Table 9. Concentrations (pg/filter) of organic contaminants in indoor dust samples (wipes)

	NILU-room	Cleanroom
Sum DPs	74353	1494
Sum PBDEs ex. BDE209	8128	6143
BDE209	12132	19449
Sum HBCDDs	18707	7196
Sum nBFRs	31394	197
DBDPE	44449	25599
TBBPA	101794	11366
Sum CPs	> 1687000	> 1034000

a)



b)

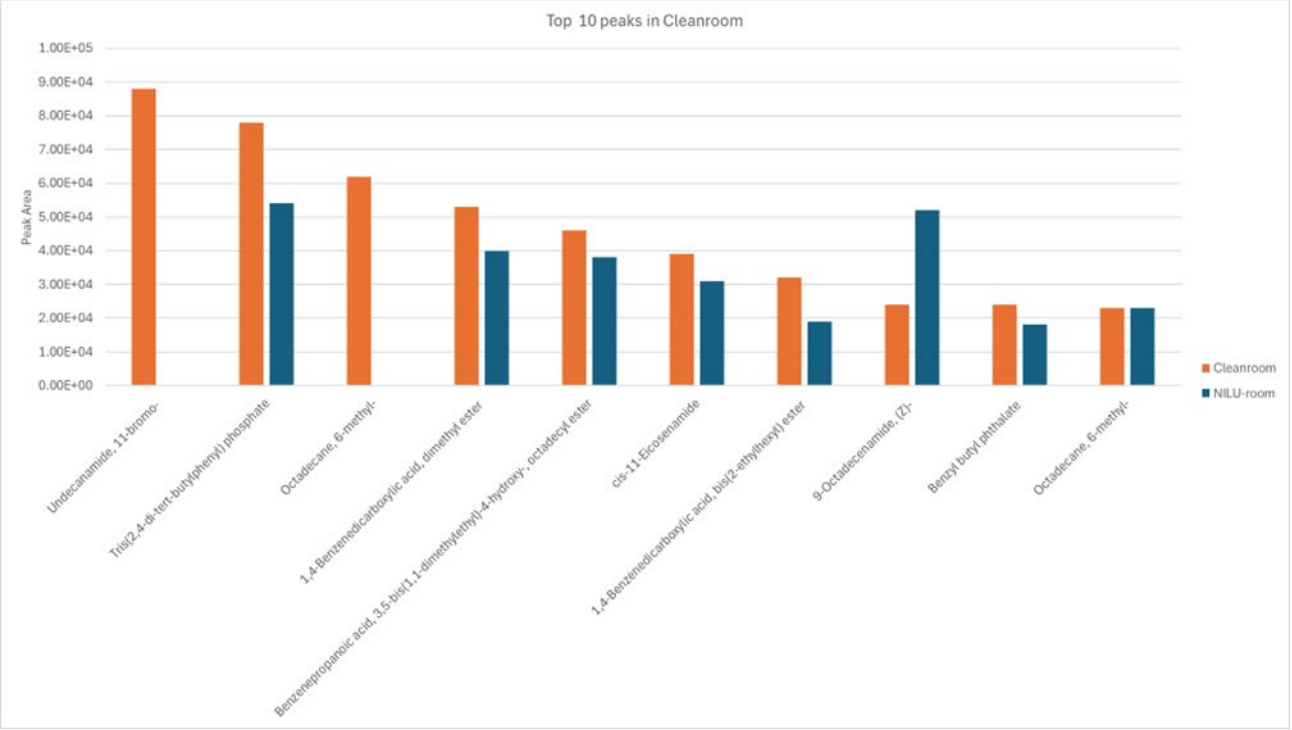


Figure 9. Non-target analysis of indoor dust. The top 10 compounds with highest peak area detected in a) NILU-room and b) Cleanroom

4.2.3 Volatile organic compounds

A full overview of the VOCs detected and their possible sources are given in Appendix D. Table D.1 shows the total amount of VOC (TVOC) at all sampling sites and the main contributors. While TVOC was relatively high at the station throughout the renovation project, TVOC was reduced sharply when the renovation finished. This was especially evident for the so-called “NILU-room” (Figure 10), where large changes were done. This indicates that pollutants introduced into the station during renovation disappear quickly and should have no impact on the air monitoring of VOCs at the station.

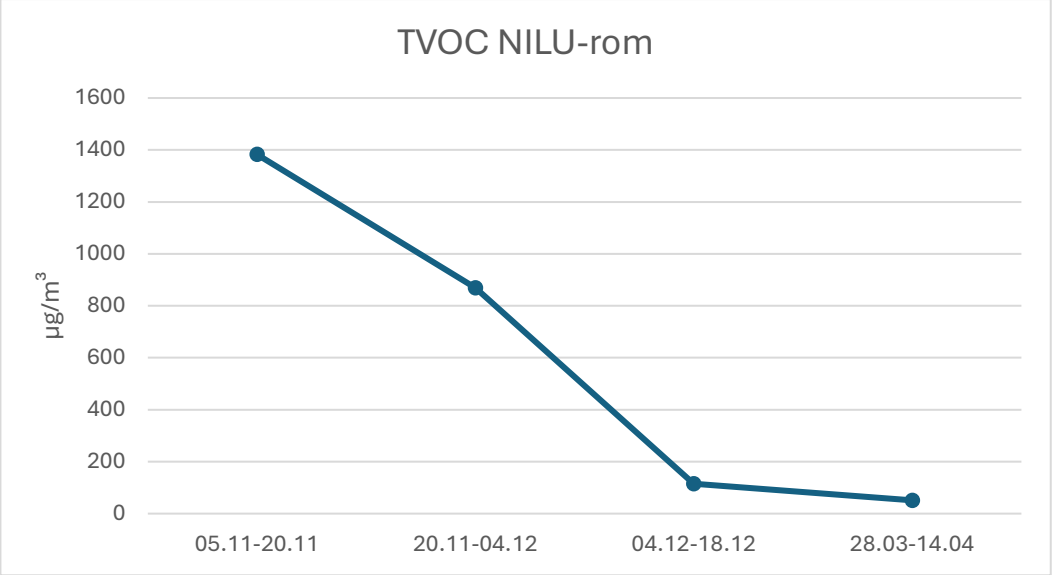


Figure 10. The total amount of VOC (TVOC calculated using toluene equivalents) in µg/m³, measured at the so-called "NILU-room" during the four different sampling periods.

4.3 Time-trends from long-term monitoring data

4.3.1 Organic contaminants

Most of the POPs measured in air were at similar or slightly lower concentrations in 2024 compared to 2023.

In 2024, updated long-term trend analysis using the Digital Filtration Technique (Hung et al., 2016) was done for BDE-47 and cis-chlordane (Figure 11). The results from the trend analysis of BDE-47 shows an estimated half-live of 28 years during the whole monitoring period at Zeppelin, while no significant trend is observed after regulation in 2010. At Birkenes, a slightly more significant decrease is observed, with an estimated half-live of 11 years during the whole monitoring period.

Cis-chlordane (cis-CHL) are currently only measured at the Zeppelin observatory. Figure 11 shows the time-trend before and after the compound was listed in the Stockholm Convention (i.e. 2004). The concentrations of cis-CHL have been declining during the whole period, with an estimated half-live of 13 years. The decrease in concentrations has been slightly more significant in the period after 2004 (half-live of 12 years), than in the period 1993-2004 (half-live of 16 years), reflecting the effect of regulations.

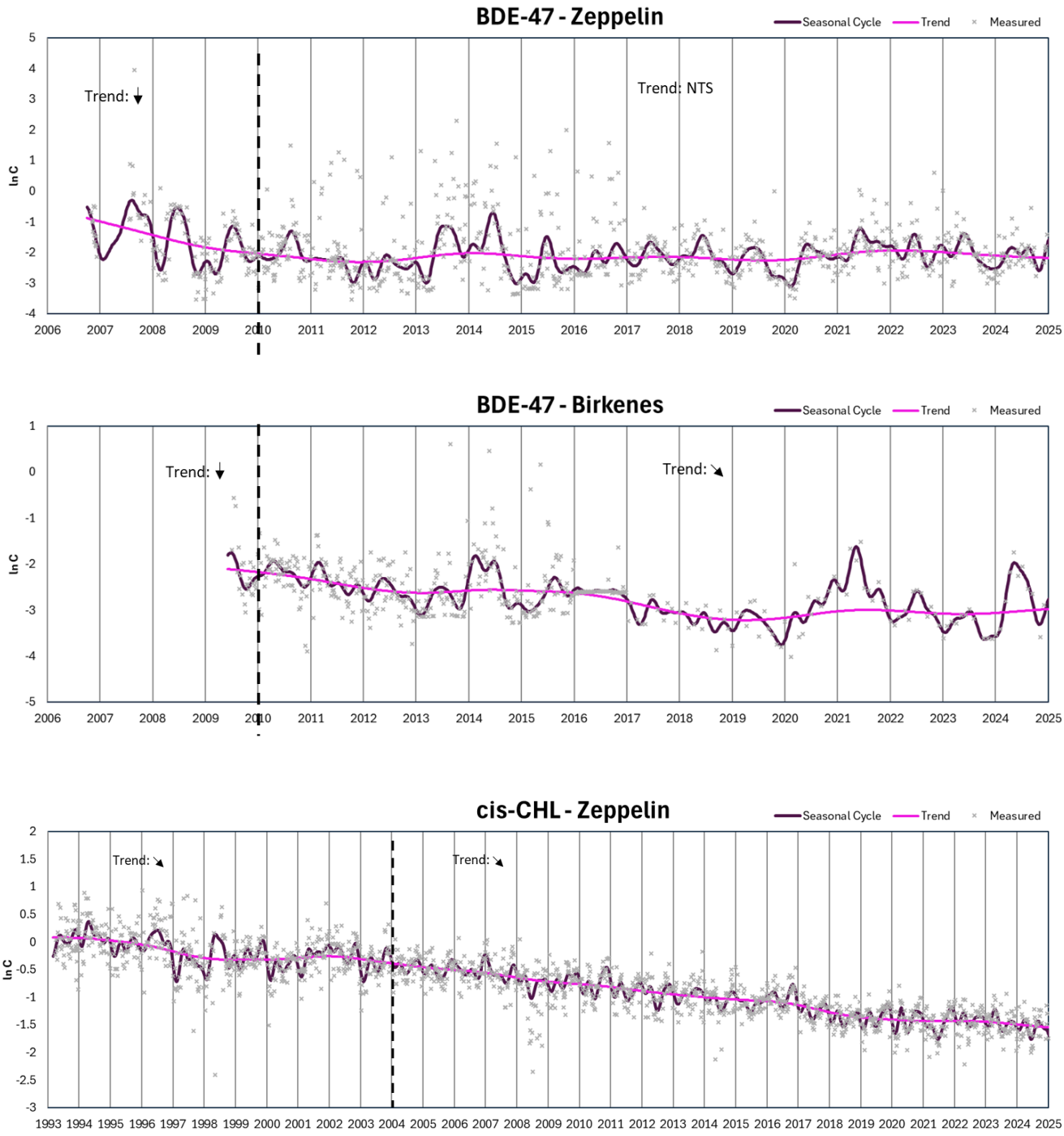


Figure 11: Temporal trends of two selected POPs measured in air at Zeppelin and Birkenes. Air concentrations (pg/m^3) are presented in natural log of concentration (ln C) on the y-axis. The dashed line in black indicates the year when Stockholm Convention was taken into force. The results of trend analyses are indicated by the arrows (↓ : decrease, ↘ : small decrease) or NST when no significant trend was detected.

5 References

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Appendix A Summary of results for individual compounds

Table A 1: Summary of measured concentrations (pg/m³ or ng/m³), detection frequencies (%) and method detection limits (MDL, pg/m³ or ng/m³) of targeted organic contaminants in air at Sofienbergparken in 2024. The colour codes indicate highest detection/concentrations in red, lowest detected concentrations in green and below MDL in white.

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
POPs (pg/m3) **Class of uncertainty: 1-3 (specification for individual compounds below)**							
BDE-17[2]	Gas+particle	11	0.005	100	0.010 - 0.025	0.015	0.012
BDE-28[1]	Gas+particle	11	0.005	100	0.014 - 0.034	0.023	0.023
BDE-47[2]	Gas+particle	11	0.046	100	0.172 - 0.540	0.316	0.265
BDE-49[2]	Gas+particle	11	0.004	100	0.009 - 0.028	0.017	0.018
BDE-66[2]	Gas+particle	11	0.003	83	<0.003 - 0.015	0.010	0.012
BDE-71[2]	Gas+particle	11	0.002	0	<0.002	0.004	<0.002
BDE-77[2]	Gas+particle	11	0.001	0	<0.001	0.003	<0.001
BDE-85[2]	Gas+particle	11	0.006	11	<0.006 - 0.010	<0.006	<0.006
BDE-99[1]	Gas+particle	11	0.020	100	0.064 - 0.175	0.102	0.088
BDE-100[2]	Gas+particle	11	0.007	100	0.017 - 0.045	0.029	0.027
BDE-119[2]	Gas+particle	11	0.002	20	<0.002 - 0.009	0.003	<0.002
BDE-126[2]	Gas+particle	11	0.002	20	<0.002 - 0.009	0.003	<0.002
BDE-138[2]	Gas+particle	11	0.010	20	<0.010 - 0.017	0.011	<0.010
BDE-153[1]	Gas+particle	11	0.006	33	<0.006 - 0.027	0.013	<0.006
BDE-154[2]	Gas+particle	11	0.003	71	<0.006 - 0.022	0.016	0.019
BDE-156[2]	Gas+particle	11	0.010	10	<0.010 - 0.023	0.013	<0.010
BDE-183[1]	Gas+particle	11	0.013	60	<0.013 - 0.038	0.020	0.013
BDE-184[2]	Gas+particle	11	0.004	11	<0.004 - 0.017	0.006	<0.004
BDE-190[2]	Gas+particle	11	0.010	20	<0.010 - 0.015	<0.010	<0.010
BDE-191[2]	Gas+particle	11	0.008	10	<0.008 - 0.018	0.011	<0.008
BDE-196[2]	Gas+particle	11	0.008	11	<0.008 - 0.030	0.010	<0.008
BDE-197[2]	Gas+particle	11	0.008	50	<0.008 - 0.032	0.015	0.008
BDE-202[2]	Gas+particle	11	0.020	22	<0.020 - 0.042	0.023	<0.020
BDE-206[2]	Gas+particle	11	0.036	38	<0.036 - 0.193	0.065	<0.036
BDE-207[2]	Gas+particle	11	0.037	43	<0.037 - 0.091	0.053	<0.037
BDE-209[3]	Gas+particle	11	0.117	100	0.306 - 1.02	0.609	0.644
sum 17 BDE[3] (ref. 2021)					0.663 - 2.221	1.26	1.19
sum 26 BDE[3]					0.756 - 2.494	1.41	1.31
sum 25 BDE (excl. 209)[2]					0.450 - 1.47	0.798	0.667
TBA[2]	Gas+particle	11	0.022	100	3.87 - 14.6	9.19	7.65
α-HBCDD[2]	Gas+particle	11	0.007	60	<0.014 - 0.161	0.052	0.033
β-HBCDD[2]	Gas+particle	11	0.005	0	<0.005	0.015	<0.005
γ-HBCDD[2]	Gas+particle	11	0.009	20	<0.009 - 0.029	0.015	<0.009
sum HBCD					0.029 - 0.221	0.081	0.058

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Ionic and volatile PFAS (pg/m3) Class of uncertainty: 2-4 (specification for individual compounds below)							
TFA[3]	Gas phase	13	5.00	100	15.2 - 373	119	55.7
TFA[3]	Particle phase	12	1.61	50	<1.61 - 10.6	2.64	<1.61
PFPrA[3]	Particle phase	12	0.109	50	<0.109 - 0.982	0.235	<0.109
PFBA[3]	Particle phase	12	0.055	92	<0.055 - 3.999	0.839	0.602
PFPeA[2]	Particle phase	12	0.073	42	<0.073 - 0.870	0.127	<0.073
PFHxA[2]	Particle phase	12	0.073	100	0.078 - 1.47	0.327	0.161
PFHpA[2]	Particle phase	12	0.055	67	<0.055 - 1.05	0.184	0.096
br-PFOA[2]	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
PFOA[2]	Particle phase	12	0.022	83	<0.022 - 0.742	0.191	0.121
PFNA[2]	Particle phase	12	0.022	67	<0.022 - 0.227	0.073	0.061
PFDA[2]	Particle phase	12	0.022	42	<0.022 - 0.137	0.041	<0.022
PFUnA[2]	Particle phase	12	0.022	33	<0.022 - 0.059	0.022	<0.022
PFDoA[2]	Particle phase	12	0.026	92	<0.026 - 0.094	0.049	0.045
PFTrA[2]	Particle phase	12	0.026	0	<0.026	<0.026	<0.026
PFTeA[2]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
PFHxDA[2]	Particle phase	12	0.160	0	<0.160	<0.160	<0.160
PFOcDA[2]	Particle phase	12	0.073	0	<0.073	<0.073	<0.073
Sum C4 - C14 PFCAs	Particle phase	12			0.345 - 5.38	1.88	1.46
TFMS[3]	Particle phase	12	0.380	8	<0.380 - 0.653	<0.380	<0.380
PFEtS[3]	Particle phase	12	0.109	0	<0.109	<0.109	<0.109
PFPrS[3]	Particle phase	12	0.109	0	<0.109	<0.109	<0.109
PFBS[2]	Particle phase	12	0.015	8	<0.015 - 1.721	0.150	<0.015
PFPS[2]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018
PFHxS[2]	Particle phase	12	0.015	8	<0.015 - 0.017	<0.015	<0.015
PFHpS[2]	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
br-PFOS[2]	Particle phase	12	0.015	8	<0.015 - 0.044	<0.015	<0.015
PFOS[2]	Particle phase	12	0.015	92	<0.015 - 0.073	0.040	0.044
PFNS[2]	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
PFDS[2]	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
PFUnS[2]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
PFDoS[2]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
PFTrS[2]	Particle phase	12	0.055	0	<0.055	<0.055	<0.055
Sum C4 - C13 PFSAs	Particle phase	12			0.128 - 1.86	0.304	0.165
Sum C4 - C14 PFAAs	Particle phase	12			0.482 - 5.54	2.19	1.71
4:2 FTSA[2]	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
6:2 FTSA[2]	Particle phase	12	0.036	50	<0.036 - 0.230	0.060	<0.036
8:2 FTSA[2]	Particle phase	12	0.055	0	<0.055	<0.055	<0.055
10:2 FTSA[2]	Particle phase	12	0.055	0	<0.055	<0.055	<0.055
12:2 FTSA[4]	Particle phase	12	0.055	0	<0.055	<0.055	<0.055
FOSA[2]	Particle phase	12	0.073	0	<0.073	<0.073	<0.073
1H-PFHpA[3]	Particle phase	12	0.292	0	<0.292	<0.292	<0.292
PF-3,7-DMOA	Particle phase	12	0.022	0	<0.022	<0.022	<0.022
7:3 FTCA[3]	Particle phase	12	0.055	0	<0.055	<0.055	<0.055
HFPO-DA (GenX)[3]	Particle phase	12	0.109	0	<0.109	<0.109	<0.109
FOSAA[3]	Particle phase	12	0.146	0	<0.146	<0.146	<0.146
MeFOSAA[3]	Particle phase	12	0.026	0	<0.026	<0.026	<0.026
EtFOSAA[3]	Particle phase	12	0.026	0	<0.026	<0.026	<0.026
6:2 F53B[3]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
F53[4]	Particle phase	12	0.109	0	<0.109	<0.109	<0.109
8Cl-PFOS[3]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
4:2 FTOH[3]	Gas phase	12	4.62	0	<4.62	<4.62	<4.62
6:2 FTOH[3]	Gas phase	12	3.18	100	19.4 - 86.1	43.0	39.7
8:2 FTOH[3]	Gas phase	12	2.60	100	14.5 - 97.3	47.8	36.9
10:2 FTOH[3]	Gas phase	12	1.58	100	3.83 - 22.3	11.2	8.58
12:2 FTOH[3]	Gas phase	12	3.16	33	<3.16 - 4.43	<3.16	<3.16
N-Me-FOSA[3]	Gas phase	12	1.22	0	<1.22	<1.22	<1.22
N-Et-FOSA[3]	Gas phase	12	0.747	0	<0.747	<0.747	<0.747
N-Me-FOSE[3]	Gas phase	12	0.599	0	<0.599	<0.599	<0.599
N-Et-FOSE[3]	Gas phase	12	0.610	0	<0.610	<0.610	<0.610
Sum Vol PFAS (basic programme)	Gas phase				50.5 - 202	108	90.2
N-MeFOSEA[3]	Gas phase	13	10.0	0	<10.0	<10.0	<10.0
FBSA[2]	Gas phase	13	1.00	8	<1.00	<1.00	<1.00
N-MeFBSA[2]	Gas phase	13	1.00	46	<1.00 - 6.71	1.88	<1.00
N-EtFBSA[2]	Gas phase	13	1.00	0	<1.00	<1.00	<1.00

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Chlorinated paraffins (pg/m3) Class of uncertainty: 3							
SCCP	Gas+particle	12	11.6	100	33.9 - 321	74.7	52.6
MCCP	Gas+particle	12	33.7	100	54.0 - 842	208	115
Siloxanes (ng/m3) Class of uncertainty: 3							
D4	Gas phase	12	0.600	100	6.89 - 23.6	13.0	11.6
D5	Gas phase	12	8.00	100	66.2 - 298	143	142
D6	Gas phase	12	0.400	100	4.73 - 14.0	8.74	8.19
sum cVMS	Gas phase				77.9 - 336	165	164
L3	Gas phase	12	0.700	100	3.60 - 22.7	9.31	8.38
L4	Gas phase	12	0.400	100	3.81 - 16.0	8.01	7.09
L5	Gas phase	12	0.400	100	3.55 - 16.9	7.58	6.18
M3T(Ph)	Gas phase	12	0.050	100	0.334 - 1.12	0.621	0.621
F3-Sil	Gas phase	12	0.050	0	<0.050	<0.05	<0.05
F4-Sil	Gas phase	12	0.050	0	<0.050	<0.05	<0.05
Ph-D4	Gas phase	12	0.050	0	<0.050	<0.05	<0.05

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
OPFRs (pg/m3) Class of uncertainty: 3-4							
TEP	Gas+particle	***	***	***	***	***	***
TCEP	Gas+particle	10	4.92	100	25.0 - 89.7	45.9	42.4
TCPP (TClPP)	Gas+particle	11	37.7	100	573 - 4760	1680	1260
TPrP (TPP)	Gas+particle	11	0.072	0	<0.072	<0.072	<0.072
TDClPP (TDCPP)	Gas+particle	11	1.31	100	18.6 - 241	55.9	30.5
TPhP (TPP)	Gas+particle	11	31.1	100	38.9 - 711	188	91
TiBP (TBP)	Gas+particle	11	3.21	100	63.3 - 282	152	109
TnBP	Gas+particle	11	2.17	100	34.7 - 99.7	53.1	45.7
TBOEP (TBEP)	Gas+particle	11	3.28	100	9.64 - 40.0	26.7	27.7
DBPhP	Gas+particle	11	2.90	0	<2.90	<2.90	<2.90
TCP (TMPP)	Gas+particle	11	1.75	100	5.04 - 172	45.2	17.4
BdPhP	Gas+particle	11	3.79	0	<3.79	<3.79	<3.79
EHDP (EHDPP)	Gas+particle	11	12.9	100	30.7 - 97.4	56.7	54.1
TXP	Gas+particle	11	3.00	0	<3.00	<3.00	<3.00
TIPPP	Gas+particle	11	1.10	0	<1.10	<1.10	<1.10
TTBPP	Gas+particle	11	10.0	0	<10.0	<10.0	<10.0
TEHP	Gas+particle	11	23.5	64	<23.5 - 194	73.5	60.5
TDBPP	Gas+particle	11	100	0	<100	<100	<100
T2B4MP[4]	Gas+particle	11	10.0	0	<10.0	<10.0	<10.0
T4B3MP[4]	Gas+particle	11	10.0	0	<10.0	<10.0	<10.0
T3B4MP[4]	Gas+particle	11	10.0	0	<10.0	<10.0	<10.0
V6	Gas+particle	11	2.00	0	<2.00	<2.00	<2.00
nBFRs (pg/m3) Class of uncertainty: 2							
ATE (TBP-AE)	Gas+particle	10	0.010	30	<0.01 - 0.015	<0.010	<0.010
a-TBECH	Gas+particle	10	0.040	100	0.695 - 7.16	3.54	3.36
b-TBECH	Gas+particle	10	0.029	100	0.426 - 3.60	1.98	2.05
g/d-TBECH	Gas+particle	10	0.020	30	<0.020 - 0.106	0.036	<0.020
BATE	Gas+particle	10	0.012	50	<0.012 - 0.043	0.014	<0.012
PBT	Gas+particle	10	0.042	100	0.204 - 1.73	0.514	0.356
PBEB	Gas+particle	10	0.014	60	<0.014 - 0.052	0.027	0.026
PBBZ	Gas+particle	10	0.044	100	0.153 - 0.902	0.434	0.379
pTBX	Gas+particle	10	0.064	100	0.133 - 0.712	0.375	0.321
HBB	Gas+particle	10	0.061	100	0.142 - 0.303	0.203	0.186
DPTE	Gas+particle	10	0.015	100	0.090 - 0.579	0.304	0.260
EHTBB	Gas+particle	10	0.019	100	0.241 - 1.26	0.542	0.477
BTBPE	Gas+particle	10	0.035	20	<0.035 - 0.095	<0.035	<0.035
TBPH (BEH /TBP)	Gas+particle	10	0.086	100	0.244 - 2.24	0.827	0.519
DBDPE	Gas+particle	10	1.35	80	<1.35 - 8.18	2.59	2.01
Sum nBFR (excl. DBDPE)	Gas+particle	10			3.08 - 13.2	8.84	9.92
TBBPA[3]	Gas+particle	10	0.046	100	2.59 - 13.1	7.27	6.88
2,2-dimethylpropan-1-ol, tribromo der.	Gas phase	13	50	0	<50.0	<50.0	<50.0
2,3,4,5-Tetrabromo-6-chlorotoluene	Gas phase	13	0.500	0	<0.500	<0.500	<0.500
2,3,5,6-Tetrabromo-p-xylene	Gas phase	13	0.500	31	<0.500	<0.500	<0.500
Brominated/Chlorinated Methanes (pg/m3) Class of uncertainty: 2-3							
$CHBr_3$	Gas phase	11	10.0	100	366 - 4680	1470	825
$CHBrCl_2$	Gas phase	13	10.0	0	<10.0	<10.0	<10.0
CH_2ClBr	Gas phase	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

SOFIENBERGPARKEN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Dechloranes (pg/m3) Class of uncertainty: 2							
syn-DP	Gas+particle	12	0.114	100	<0.114 - 0.755	0.195	0.145
anti-DP	Gas+particle	12	0.172	92	<0.172 - 0.874	0.243	0.173
Dec 601	Gas+particle	12	0.024	0	<0.024	<0.024	<0.024
Dec 602	Gas+particle	12	0.024	0	<0.024	<0.024	<0.024
Dec 603	Gas+particle	12	0.021	0	<0.021	<0.021	<0.021
Dec 604	Gas+particle	12	0.240	0	<0.240	<0.24	<0.24
Dec 604B	Gas+particle	12	0.207	0	<0.207	0.229	<0.207
Dibromoaldrin	Gas+particle	12	0.230	0	<0.230	<0.23	<0.230
Chlordene plus	Gas+particle	12	0.065	0	<0.065	<0.065	<0.065
Dechlorane plus Cl10	Gas+particle	12	0.015	0	<0.015	<0.015	<0.015
Dechlorane plus axx Cl10	Gas+particle	12	0.021	0	<0.021	<0.021	<0.021
Dechlorane plus ax Cl11	Gas+particle	12	0.018	0	<0.018	<0.018	<0.018
Dechlorane plus Cl11	Gas+particle	12	0.018	0	<0.018	<0.018	<0.018
Chlorendic anhydride[3]	Gas phase	13	250	0	<250	<250	<250
Volatile fluorinated and chlorinated substances (pg/m3) Class of uncertainty: 3							
PFTBA	Gas phase	11	50.0	100	2170 - 5330	2750	2430
TCPFB	Gas phase	11	10.0	100	18.7 - 230	88.4	75.0
PFTPeA	Gas phase	11	10.0	100	45.8 - 79.2	57.7	55.2
HCBD	Gas phase	11	5.00	100	1680 - 2630	1970	1850
PFPHP	Gas phase	11	10.0	100	11.8 - 33.5	22.4	22.2
DCTFP	Gas phase	11	1.00	9	<1.00 - 1.33	<1.00	<1.00
PCTol	Gas phase	11	5.00	18	<5.00 - 8.21	<5.00	<5.00
DCPFcH	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBB	Gas phase	11	0.200	0	<0.200	<0.200	<0.200
bTFMBB	Gas phase	11	1.00	0	<1.00	<1.00	<1.00
2,3-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
3,4-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBCH	Gas phase	11	100	0	<100	<100	<100
UV Substances (pg/m3) Class of uncertainty: 2-3 (specification for individual compounds below)							
2-EthylHexyl-4-MethoxyCinnamate[2]	Gas+particle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Octocrylene[2]	Gas+particle	12	15.0	100	34.8 - 260	85.2	78.4
OxyBenzone[2]	Gas+particle	12	10.0	67	<10.0 - 117	15.3	14.3
Accelerator CZ[3]	Gas+particle	12	100	0	<100	<100	<100
UV-320(tBu2)[2]	Gas+particle	12	2.50	0	<2.50	<2.50	<2.50
UV-326(Me,tBu,Cl)[2]	Gas+particle	12	2.50	50	<2.50 - 13.0	3.07	3.35
UV-327(tBu2,Cl)[2]	Gas+particle	12	5.00	0	<5.00	<5.00	<5.00
UV-328(tAm2)[2]	Gas+particle	12	0.380	100	0.591 - 103	2.42	1.55
UV-329(tOct)[2]	Gas+particle	12	1.150	100	1.277 - 71.7	5.49	4.30
Tolyltriazole[3]	Gas+particle	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
PCA and PCP (pg/m3) Class of uncertainty: 2-3 (specification for individual compounds below)							
Pentachloroanisole[2]	Gas phase	12	1.000	100	4.40 - 28.6	13.0	13.5
Pentachlorophenol[3]	Gas phase	12	0.600	33	<0.600 - 3.67	<0.600	<0.600

*MDLs are presented as a guidance based on average sample volume per compound group. The MDL is however variable over the year due to variable sample volume and analytical conditions.

**No standards available, not analysed (n.a.)

***Method under development/no recovery of internal standard (n.d.)

Table A 2: Summary of measured concentrations (pg/m³ or ng/m³), detection frequencies (%) and method detection limits (MDL, pg/m³ or ng/m³) of targeted organic contaminants in air at Birkenes in 2024. The colour codes indicate highest detection/concentrations in red, lowest detected concentrations in green and below MDL in white.

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
POPs (pg/m3) **Class of uncertainty:1-2 (specification for individual compounds below)**							
HCB[1]	Gas+particle	52	0.473	100	19.8 - 55.0	36.1	37.9
α-HCH[1]	Gas+particle	12	0.023	100	1.41 - 10.1	2.85	2.61
γ-HCH[1]	Gas+particle	12	0.034	100	0.235 - 3.48	1.50	1.23
p,p'-DDT[1]	Gas+particle	12	0.010	100	0.022 - 0.750	0.198	0.115
o,p'-DDT[1]	Gas+particle	12	0.009	100	0.032 - 0.706	0.198	0.100
p,p'-DDE[1]	Gas+particle	12	0.025	100	0.242 - 3.27	0.783	0.452
o,p'-DDE[1]	Gas+particle	12	0.004	90	<0.004 - 0.125	0.046	0.028
p,p'-DDD[1]	Gas+particle	12	0.005	36	<0.005 - 0.028	0.008	<0.005
o,p'-DDD[1]	Gas+particle	12	0.005	75	<0.005 - 0.036	0.013	0.012
Sum DDT[1]	Gas+particle				0.330 - 4.29	1.31	0.833
PCB-18[1]	Gas+particle	52	0.031	100	0.222 - 3.99	0.933	0.679
PCB-28[1]	Gas+particle	52	0.029	100	0.168 - 3.18	0.576	0.399
PCB-31[1]	Gas+particle	52	0.027	100	0.138 - 2.47	0.516	0.38
PCB-33[1]	Gas+particle	52	0.019	100	0.074 - 1.36	0.282	0.201
PCB-37[1]	Gas+particle	52	0.007	98	<0.007 - 0.153	0.043	0.033
PCB-47[1]	Gas+particle	52	0.065	100	0.093 - 1.53	0.452	0.362
PCB-52[1]	Gas+particle	52	0.036	100	0.181 - 2.77	0.622	0.467
PCB-66[1]	Gas+particle	52	0.015	100	0.031 - 0.665	0.140	0.102
PCB-74[1]	Gas+particle	52	0.010	100	0.023 - 0.471	0.096	0.070
PCB-99[1]	Gas+particle	52	0.008	100	0.031 - 0.732	0.134	0.109
PCB-101[1]	Gas+particle	52	0.027	100	0.074 - 1.52	0.368	0.286
PCB-105[1]	Gas+particle	52	0.004	100	0.007 - 0.159	0.025	0.018
PCB-114[1]	Gas+particle	52	0.001	41	<0.001 - 0.015	0.002	<0.001
PCB-118[1]	Gas+particle	52	0.011	100	0.021 - 0.521	0.092	0.070
PCB-122[1]	Gas+particle	52	0.001	26	<0.001 - 0.008	0.002	<0.001
PCB-123[1]	Gas+particle	52	0.001	64	<0.001 - 0.017	0.004	0.003
PCB-128[1]	Gas+particle	52	0.002	94	<0.002 - 0.074	0.016	0.013
PCB-138[1]	Gas+particle	52	0.015	100	0.018 - 0.468	0.121	0.093
PCB-141[1]	Gas+particle	52	0.004	100	0.005 - 0.129	0.035	0.027
PCB-149[1]	Gas+particle	52	0.017	100	0.031 - 0.790	0.249	0.190
PCB-153[1]	Gas+particle	52	0.023	100	0.029 - 0.717	0.211	0.168
PCB-156[1]	Gas+particle	52	0.002	82	<0.002 - 0.022	0.005	0.005
PCB-157[1]	Gas+particle	52	0.001	20	<0.001 - 0.004	<0.001	<0.001
PCB-167[1]	Gas+particle	52	0.001	67	<0.001 - 0.013	0.003	0.003
PCB-170[1]	Gas+particle	52	0.004	87	<0.004 - 0.043	0.012	0.009
PCB-180[1]	Gas+particle	52	0.008	98	<0.008 - 0.124	0.038	0.032
PCB-183[1]	Gas+particle	52	0.002	98	<0.003 - 0.055	0.017	0.015
PCB-187[1]	Gas+particle	52	0.006	98	<0.007 - 0.137	0.051	0.046
PCB-189[1]	Gas+particle	52	0.002	2	<0.002 - 0.004	<0.002	<0.002
PCB-194[1]	Gas+particle	52	0.002	36	<0.002 - 0.008	0.003	<0.002
PCB-206[1]	Gas+particle	52	0.002	14	<0.002 - 0.014	0.003	<0.002
PCB-209[1]	Gas+particle	52	0.002	54	<0.002 - 0.043	0.004	0.002
sum 7 PCB[1]	Gas+particle				0.498 - 9.30	2.03	1.52
sum 32 PCB[1]	Gas+particle				1.19 - 22.2	5.06	3.79
sum PCB[1]	Gas+particle				1.90 - 35.4	7.72	5.84

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
BDE-17[2]	Gas+particle	12	0.003	78	<0.003 - 0.006	0.004	0.004
BDE-28[1]	Gas+particle	12	0.002	100	0.003 - 0.013	0.006	0.006
BDE-47[2]	Gas+particle	12	0.024	100	0.028 - 0.174	0.080	0.071
BDE-49[2]	Gas+particle	12	0.002	90	<0.002 - 0.017	0.007	0.006
BDE-66[2]	Gas+particle	12	0.001	90	<0.001 - 0.010	0.005	0.004
BDE-71[2]	Gas+particle	12	0.001	20	<0.001 - 0.003	<0.001	<0.001
BDE-77[2]	Gas+particle	12	0.001	0	<0.001	<0.001	<0.001
BDE-85[2]	Gas+particle	12	0.003	0	<0.003	<0.003	<0.003
BDE-99[1]	Gas+particle	12	0.011	73	<0.011 - 0.043	0.022	0.027
BDE-100[2]	Gas+particle	12	0.004	73	<0.004 - 0.010	0.006	0.005
BDE-119[2]	Gas+particle	12	0.001	0	<0.001	0.001	<0.001
BDE-126[2]	Gas+particle	12	0.001	0	<0.001	0.001	<0.001
BDE-138[2]	Gas+particle	12	0.005	0	<0.005	0.007	<0.005
BDE-153[1]	Gas+particle	12	0.003	0	<0.003	0.006	<0.003
BDE-154[2]	Gas+particle	12	0.002	18	<0.002 - 0.009	0.004	<0.002
BDE-156[2]	Gas+particle	12	0.005	0	<0.005	0.009	<0.005
BDE-183[1]	Gas+particle	12	0.007	0	<0.007	0.007	<0.007
BDE-184[2]	Gas+particle	12	0.002	0	<0.002	<0.002	<0.002
BDE-190[2]	Gas+particle	12	0.006	0	<0.006	<0.006	<0.006
BDE-191[2]	Gas+particle	12	0.004	0	<0.004	0.005	<0.004
BDE-196[2]	Gas+particle	12	0.004	0	<0.004	0.005	<0.004
BDE-197[2]	Gas+particle	12	0.004	0	<0.004	0.005	<0.004
BDE-202[2]	Gas+particle	12	0.011	0	<0.011	0.011	<0.011
BDE-206[2]	Gas+particle	12	0.019	0	<0.019	0.019	<0.019
BDE-207[2]	Gas+particle	12	0.020	0	<0.020	<0.020	<0.020
BDE-209[3]	Gas+particle	12	0.062	64	<0.062 - 0.440	0.144	0.084
sum 17 BDE[3] (ref. 2021)	Gas+particle				0.155 - 0.783	0.325	0.251
sum 26 BDE[3]	Gas+particle				0.208 - 0.861	0.387	0.308
sum 25 BDE (excl. 209)[2]	Gas+particle				0.146 - 0.421	0.242	0.224
TBA[2]	Gas+particle	12	0.012	100	1.57 - 10.1	4.91	4.53
α-HBCDD[2]	Gas+particle	12	0.004	18	<0.004 - 0.020	0.007	<0.004
β-HBCDD[2]	Gas+particle	12	0.002	18	<0.002 - 0.005	0.003	<0.002
γ-HBCDD[2]	Gas+particle	12	0.005	0	<0.005	0.005	<0.005

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
PAHs (ng/m3) Class of uncertainty:1							
1-Methylnaphthalene	Gas+particle	52	0.011	71	<0.011 - 0.166	0.040	0.024
1-Methylphenanthrene	Gas+particle	52	0.003	100	0.010 - 0.099	0.034	0.028
2-Methylanthracene	Gas+particle	52	0.008	4	<0.008 - 0.012	0.008	<0.008
2-Methylnaphthalene	Gas+particle	52	0.016	71	<0.016 - 0.197	0.048	0.029
2-Methylphenanthrene	Gas+particle	52	0.007	100	0.012 - 0.108	0.043	0.038
3-Methylphenanthrene	Gas+particle	52	0.003	100	0.010 - 0.089	0.038	0.035
9-Methylphenanthrene	Gas+particle	52	0.003	100	0.004 - 0.038	0.015	0.013
Acenaphthene*	Gas+particle	52	0.009	96	<0.011 - 0.286	0.061	0.043
Acenaphthylene*	Gas+particle	52	0.004	48	<0.004 - 0.252	0.025	<0.004
Anthanthrene	Gas+particle	52	0.001	37	<0.001 - 0.012	0.002	<0.001
Anthracene*	Gas+particle	52	0.003	50	<0.003 - 0.124	0.011	0.004
Benz(a)anthracene*	Gas+particle	52	0.001	94	<0.001 - 0.037	0.008	0.004
Benzo(a)fluoranthene	Gas+particle	52	0.001	42	<0.001 - 0.016	0.003	<0.001
Benzo(a)fluorene	Gas+particle	52	0.002	81	<0.002 - 0.031	0.006	0.004
Benzo(a)pyrene*	Gas+particle	52	0.001	96	<0.001 - 0.052	0.010	0.005
Benzo(b)fluoranthene*	Gas+particle	52	0.001	100	0.006 - 0.093	0.027	0.018
Benzo(b)fluorene	Gas+particle	52	0.002	46	<0.002 - 0.031	0.004	<0.002
Benzo(e)pyrene	Gas+particle	52	0.001	100	0.003 - 0.059	0.017	0.011
Benzo(ghi)fluoranthene	Gas+particle	52	0.001	100	0.011 - 0.011	0.011	0.011
Benzo(ghi)perylene*	Gas+particle	52	0.001	100	0.002 - 0.078	0.020	0.013
Benzo(j)fluoranthene	Gas+particle	52	0.001	100	0.002 - 0.051	0.012	0.006
Benzo(k)fluoranthene*	Gas+particle	52	0.001	100	0.002 - 0.042	0.010	0.006
Biphenyl	Gas+particle	52	0.000	100	0.020 - 0.788	0.149	0.064
Chrysene*	Gas+particle	52	0.001	100	0.006 - 0.093	0.026	0.017
Coronene	Gas+particle	52	0.002	85	<0.002 - 0.045	0.009	0.005
Cyclopenta(cd)pyrene	Gas+particle	52	0.001	29	<0.001 - 0.003	0.002	<0.001
Dibenzo(ac)anthracene	Gas+particle	52	0.001	29	<0.001 - 0.005	0.002	<0.001
Dibenzo(ae)pyrene	Gas+particle	52	0.002	40	<0.002 - 0.011	0.003	<0.002
Dibenzo(ah)anthracene*	Gas+particle	52	0.001	44	<0.001 - 0.008	0.002	<0.001
Dibenzo(ah)pyrene	Gas+particle	52	0.002	0	<0.002	0.002	<0.002
Dibenzo(ai)pyrene	Gas+particle	52	0.002	2	<0.002 - 0.004	0.002	<0.002
Dibenzofuran	Gas+particle	52	0.009	100	0.074 - 2.20	0.520	0.277
Dibenzothiophene	Gas+particle	52	0.004	98	<0.004 - 0.068	0.019	0.017
Fluoranthene*	Gas+particle	52	0.005	100	0.044 - 0.429	0.152	0.111
Fluorene*	Gas+particle	52	0.006	100	0.060 - 1.47	0.384	0.254
Indeno(123-cd)pyrene*	Gas+particle	52	0.001	100	0.002 - 0.083	0.020	0.011
Naphthalene*	Gas+particle	52	0.046	48	<0.046 - 0.630	0.106	<0.046
Perylene	Gas+particle	52	0.001	35	<0.001 - 0.008	0.002	<0.001
Phenanthrene*	Gas+particle	52	0.016	100	0.211 - 1.64	0.697	0.628
Pyrene*	Gas+particle	52	0.002	100	0.016 - 0.280	0.074	0.053
Retene	Gas+particle	52	0.005	98	<0.005 - 0.078	0.033	0.030
triphenylene	Gas+particle	52	0.001	100	0.002 - 0.023	0.007	0.005
Sum 39 PAH (ref. 2021)	Gas+particle				0.617 - 9.68	2.65	1.83
Sum 42 PAH	Gas+particle				0.622 - 9.75	2.67	1.84
Sum 16 PAH(*)	Gas+particle				0.415 - 5.60	1.64	1.22

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Ionic and volatile PFAS (pg/m3) Class of uncertainty: 2-3 (specification for individual compounds below)							
TFA[3]	Particle phase	12	0.802	67	<0.802 - 9.80	3.43	2.24
PFPrA[3]	Particle phase	12	0.054	75	<0.054 - 0.449	0.179	0.165
PFBA[3]	Particle phase	12	0.027	100	0.305 - 2.37	1.11	0.864
PFPeA[2]	Particle phase	12	0.036	33	<0.036 - 0.077	<0.036	<0.036
PFHxA[2]	Particle phase	12	0.036	83	<0.036 - 0.229	0.098	0.075
PFHpA[2]	Particle phase	12	0.027	75	<0.027 - 0.180	0.074	0.06
br-PFOA[2]	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
PFOA[2]	Particle phase	12	0.011	100	0.018 - 0.190	0.088	0.073
PFNA[2]	Particle phase	12	0.011	100	0.019 - 0.146	0.065	0.053
PFDA[2]	Particle phase	12	0.011	33	<0.011 - 0.057	0.017	<0.011
PFUnA[2]	Particle phase	12	0.011	33	<0.011 - 0.035	0.013	<0.011
PFDoA[2]	Particle phase	12	0.013	25	<0.013 - 0.032	<0.013	<0.013
PFTrA[2]	Particle phase	12	0.013	8	<0.013 - 0.015	<0.013	<0.013
PFTeA[2]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018
PFHxDA[2]	Particle phase	12	0.080	0	<0.080	<0.080	<0.080
PFOcDA[2]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
Sum C4 - C14 PFCAs	Particle phase				0.914 - 2.50	1.52	1.42
TFMS[3]	Particle phase	12	0.054	0	<0.054	<0.054	<0.054
PFEtS[3]	Particle phase	12	0.054	0	<0.054	<0.054	<0.054
PFPrS[3]	Particle phase	12	0.054	0	<0.054	<0.054	<0.054
PFBS[2]	Particle phase	12	0.007	0	<0.007	<0.007	<0.007
PFPS[2]	Particle phase	12	0.009	0	<0.009	<0.009	<0.009
PFHxS[2]	Particle phase	12	0.007	8	<0.007 - 0.017	<0.007	<0.007
PFHpS[2]	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
br-PFOS[2]	Particle phase	12	0.007	58	<0.007 - 0.055	0.014	0.009
PFOS[2]	Particle phase	12	0.007	92	<0.007 - 0.071	0.025	0.019
PFNS[2]	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
PFDS[2]	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
PFUnS[2]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018
PFDoS[2]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018
PFTrS[2]	Particle phase	12	0.027	0	<0.027	<0.027	<0.027
Sum C4 - C13 PFSAs	Particle phase				0.063 - 0.144	0.086	0.079
Sum C4 - C14 PFAAs					1.02 - 2.57	1.61	1.51
4:2 FTSA[2]	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
6:2 FTSA[2]	Particle phase	12	0.018	67	<0.018 - 0.063	0.029	0.027
8:2 FTSA[2]	Particle phase	12	0.027	0	<0.027	<0.027	<0.027
10:2 FTSA[2]	Particle phase	12	0.027	0	<0.027	<0.027	<0.027
12:2 FTSA[4]	Particle phase	12	0.027	0	<0.027	<0.027	<0.027
FOSA[2]	Particle phase	12	0.036	0	<0.036	<0.036	<0.036
1H-PFHpA[3]	Particle phase	12	0.145	0	<0.145	<0.145	<0.145
PF-3,7-DMOA	Particle phase	12	0.011	0	<0.011	<0.011	<0.011
7:3 FTCA[3]	Particle phase	12	0.027	0	<0.027	<0.027	<0.027
HFPO-DA (GenX)[3]	Particle phase	12	0.054	0	<0.054	<0.054	<0.054
FOSAA[3]	Particle phase	12	0.073	0	<0.073	<0.073	<0.073
MeFOSAA[3]	Particle phase	12	0.013	0	<0.013	<0.013	<0.013
EtFOSAA[3]	Particle phase	12	0.013	0	<0.013	<0.013	<0.013
6:2 F53B[3]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018
F53[4]	Particle phase	12	0.054	0	<0.054	<0.054	<0.054
8Cl-PFOS[3]	Particle phase	12	0.018	0	<0.018	<0.018	<0.018

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
4:2 FTOH[3]	Gas phase	12	2.28	0	<2.28	<2.28	<2.28
6:2 FTOH[3]	Gas phase	12	1.57	100	3.26 - 25.3	8.41	5.24
8:2 FTOH[3]	Gas phase	12	1.29	100	2.21 - 11.3	5.58	4.81
10:2 FTOH[3]	Gas phase	12	0.782	100	0.924 - 4.29	2.24	2.03
12:2 FTOH[3]	Gas phase	12	1.56	17	<1.56 - 2.12	<1.56	<1.56
N-Me-FOSA[3]	Gas phase	12	0.602	0	<0.602	<0.602	<0.602
N-Et-FOSA[3]	Gas phase	12	0.369	0	<0.369	<0.369	<0.369
N-Me-FOSE[3]	Gas phase	12	0.296	0	<0.296	<0.296	<0.296
N-Et-FOSE[3]	Gas phase	12	0.301	0	<0.301	<0.301	<0.301
Sum Vol PFAS	Gas phase				10.4 - 44.8	19.2	13.7

BIRKENES – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Chlorinated paraffins (pg/m3) Class of uncertainty: 3							
SCCP	Gas+particle	12	23.4	92	<23.4 - 43.1	28.4	30.3
MCCP	Gas+particle	12	68	33	<68.2 - 182	<68.2	<68.2
Siloxanes (ng/m3) Class of uncertainty: 3							
D4	Gas phase	12	0.080	100	0.408 - 2.32	1.37	1.45
D5	Gas phase	12	0.460	100	1.07 - 8.39	4.67	4.50
D6	Gas phase	12	0.040	100	0.082 - 0.515	0.279	0.261
sum cVMS	Gas phase				1.57 - 11.1	6.31	6.40
Brominated/Chlorinated Methanes (pg/m3) Class of uncertainty: 3							
$CHBr_3$	Gas phase	11	10.0	100	467 - 3760	1910	1460

Volatile fluorinated and chlorinated substances (pg/m3) Class of uncertainty: 3							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
PFTBA	Gas phase	11	50.0	100	1550 - 2480	2160	2150
TCPFB	Gas phase	11	10.0	100	30.5 - 207	119	90.2
PFTPeA	Gas phase	11	10.0	100	68.8 - 107	80.5	81.1
HCBD	Gas phase	11	5.00	100	1770 - 2210	1960	1930
PFPHP	Gas phase	11	10.0	100	13.4 - 40.0	24.9	24.3
DCTFP	Gas phase	11	1.00	0	<1.00	<1.00	<1.00
PCTol	Gas phase	11	5.00	64	<5.00 - 8.99	5.48	5.59
DCPFcH	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBB	Gas phase	11	0.200	0	<0.200	<0.200	<0.200
bTFMBB	Gas phase	11	1.00	0	<1.00	<1.00	<1.00
2,3-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
3,4-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBCH	Gas phase	11	100	0	<100	<100	<100

*MDLs are presented as a guidance based on average sample volume per compound group. The MDL is however variable over the year due to variable sample volume and analytical conditions.

**No standards available, not analysed (n.a.)

***Method under development/no recovery of internal standard (n.d.)

Table A 3: Summary of measured concentrations (ng/L), detection frequencies (%) and method detection limits (MDL, ng/L) of POPs in precipitation at Birkenes in 2024. The colour codes indicate highest concentrations in red, lowest detected concentrations in green and below MDL in white.

BIRKENES – Precipitation							
POPs (ng/L) Class of uncertainty:1							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean****	**Annual median**
HCB	Precipitation	49	0.050	36	<0.050 - 0.499	0.070	<0.050
α-HCH	Precipitation	49	0.036	74	<0.036 - 0.365	0.064	0.065
β-HCH	Precipitation	49	0.015	36	<0.015 - 0.149	0.021	<0.015
γ-HCH	Precipitation	49	0.022	91	<0.022 - 0.406	0.159	0.148
PCB-28	Precipitation	49	0.024	20	<0.024 - 0.247	0.025	<0.024
PCB-52	Precipitation	49	0.008	42	<0.008 - 0.081	0.009	<0.008
PCB-101	Precipitation	49	0.014	33	<0.014 - 0.138	0.014	<0.014
PCB-118	Precipitation	49	0.007	7	<0.007 - 0.069	0.007	<0.007
PCB-138	Precipitation	49	0.006	27	<0.006 - 0.061	<0.006	<0.006
PCB-153	Precipitation	49	0.009	29	<0.009 - 0.088	0.009	<0.009
PCB-180	Precipitation	49	0.003	30	<0.003 - 0.026	0.003	<0.003
sum PCB-7	Precipitation				0.035 - 0.710	0.074	0.073

*MDLs are presented as a guidance based on median sample volume per compound group. The MDL is however variable over the year due to variable sample volume and analytical conditions.

** Annual mean concentrations in precipitation are weighted using the weekly concentrations and precipitation amounts to derive so-called volume-weighted concentrations (ng/L).

Table A 4: Summary of measured concentrations (pg/m³ or ng/m³), detection frequencies (%) and method detection limits (MDL, pg/m³ or ng/m³) of targeted organic contaminants at Zeppelin in 2024. The colour codes indicate highest detection/concentrations in red, lowest detected concentrations in green and below MDL in white.

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
POPs (pg/m3) **Class of uncertainty:1-2 (specification for individual compounds below)**							
HCB[1]	Gas+particle	45	0.260	100	38.9 - 63.6	49.6	50.1
α-HCH[1]	Gas+particle	45	0.013	100	1.23 - 3.75	2.23	2.08
γ-HCH[1]	Gas+particle	45	0.019	100	0.303 - 2.56	0.496	0.413
p,p'-DDT[1]	Gas+particle	45	0.005	77	<0.005 - 0.066	0.027	0.024
o,p'-DDT[1]	Gas+particle	45	0.005	98	<0.006 - 0.107	0.048	0.042
p,p'-DDE[1]	Gas+particle	45	0.014	100	0.021 - 0.668	0.198	0.094
o,p'-DDE[1]	Gas+particle	45	0.002	98	<0.002 - 0.083	0.028	0.015
p,p'-DDD[1]	Gas+particle	45	0.003	16	<0.003 - 0.01	0.004	<0.003
o,p'-DDD[1]	Gas+particle	45	0.003	50	<0.003 - 0.015	0.005	0.004
Sum DDT[1]	Gas+particle				0.047 - 0.936	0.301	0.194
cis-CD[1]	Gas+particle	44	0.013	100	0.135 - 0.339	0.225	0.219
cis-NO[1]	Gas+particle	44	0.008	86	<0.008 - 0.044	0.020	0.020
trans-CD[1]	Gas+particle	44	0.008	100	0.025 - 0.191	0.080	0.064
trans-NO[1]	Gas+particle	44	0.008	100	0.123 - 0.323	0.201	0.194
Sum Chlordane[1]	Gas+particle				0.290 - 0.897	0.525	0.497
PCB-18[1]	Gas+particle	45	0.017	100	0.269 - 1.98	0.680	0.655
PCB-28[1]	Gas+particle	45	0.016	100	0.292 - 1.85	0.592	0.513
PCB-31[1]	Gas+particle	45	0.015	100	0.248 - 2.34	0.568	0.473
PCB-33[1]	Gas+particle	45	0.011	100	0.193 - 1.04	0.375	0.316
PCB-37[1]	Gas+particle	45	0.004	100	0.043 - 0.216	0.095	0.083
PCB-47[1]	Gas+particle	45	0.036	96	<0.089 - 0.309	0.189	0.180
PCB-52[1]	Gas+particle	45	0.020	100	0.162 - 0.688	0.346	0.340
PCB-66[1]	Gas+particle	45	0.008	100	0.051 - 0.201	0.115	0.110
PCB-74[1]	Gas+particle	45	0.006	100	0.033 - 0.157	0.080	0.074
PCB-99[1]	Gas+particle	45	0.004	100	0.035 - 0.138	0.074	0.070
PCB-101[1]	Gas+particle	45	0.015	100	0.102 - 0.397	0.194	0.186
PCB-105[1]	Gas+particle	45	0.002	100	0.007 - 0.118	0.022	0.018
PCB-114[1]	Gas+particle	45	0.001	51	<0.001 - 0.006	0.002	0.002
PCB-118[1]	Gas+particle	45	0.006	100	0.028 - 0.278	0.066	0.058
PCB-122[1]	Gas+particle	45	0.001	30	<0.001 - 0.005	0.002	<0.001
PCB-123[1]	Gas+particle	45	0.001	59	<0.001 - 0.004	0.002	0.002
PCB-128[1]	Gas+particle	45	0.001	98	<0.002 - 0.068	0.010	0.008
PCB-138[1]	Gas+particle	45	0.008	100	0.026 - 0.256	0.058	0.048
PCB-141[1]	Gas+particle	45	0.002	100	0.007 - 0.054	0.015	0.013
PCB-149[1]	Gas+particle	45	0.009	100	0.059 - 0.261	0.101	0.094
PCB-153[1]	Gas+particle	45	0.013	100	0.038 - 0.223	0.083	0.071
PCB-156[1]	Gas+particle	45	0.001	84	<0.001 - 0.032	0.004	0.003
PCB-157[1]	Gas+particle	45	0.001	14	<0.001 - 0.006	0.001	<0.001
PCB-167[1]	Gas+particle	45	0.001	63	<0.001 - 0.011	0.002	0.001
PCB-170[1]	Gas+particle	45	0.002	86	<0.002 - 0.020	0.004	0.004
PCB-180[1]	Gas+particle	45	0.005	88	<0.005 - 0.032	0.012	0.011
PCB-183[1]	Gas+particle	45	0.001	95	<0.002 - 0.017	0.006	0.005
PCB-187[1]	Gas+particle	45	0.003	100	0.008 - 0.054	0.017	0.014
PCB-189[1]	Gas+particle	45	0.001	0	<0.001	<0.001	<0.001
PCB-194[1]	Gas+particle	45	0.001	19	<0.001 - 0.003	<0.001	<0.001
PCB-206[1]	Gas+particle	45	0.001	20	<0.001 - 0.014	0.002	<0.001
PCB-209[1]	Gas+particle	45	0.001	71	<0.001 - 0.016	0.003	0.003
sum 7 PCB[1]	Gas+particle				0.653 - 3.72	1.35	1.23
sum 32 PCB[1]	Gas+particle				1.71 - 10.8	3.72	3.36
sum PCB[1]	Gas+particle				2.63 - 13.8	5.68	5.50

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
POPs (pg/m3) **Class of uncertainty:1-2 (specification for individual compounds below)**							
BDE-17[2]	Gas+particle	45	0.004	20	<0.004 - 0.007	0.004	<0.004
BDE-28[1]	Gas+particle	45	0.004	100	0.004 - 0.015	0.008	0.007
BDE-47[2]	Gas+particle	45	0.035	100	0.050 - 0.578	0.146	0.122
BDE-49[2]	Gas+particle	45	0.003	77	<0.003 - 0.160	0.014	0.005
BDE-66[2]	Gas+particle	45	0.002	80	<0.002 - 0.175	0.008	0.003
BDE-71[2]	Gas+particle	45	0.001	13	<0.001 - 0.158	0.005	<0.001
BDE-77[2]	Gas+particle	45	0.001	5	<0.001 - 0.005	0.001	<0.001
BDE-85[2]	Gas+particle	45	0.005	2	<0.005 - 0.008	0.005	<0.005
BDE-99[1]	Gas+particle	45	0.016	80	<0.016 - 0.131	0.038	0.033
BDE-100[2]	Gas+particle	45	0.005	87	<0.005 - 0.048	0.014	0.012
BDE-119[2]	Gas+particle	45	0.001	7	<0.001 - 0.007	0.002	<0.001
BDE-126[2]	Gas+particle	45	0.001	7	<0.001 - 0.005	0.002	<0.001
BDE-138[2]	Gas+particle	45	0.008	4	<0.008 - 0.018	0.008	<0.008
BDE-153[1]	Gas+particle	45	0.005	7	<0.005 - 0.016	0.007	<0.005
BDE-154[2]	Gas+particle	45	0.003	17	<0.003 - 0.012	0.005	<0.003
BDE-156[2]	Gas+particle	45	0.008	2	<0.008 - 0.027	0.008	<0.008
BDE-183[1]	Gas+particle	45	0.010	7	<0.010 - 0.015	0.010	<0.01
BDE-184[2]	Gas+particle	45	0.003	5	<0.003 - 0.009	0.004	<0.003
BDE-190[2]	Gas+particle	45	0.008	2	<0.008 - 0.022	<0.008	<0.008
BDE-191[2]	Gas+particle	45	0.006	2	<0.007 - 0.014	0.008	<0.006
BDE-196[2]	Gas+particle	45	0.006	7	<0.006 - 0.023	0.008	<0.006
BDE-197[2]	Gas+particle	45	0.006	10	<0.006 - 0.021	0.009	<0.006
BDE-202[2]	Gas+particle	45	0.016	2	<0.016 - 0.04	0.018	<0.016
BDE-206[2]	Gas+particle	45	0.028	49	<0.028 - 1.80	0.178	<0.028
BDE-207[2]	Gas+particle	45	0.028	36	<0.028 - 0.581	0.082	<0.028
BDE-209[3]	Gas+particle	45	0.090	79	<0.093 - 94.2	9.47	1.91
sum 17 BDE[3] (ref. 2021)	Gas+particle				0.234 - 97.4	9.93	2.19
sum 26 BDE[3]	Gas+particle				0.307 - 98.1	10.1	2.28
sum 25 BDE (excl. 209)[2]	Gas+particle				0.214 - 3.90	0.600	0.366
TBA[2]	Gas+particle	45	0.017	100	1.54 - 32.0	9.13	7.31
α-HBCDD[2]	Gas+particle	11	0.003	73	<0.003 - 0.043	0.018	0.016
β-HBCDD[2]	Gas+particle	11	0.002	45	<0.002 - 0.006	0.003	<0.002
γ-HBCDD[2]	Gas+particle	11	0.004	9	<0.004 - 0.005	0.004	<0.004

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
PAHs (ng/m3) Class of uncertainty:1							
1-Methylnaphthalene	Gas+particle	45	0.006	89	<0.006 - 0.831	0.067	0.025
1-Methylphenanthrene	Gas+particle	45	0.001	35	<0.001 - 0.009	0.002	<0.001
2-Methylanthracene	Gas+particle	45	0.004	0	<0.004	0.004	<0.004
2-Methylnaphthalene	Gas+particle	45	0.008	91	<0.008 - 1.23	0.085	0.046
2-Methylphenanthrene	Gas+particle	45	0.003	20	<0.003 - 0.010	0.004	<0.003
3-Methylphenanthrene	Gas+particle	45	0.001	51	<0.001 - 0.008	0.002	0.002
9-Methylphenanthrene	Gas+particle	45	0.002	20	<0.002 - 0.004	0.002	<0.002
Acenaphthene*	Gas+particle	45	0.005	47	<0.005 - 0.038	0.007	<0.005
Acenaphthylene*	Gas+particle	45	0.002	34	<0.002 - 0.015	0.003	<0.002
Anthanthrene	Gas+particle	45	0.001	2	<0.001 - 0.001	0.001	<0.001
Anthracene*	Gas+particle	45	0.001	11	<0.001 - 0.012	0.002	<0.001
Benz(a)anthracene*	Gas+particle	45	0.001	40	<0.001 - 0.011	0.001	<0.001
Benzo(a)fluoranthene	Gas+particle	45	0.001	2	<0.001 - 0.002	0.001	<0.001
Benzo(a)fluorene	Gas+particle	45	0.001	9	<0.001 - 0.005	0.001	<0.001
Benzo(a)pyrene*	Gas+particle	45	0.001	16	<0.001 - 0.010	0.001	<0.001
Benzo(b)fluoranthene*	Gas+particle	45	0.001	56	<0.001 - 0.027	0.003	0.002
Benzo(b)fluorene	Gas+particle	45	0.001	7	<0.001 - 0.003	0.001	<0.001
Benzo(e)pyrene	Gas+particle	45	0.001	49	<0.001 - 0.015	0.002	<0.001
Benzo(ghi)fluoranthene	Gas+particle	45	0.001	0	<0.001	0.001	<0.001
Benzo(ghi)perylene*	Gas+particle	45	0.001	29	<0.001 - 0.016	0.002	<0.001
Benzo(j)fluoranthene	Gas+particle	45	0.001	27	<0.001 - 0.013	0.002	<0.001
Benzo(k)fluoranthene*	Gas+particle	45	0.001	22	<0.001 - 0.011	0.002	<0.001
Biphenyl	Gas+particle	45	0.001	98	<0.008 - 1.42	0.264	0.065
Chrysene*	Gas+particle	45	0.001	56	<0.001 - 0.025	0.003	0.002
Coronene	Gas+particle	45	0.001	16	<0.001 - 0.007	0.001	<0.001
Cyclopenta(cd)pyrene	Gas+particle	45	0.001	2	<0.001 - 0.001	0.001	<0.001
Dibenzo(ac)anthracene	Gas+particle	45	0.001	2	<0.001 - 0.002	0.001	<0.001
Dibenzo(ae)pyrene	Gas+particle	45	0.001	4	<0.001 - 0.003	<0.001	<0.001
Dibenzo(ah)anthracene*	Gas+particle	45	0.001	4	<0.001 - 0.002	0.001	<0.001
Dibenzo(ah)pyrene	Gas+particle	45	0.001	0	<0.001	<0.001	<0.001
Dibenzo(ai)pyrene	Gas+particle	45	0.001	0	<0.001	0.001	<0.001
Dibenzofuran	Gas+particle	45	0.005	100	0.016 - 0.948	0.293	0.137
Dibenzothiophene	Gas+particle	45	0.002	38	<0.002 - 0.009	0.003	<0.002
Fluoranthene*	Gas+particle	45	0.003	67	<0.003 - 0.090	0.011	0.007
Fluorene*	Gas+particle	45	0.003	100	0.004 - 0.620	0.113	0.024
Indeno(123-cd)pyrene*	Gas+particle	45	0.001	29	<0.001 - 0.017	0.002	<0.001
Naphthalene*	Gas+particle	45	0.024	89	<0.024 - 3.89	0.326	0.129
Perylene	Gas+particle	45	0.001	2	<0.001 - 0.001	0.001	<0.001
Phenanthrene*	Gas+particle	45	0.008	82	<0.008 - 0.178	0.029	0.016
Pyrene*	Gas+particle	45	0.001	67	<0.001 - 0.046	0.005	0.004
Retene	Gas+particle	45	0.003	7	<0.003 - 0.010	0.003	<0.003
triphenylene	Gas+particle	45	0.001	16	<0.001 - 0.005	0.001	<0.001
Sum 39 PAH (ref. 2021)	Gas+particle	45			0.114 - 9.54	1.25	0.501
Sum 42 PAH	Gas+particle	45			0.117 - 9.56	1.26	0.504
Sum 16 PAH(*)	Gas+particle	45			0.052 - 5.01	0.51	0.198

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Ionic and volatile PFAS (pg/m3) **Class of uncertainty: 2-3 (specification for individual compounds below)**							
TFA[3]	Particle phase	9	1.00	67	<1.00 - 12.3	4.54	4.59
PFPrA[3]	Particle phase	9	0.068	89	<0.068 - 2.70	0.439	0.177
PFBA[3]	Particle phase	9	0.034	100	0.297 - 13.2	2.11	0.552
PFPeA[2]	Particle phase	9	0.045	11	<0.045 - 0.046	<0.045	<0.045
PFHxA[2]	Particle phase	9	0.045	33	<0.045 - 0.079	<0.045	<0.045
PFHpA[2]	Particle phase	9	0.034	33	<0.034 - 0.068	<0.034	<0.034
br-PFOA[2]	Particle phase	9	0.014	0	<0.014	<0.014	<0.014
PFOA[2]	Particle phase	9	0.014	44	<0.014 - 0.089	0.028	<0.014
PFNA[2]	Particle phase	9	0.014	67	<0.014 - 0.051	0.026	0.024
PFDA[2]	Particle phase	9	0.014	22	<0.014 - 0.041	<0.014	<0.014
PFUnA[2]	Particle phase	9	0.014	33	<0.014 - 0.021	<0.014	<0.014
PFDoA[2]	Particle phase	9	0.016	22	<0.016 - 0.034	<0.016	<0.016
PFTrA[2]	Particle phase	9	0.016	0	<0.016	<0.016	<0.016
PFTeA[2]	Particle phase	9	0.023	0	<0.023	<0.023	<0.023
PFHxDA[2]	Particle phase	9	0.100	0	<0.100	<0.100	<0.100
PFOcDA[2]	Particle phase	9	0.045	0	<0.045	<0.045	<0.045
Sum C4 - C14 PFCAs	Particle phase				0.487 - 13.3	2.31	0.710
TFMS[3]	Particle phase	9	0.068	0	<0.068	<0.068	<0.068
PFEtS[3]	Particle phase	9	0.068	0	<0.068	<0.068	<0.068
PFPrS[3]	Particle phase	9	0.068	0	<0.068	<0.068	<0.068
PFBS[2]	Particle phase	9	0.009	22	<0.009 - 0.042	0.011	<0.009
PFPS[2]	Particle phase	9	0.011	0	<0.011	<0.011	<0.011
PFHxS[2]	Particle phase	9	0.009	0	<0.009	<0.009	<0.009
PFHpS[2]	Particle phase	9	0.014	0	<0.014	<0.014	<0.014
br-PFOS[2]	Particle phase	9	0.009	0	<0.009	<0.009	<0.009
PFOS[2]	Particle phase	9	0.009	33	<0.009 - 0.015	<0.009	<0.009
PFNS[2]	Particle phase	9	0.014	0	<0.014	<0.014	<0.014
PFDS[2]	Particle phase	9	0.014	0	<0.014	<0.014	<0.014
PFUnS[2]	Particle phase	9	0.023	0	<0.023	<0.023	<0.023
PFDoS[2]	Particle phase	9	0.023	0	<0.023	<0.023	<0.023
PFTrS[2]	Particle phase	9	0.034	0	<0.034	<0.034	<0.034
Sum C4 - C13 PFSAs	Particle phase				0.079 - 0.128	0.089	0.079
Sum C4 - C14 PFAAs					0.567 - 13.4	2.40	0.790
4:2 FTSA[2]	Particle phase	9	0.014	11	<0.014 - 0.025	<0.014	<0.014
6:2 FTSA[2]	Particle phase	9	0.023	11	<0.023 - 0.076	<0.023	<0.023
8:2 FTSA[2]	Particle phase	9	0.034	0	<0.034	<0.034	<0.034
10:2 FTSA[2]	Particle phase	9	0.034	0	<0.034	<0.034	<0.034
12:2 FTSA[4]	Particle phase	9	0.034	0	<0.034	<0.034	<0.034
FOSA[2]	Particle phase	9	0.045	0	<0.045	<0.045	<0.045
1H-PFHpA[3]	Particle phase	9	0.292	0	<0.292	<0.292	<0.292
PF-3,7-DMOA	Particle phase	9	0.022	0	<0.022	<0.022	<0.022
7:3 FTCA[3]	Particle phase	9	0.055	0	<0.055	<0.055	<0.055
HFPO-DA (GenX)[3]	Particle phase	9	0.109	0	<0.109	<0.109	<0.109
FOSAA[3]	Particle phase	9	0.146	0	<0.146	<0.146	<0.146
MeFOSAA[3]	Particle phase	9	0.026	0	<0.026	<0.026	<0.026
EtFOSAA[3]	Particle phase	9	0.026	0	<0.026	<0.026	<0.026
6:2 F53B[3]	Particle phase	9	0.036	0	<0.036	<0.036	<0.036
F53[4]	Particle phase	9	0.109	0	<0.109	<0.109	<0.109
8Cl-PFOS[3]	Particle phase	9	0.036	0	<0.036	<0.036	<0.036

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
4:2 FTOH[3]	Gas phase	10	2.41	0	<2.41	<2.41	<2.41
6:2 FTOH[3]	Gas phase	10	1.66	90	<1.66 - 6.97	3.42	2.99
8:2 FTOH[3]	Gas phase	10	1.36	90	<1.36 - 8.75	5.10	5.07
10:2 FTOH[3]	Gas phase	10	0.827	80	<0.827 - 3.97	1.94	1.70
12:2 FTOH[3]	Gas phase	10	1.65	20	<1.65 - 7.20	1.70	<1.65
N-Me-FOSA[3]	Gas phase	10	0.636	0	<0.636	<0.636	<0.636
N-Et-FOSA[3]	Gas phase	10	0.390	0	<0.390	<0.390	<0.390
N-Me-FOSE[3]	Gas phase	10	0.313	0	<0.313	<0.313	<0.313
N-Et-FOSE[3]	Gas phase	10	0.319	0	<0.319	<0.319	<0.319
Sum Vol PFAS	Gas phase				9.01 - 22.7	14.8	13.7

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
Chlorinated paraffins (pg/m3) Class of uncertainty: 3							
SCCP	Gas+particle	45	13.1	98	<13.1 - 52.1	24.1	23.7
MCCP	Gas+particle	45	127	7	<127 - 159	<127	<127
Siloxanes (ng/m3) Class of uncertainty: 3							
D4	Gas phase	52	0.030	100	0.102 - 2.344	0.699	0.365
D5	Gas phase	52	0.030	100	0.110 - 4.22	1.05	0.526
D6	Gas phase	52	0.020	98	<0.020 - 0.210	0.054	0.034
sum cVMS	Gas phase				0.231 - 6.49	1.80	1.02

ZEPPELIN – Air							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
nBFRs (pg/m3) Class of uncertainty: 2-3							
ATE (TBP-AE)	Gas+particle	10	0.004	30	<0.004 - 0.011	0.004	<0.004
a-TBECH	Gas+particle	10	0.015	0	<0.015	<0.015	<0.015
b-TBECH	Gas+particle	10	0.011	0	<0.011	<0.011	<0.011
g/d-TBECH	Gas+particle	10	0.008	0	<0.008	<0.008	<0.008
BATE	Gas+particle	10	0.005	30	<0.005 - 0.009	<0.005	<0.005
PBT	Gas+particle	10	0.016	60	<0.016 - 0.062	0.021	0.018
PBEB	Gas+particle	10	0.005	20	<0.005 - 0.007	<0.005	<0.005
PBBZ	Gas+particle	10	0.017	50	<0.017 - 0.042	0.019	<0.017
pTBX	Gas+particle	10	0.025	10	<0.025	<0.025	<0.025
HBB	Gas+particle	10	0.024	80	<0.024 - 0.053	0.033	0.035
DPTE	Gas+particle	10	0.006	40	<0.006 - 0.017	0.007	<0.006
EHTBB	Gas+particle	10	0.007	0	<0.007	<0.007	<0.007
BTBPE	Gas+particle	10	0.013	10	<0.013	<0.013	<0.013
TBPH (BEH /TBP)	Gas+particle	10	0.033	0	<0.033	<0.033	<0.033
DBDPE	Gas+particle	10	0.523	30	<0.523 - 2.58	0.557	<0.523
Sum nBFR (excl. DBDPE)	Gas+particle				0.095 - 0.231	0.154	0.142
TBBPA[3]	Gas+particle	11	0.018	73	<0.018 - 0.209	0.084	0.084
Brominated/Chlorinated Methanes (pg/m3) Class of uncertainty: 3							
$CHBr_3$	Gas phase	11	10.0	100	1170 - 21500	8040	4310

ZEPPELIN – Air							
Dechloranes (pg/m3)							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
syn-DP	Gas+particle	12	0.047	0	<0.047	<0.047	<0.047
anti-DP	Gas+particle	12	0.088	0	<0.088	<0.088	<0.088
Dec 601	Gas+particle	12	0.012	0	<0.012	<0.012	<0.012
Dec 602	Gas+particle	12	0.011	0	<0.011	<0.011	<0.011
Dec 603	Gas+particle	12	0.010	0	<0.010	<0.010	<0.010
Dec 604	Gas+particle	12	0.119	0	<0.119	<0.119	<0.119
Dibromoaldrin	Gas+particle	12	0.082	0	<0.082	<0.082	<0.082
Volatile fluorinated and chlorinated substances (pg/m3) Class of uncertainty: 3							
Compound	**Matrix**	**No. of Samples**	**MDL***	**DF (%)**	**Concentration range**	**Annual mean**	**Annual median**
PFTBA	Gas phase	9	50.0	100	2090 - 2600	2390	2390
TCPFB	Gas phase	11	10.0	100	104 - 272	207	226
PFTPeA	Gas phase	9	10.0	100	54.2 - 74.2	63.8	62.4
HCBD	Gas phase	11	5.00	100	1650 - 2300	1840	1740
PFPHP	Gas phase	9	10.0	100	14.8 - 35.7	24.4	23.5
DCTFP	Gas phase	11	1.00	55	<1.00 - 1.90	1.13	1.28
PCTol	Gas phase	11	5.00	0	<5.00	<5.00	<5.00
DCPFcH	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBB	Gas phase	11	0.200	0	<0.200	<0.200	<0.200
bTFMBB	Gas phase	11	1.00	0	<1.00	<1.00	<1.00
2,3-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
3,4-DCBTC	Gas phase	11	10.0	0	<10.0	<10.0	<10.0
PFBCH	Gas phase	11	100	0	<100	<100	<100

*MDLs are presented as a guidance based on median sample volume per compound group. The MDL is however variable over the year due to variable sample volume and analytical conditions.

**No standards available, not analysed (n.a.)

***Method under development/no recovery of internal standard (n.d.)

Table A 5: Summary of measured concentrations (ng/m3) and detection frequencies (%) of heavy metals in air at Birkenes, Zeppelin, Svanvik, Sofienbergparken and Troll in 2024. The colour codes indicate highest detection/concentrations in red and lowest detection/concentrations in green.

HEAVY METALS - Air 2024							
Compound	Matrix	No. of samples	MDL	DF (%)	Concentration range	Annual mean	Annual median
Birkenes - Air (ng/m^3) Class of uncertainty: 1							
Al	Particle phase	50		76	1.8175 - 370	34.8	11.05
As	Particle phase	50		100	0.005 - 0.438	0.097	0.078
Cd	Particle phase	50		100	0.002 - 0.431	0.027	0.012
Cr	Particle phase	50		16	0.0895 - 0.9145	0.290	0.092
Co	Particle phase	50		100	0.001 - 0.117	0.018	0.009
Cu	Particle phase	50		100	0.031 - 1.32	0.323	0.241
Fe	Particle phase	50		98	0.619 - 285	32.2	13.8
Pb	Particle phase	50		98	0.0385 - 2.49	0.562	0.364
Mn	Particle phase	50		100	0.085 - 10.2	1.074	0.477
Ni	Particle phase	50		98	0.014 - 0.549	0.170	0.151
Ti	Particle phase	50		20	0.5605 - 13.3	2.24	0.58
V	Particle phase	50		100	0.008 - 1.3	0.313	0.191
Zn	Particle phase	50		98	0.248 - 8.86	2.21	1.51
Hg	Gas phase	8107		96	0.676 - 3.26	1.46	1.48
Zeppelin - Air (ng/m^3) Class of uncertainty: 1							
Al	Particle phase	46		100	2.92 - 346	52.7	19.7
As	Particle phase	46		100	0.002 - 0.419	0.061	0.018
Cd	Particle phase	45		73	0.001 - 1.98	0.063	0.009
Cr	Particle phase	46		26	0.047 - 0.8795	0.186	0.097
Co	Particle phase	46		91	0.0005 - 0.075	0.011	0.004
Cu	Particle phase	46		74	0.013 - 1.06	0.192	0.105
Fe	Particle phase	46		98	0.6965 - 151	20.5	7.3
Pb	Particle phase	46		61	0.02 - 2.22	0.253	0.079
Mn	Particle phase	46		100	0.032 - 3.05	0.519	0.243
Ni	Particle phase	46		35	0.032 - 0.347	0.092	0.039
Ti	Particle phase	46		98	0.056 - 15	1.55	0.58
V	Particle phase	46		98	0.001 - 0.406	0.070	0.035
Zn	Particle phase	46		96	0.0525 - 8.36	1.78	0.76
Hg-GEM	Gas phase	4735		100	0 - 1.963	1.53	1.56
Hg-GOM	Gas phase	2160		79	0 - 94.2	2.9	1.1
Hg-PBM	Particle phase	2166		79	0 - 274	7.6	4.1

Svanvik - Air (ng/m^3)							
Class of uncertainty: 1							
Al	Particle phase	52		58	0.866 - 129	30.9	30.1
As	Particle phase	52		100	0.002 - 0.797	0.085	0.046
Cd	Particle phase	52		87	0.001 - 0.081	0.012	0.008
Cr	Particle phase	52		13	0.022 - 2.213	0.623	0.134
Co	Particle phase	52		94	0.0005 - 0.7	0.049	0.024
Cu	Particle phase	52		69	0.012 - 0.7	0.450	0.255
Fe	Particle phase	52		79	0.131 - 6.65	38.7	28.3
Pb	Particle phase	52		100	0.061 - 178	0.358	0.197
Mn	Particle phase	52		98	0.0055 - 2.19	0.609	0.566
Ni	Particle phase	52		94	0.0045 - 2.24	1.05	0.455
Ti	Particle phase	52		23	0.1105 - 15.2	4.03	2.010
V	Particle phase	52		100	0.013 - 13.7535	1.61	0.701
Zn	Particle phase	52		77	0.14 - 9.47	1.21	0.84
Sofienbergparken - Air (ng/m^3)							
Class of uncertainty: 1							
Al	Particle phase	12		100	35.8 - 1200	308	225
As	Particle phase	12		100	0.048 - 1.1	0.337	0.27
Cd	Particle phase	12		100	0.026 - 1.35	0.292	0.099
Cr	Particle phase	12		100	0.259 - 2.48	1.32	1.33
Co	Particle phase	12		100	0.019 - 0.475	0.162	0.134
Cu	Particle phase	12		100	1.72 - 15.7	7.30	6.17
Fe	Particle phase	12		100	82 - 1060	382	372
Pb	Particle phase	12		100	0.193 - 2.16	1.00	1.045
Mn	Particle phase	12		100	1.39 - 20.9	7.1	6.27
Ni	Particle phase	12		100	0.041 - 1.56	0.85	0.897
Ag	Particle phase	12		100	0.003 - 0.035	0.015	0.012
Ti	Particle phase	12		100	1.98 - 74.6	17.3	10.75
V	Particle phase	12		100	0.137 - 4.03	1.49	1.36
Zn	Particle phase	12		100	4.01 - 32.7	15.0	13.5
Hg	Gas phase	6973		83	1.077 - 4.172	1.5007	1.5
Troll - Air (ng/m^3)							
Class of uncertainty: 1							
Hg	Gas phase	8455		100	0.315 - 3.314	1.0417	1.072

Table A 6: Summary of measured concentrations (µg/L) and detection frequencies (%) of heavy metals in precipitation at Birkenes, Kårvatn, Hurdal and Svanvik in 2024. The colour codes indicate highest detection/concentrations in red and lowest detection/concentrations in green.

HEAVY METALS - Precipitation 2024							
Compound	Matrix	No. of samples	MDL	DF (%)	Concentration range	Annual mean	Annual median
Birkenes (µg/l) Class of uncertainty: 1							
As	Precip	52	0.05	44	0.025 - 0.42	0.046	0.025
Cd	Precip	52	0.003	96	0.0015 - 0.121	0.013	0.011
Cr	Precip	52	0.09	37	0.045 - 0.9	0.072	0.045
Co	Precip	52	0.008	65	0.004 - 0.168	0.019	0.016
Cu	Precip	52	0.05	100	0.125 - 13	1.00	1.00
Pb	Precip	52	0.04	98	0.02 - 2.3	0.281	0.273
Mn	Precip	52	0.2	90	0.1 - 12.7	1.23	0.938
Ni	Precip	52	0.06	90	0.03 - 1.49	0.134	0.139
V	Precip	52	0.02	98	0.01 - 1.56	0.177	0.137
Zn	Precip	52	0.6	98	0.3 - 43.7	3.26	2.94
Hg (ng/L)	Precip	45	1.0	80	1 - 23.88	3.39	3.47
Kårvatn (µg/l) Class of uncertainty: 1							
As	Precip	47	0.05	15	0.025 - 0.206	0.026	0.025
Cd	Precip	47	0.003	68	0.0015 - 0.067	0.008	0.006
Cr	Precip	47	0.09	38	0.045 - 0.864	0.070	0.045
Co	Precip	47	0.008	70	0.004 - 0.263	0.011	0.012
Cu	Precip	47	0.05	98	0.025 - 9.97	0.62	0.475
Pb	Precip	47	0.04	68	0.02 - 1.11	0.065	0.067
Mn	Precip	47	0.2	94	0.1 - 30.7	0.901	1.020
Ni	Precip	47	0.06	77	0.03 - 1.7	0.094	0.091
V	Precip	47	0.02	74	0.01 - 0.539	0.037	0.035
Zn	Precip	47	0.6	91	0.3 - 15	1.80	2.34
Hg (ng/L)	Precip	37	1	65	1 - 8.9	1.92	2.41

Svanvik (µg/l)							
Class of uncertainty: 1							
Al	Precip	44	0.6	100	1.32 - 131	12.5762	13.95
As	Precip	44	0.05	25	0.025 - 0.122	0.0338	0.025
Cd	Precip	44	0.003	77	0.0015 - 0.051	0.008	0.006
Cr	Precip	44	0.09	55	0.045 - 0.55	0.106	0.095
Co	Precip	44	0.008	91	0.004 - 0.334	0.035	0.034
Cu	Precip	44	0.05	100	0.179 - 23.2	2.35	2.00
Pb	Precip	44	0.04	95	0.02 - 3.98	0.215	0.158
Mn	Precip	44	0.2	91	0.1 - 16.4	1.363	0.768
Ni	Precip	44	0.06	100	0.099 - 3.67	0.512	0.57
V	Precip	44	0.02	100	0.045 - 3.56	0.318	0.278
Zn	Precip	44	0.6	93	0.3 - 39.5	2.82	2.54
Hurdal (µg/l)							
Class of uncertainty: 1							
As	Precip	51	0.05	43	0.025 - 4.28	0.046	0.025
Cd	Precip	51	0.003	100	0.004 - 0.086	0.017	0.014
Cr	Precip	51	0.09	71	0.045 - 2.1	0.193	0.158
Co	Precip	51	0.008	88	0.004 - 0.384	0.024	0.020
Cu	Precip	51	0.05	100	0.225 - 32.5	2.36	1.92
Pb	Precip	51	0.04	100	0.05 - 4.64	0.295	0.285
Mn	Precip	51	0.2	100	0.316 - 57.1	2.35	1.58
Ni	Precip	51	0.06	100	0.065 - 2.66	0.248	0.270
V	Precip	51	0.02	100	0.025 - 1.23	0.133	0.099
Zn	Precip	51	0.6	100	1.13 - 40.2	6.43	6.19
Hg (ng/L)	Precip	43	1	88	1 - 22.57	4.71	5.36

Appendix B Material and methods for sampling, chemical analysis and quality assurance and control

B1. Heavy metals

Sampling and analytical methods

Collection of precipitation, for analysis of heavy metals, is done using a bulk sampler (funnel+collector) from Innovation NILU. Precipitation amount is determined by weighing. The sample is sent to NILUs laboratory at Kjeller where it is preserved to 1% HNO_3 for analysis of heavy metals. Identification and quantification are performed by inductively coupled plasma mass spectrometry (ICP-MS), and indium (In) is used as internal standard. The ion optic is optimized for 115 In (Table B.6).

For heavy metals, there are specific requirements for cleanliness to avoid contamination, i.e. all sample preparation is done in a clean room and all equipment used is acid-washed.

Air sampling for the analysis of heavy metals in particles at Birkenes and Svanvik is done using a Kleinfiltergerät with a PM_{10}-impactor and an airflow of 2.3 m^3/hour. Weekly samples (7 days) are collected. At Birkenes, particles are collected on Whatman 47 mm quartz filters and at Svanvik, Pall Zefluor 47 mm filters. At the Zeppelin Observatory and Sofienbergparken, sampling of heavy metals on particles are done using a Digitel high volume air sampler. At Zeppelin the sampler is used with PM_3-cut-off, and samples are collected on weekly basis, using Whatman grade 41 filter papers for 48 hours with an airflow rate of 48 m^3/hour. In Sofienbergparken, the sampler is used with a PM_{10}-impactor, samples are collected once a month for 48 hours, using Whatman grade 41 filter papers at an airflow rate of 30 m^3/hour. The filters are digested with nitric acid by Ultraclave, a microwave-based decomposition technique. Identification and quantification are performed by ICP-MS, and In is used as internal standard. The ion optic is optimized for 115 In (Table B.4).

B2. Mercury

Sampling and analytical methods

Collection of precipitation, for analysis of Hg, is done using the IVL designed bulk sampler according to the EMEP manual (EMEP, 2014), which is based on Iverfeldt (1991a) and Iverfeldt (1991b). The sampling system consists of a borosilicate glass funnel and bottle that are connected via a capillary tube (Table B.4). The capillary tube prevents the sample from evaporation. To preserve the collected precipitation, concentrated hydrochloric acid is added to the borosilicate glass bottle. The sampling train is housed in a polypropylene tube that is insulated and heated when temperature drops below 4°C. Field operators collect samples weekly using clean techniques and replace the collection bottles.

Precipitation samples are returned to NILUs laboratory and analysed for total mercury using accredited methods based on the US-EPA-method 1631. Briefly, this method utilizes BrCl oxidation, followed by $SnCl_2$ reduction, dual gold trap amalgamation, thermal desorption and cold vapour atomic fluorescence spectrometry (CVAFS) (Bloom et al., 1988; EMEP, 2014). The detection limit is 0.05 ng/L.

Gaseous elemental mercury (GEM) in air is monitored using a Tekran 2537 Hg vapour analyzer (Table B.6). The sampling principle is as follows: ambient air is sampled at 1.5 l/min through a Teflon filter via a heated sampling line. A soda-lime trap is mounted in-line before the instrument filter. Hg in air is pre-concentrated for 5 minutes by amalgamation on two gold cartridges, which alternates between collection and thermal desorption, and detection by CVAFS continuous monitoring. The instruments are auto-calibrated every 25 hours using an internal Hg permeation source and verified during routine site audits by manual injections of Hg from an external source. The detection limit is 0.01 ng/m^3.

Mercury species, Gaseous Oxidized Mercury (GOM) and Particulate Bound Mercury (PBM), are collected in the following way: air is pulled into the analyzer through a Teflon-coated elutriator and an impactor designed to remove particles > 2.5 µm at flow rates of 10 L min−1. The sample air flows over a KCl-coated quartz denuder to trap gaseous organic mercury (GOM) and then over a quartz particulate filter to trap particulate-bound mercury (PBM). GOM and PBM accumulate for 1 to 2 h followed by consecutive thermal desorption and AFS detection by the Tekran 2537, as with gaseous elemental mercury. The detection limit depends on sample volume and blank level and is typically 1 pg/m^3.

B3. POPs and organic contaminants of emerging concern

Sampling and analytical methods

Air sampling of HCB, OCPs, PCBs, PAHs, PBDEs, HBCDDs, TBA, TBBPA, ionic and volatile PFAS, S/MCCPs, nBFRs, OPFRs, dechloranes and other chlorinated FRs, and particle fraction of PCA/PCP and UV compounds

Air samples are collected with two types of high-volume air samplers: Digitel and NILU sampler. The samplers consist of a pump that draws air through the samplers with an average airflow rate of 25 m^3/hour; a glass fibre filter (GFF) that collects the particle-associated compounds; and a set of two pre-cleaned PUF plugs or a set of PUF/XAD/PUF sandwich that collect the gas phase compounds. For most POPs and CECs, the data are reported for sum gas- and particle phase (i.e. bulk concentrations) from filter and PUFs. For ionic PFAS, only a GFF is used for analysis and data are reported for particle phase only. For volatile PFAS, only the PUF/XAD/PUF sandwich is used, and data are reported for gas phase only. In 2023, PCA/PCP and UV compounds in particle phase were sampled with filter, while the PUF/XAD/PUF sandwich was discarded (due to analytical issues in 2022). Specification on each sampler type is given in Table B.1. Flowrate and sampling conditions were digitally monitored and documented (e.g. power failures, etc.) as an integrated part of the sampling and quality control procedure.

Table B 1: Specification on air samplers for POPs and CECs.

	DIGITEL	**DIGITEL (NILU custom)**	**NILU sampler**
Flow rate	~30 m^3/hour	~30 m^3/hour	~25 m^3/hour
Filter	GFF: Whatman Type GF/C, diameter 150 mm, pore size 1.2 µm	GFF: Whatman Type GF/C, diameter 150 mm, pore size 1.2 µm	GFF: Gelman Type AE, diameter 142 mm, pore size 1 µm
PUF plugs	Diameter 110 mm, length 50 mm, density 25 kg/m^3	Diameter 75 mm, length 40 mm, density 25 kg/m^3	Diameter 110 mm, length 50 mm, density 25 kg/m^3
Usage	iPFAS/vPFAS (Zeppelin/Birkenes) iPFAS/vPFAS, PCA/PCP, UV compounds, M/SCCPs, dechloranes, PBDEs, HBCDDs, TBBPA, nBFRs, OPFRs, other chlorinated FRs (Sofienbergparken)	HCB, OCPs, PCBs, PBDEs, TBA, HBCDDs, PAHs, M/SCCPs (Birkenes)	HCB, OCPs, PCBs, PAHs, PBDEs, TBA, HBCDDs, TBBPA, nBFRs, S/MCCPs, dechloranes (Zeppelin)

Sampling is done on a weekly or monthly basis for individual compounds and observatory according to Tables 1-2. The sampling duration for each observatory and POP class varies according to Table B.2. The variable sampling lengths result in total air volumes of 600-2000 m^3 (as reported on sampling protocols).

Table B 2: Sampling durations for individual POP and CEC classes at each sampling station.

	Sofienbergparken	Birkenes	Zeppelin
HCB	-	24 h	48 h
OCPs	-	24 h	48 h
PCBs	-	24 h	48 h
PAHs	-	24 h	48 h
PBDEs	48 h	48 h*	72 h
HBCDDs	48 h	48 h*	72 h
TBA	48 h	48 h*	72 h
TBBPA	48 h	-	72 h
nBFRs	48 h	-	72 h
OPFRs	48 h	-	72 h
PFAS	48 h	48 h*	48 h*
PCA/PCP+UV compounds	72 h	-	-
S/MCCPs	48 h	24 h	48 h
Dechloranes	48 h	-	48 h
Other chlorinated FRs	48 h	-	-
cVMS/lCMS	48 h	72 h	72 h
Volatile F+Cl substances	48-72 h	-	72 hr
Other brominated FRs	72 h	-	-

*Two samples are combined in the lab and extracted as one aggregated sample.

After sampling, the exposed samples (GFF, PUFs, PUF/XAD/PUF) are sealed separately in gas-tight containers and transported to NILU's laboratory for further processing and quantification. In addition, a number of field blank samples follow the yearly sample batch in order to control potential contamination risks during storage and transportation (as a part of the extensive control procedures of the accredited quality system). All exposed samples are registered and stored cold (6˚C) prior to analysis and quantification. The GFF and PUFs are extracted in the same solvent to obtain the bulk concentration (gas+particle phase) of the individual target compounds (below). Exceptions are samples for PFAS, for which only GFFs are used for ionic PFAS representing the particle phase concentrations only and PUF/XAD/PUF is used for volatile PFAS representing concentrations in the gas phase only.

Sampling and analysis of volatile methyl siloxanes (cVMS and lVMS), volatile fluorinated and/or chlorinated substances, other brominated FRs, PCA/PCP, UV compounds and FBSAs

Sampling of siloxanes, UV compounds, PCP/PCA, chlorendic anhydride, volatile fluorinated and/or chlorinated substances and some "other" brominated FRs (Sofienbergparken) differ from the rest of the organic compounds. Sampling is done with a solid-phase extraction active air sampling (SPE-AAS) method with an ABN sorbent with a flow rate of 0.7 m^3 per hour (Warner et al., 2020).

Sampling for siloxanes is done every week at Zeppelin and once per month at Birkenes and Sofienbergparken. At Birkenes and Zeppelin, the siloxane samples are collected from Friday-Monday (~72 h), in order to minimize the risk of contamination during sampling. Normally there is no human activity at the stations during the weekends which reduces the risk of possible local siloxane inputs. In addition, the

sampling technicians are ordered not to use any personal-care products on the days of starting and stopping the siloxane samples.

The volatile fluorinated and/or chlorinated substances and $CHBr_3$ were in 2024 sampled at Zeppelin, Birkenes and Sofienbergparken every month for ca 48 – 72 hrs with ABN cartridges. Sampling at Sofienbergparken also included three "other" BFRs (2,2-dimethylpropan-1-ol, tribromo derivative, 2,3,4,5-Tetrabromo-6-chlorotoluene and 2,3,5,6-Tetrabromo-p-xylene), $CHBrCl_2$, CH_2ClBr, TFA (gas phase), FBSA, MeFBSA, EtFBSA, MeFOSEA and chlorendic anhydride as well as the cyclic and linear siloxanes, UV-compounds, and PCP/PCA.

Each sample for volatile fluorinated and/or chlorinated substances, $CHBr_3$, "other" BFRs, $CHBrCl_2$, CH_2ClBr, TFA (gas phase), FBSA, MeFBSA, EtFBSA, MeFOSEA and chlorendic anhydride as well as UV-compounds, and PCP/PCA used three SPE-AAS cartridges: two used for sampling in parallel (pump 1 and pump 2) and one used as a field blank. This gave one field blank per sample. Each of the cartridge sets were extracted individually.

In 2024, cyclic VMS were analyzed on the samples from all stations, while linear and other VMS were analyzed on the samples from Sofienbergparken only. All lab operations were strictly performed in a laminar flow clean cabinet or in a clean room that are fitted with HEPA and charcoal filter to remove dust and airborne contaminants from the laboratory air and laboratory personnel, who worked without personal-care products, in order to reduce the risk of contamination during the preparation and analytical steps. All samples were spiked with 20 µL of internal standard (IS) containing ^{13}C-labelled D4, D5 and D6 (1 ng/µL). The cartridges were then eluted slowly with 5 mL of hexane, which was collected directly into a vial. Before quantitative analysis, 20 µL of a recovery standard containing tetrakis(trimethylsilyloxy)silane (0.2 ng/µL) was added to the vial and the vial was sealed immediately. An aliquot was taken and transferred to a GC vial prior to instrumental analysis (Warner et al., 2020).

Extracts were analysed for cVMS on an Agilent 6890 GC connected to an Agilent 5973 MS detector. For separation, a 30 m DB-5 column (Agilent Technologies, 0.25 mm I.D., 0.25 µm film thickness) and a 10 m Rxi guard column (Restek, 0.25 mm I.D.) was used. Two ions were monitored for each compound (m/z 281 and 282 for D4, 285 and 286 for ^{13}C4-D4, 267 and 355 for D5, 364 and 365 for ^{13}C10-D5, 341 and 429 for D6, 434 and 435 for ^{13}C6-D6). 4 quantification standards (10 ng/mL to 60 ng/mL) were used for quantification.

Extracts targeted for other siloxanes were analyzed on a Thermo Trace 1310 GC connected to a Thermo GC Q Exactive MS detector. For separation, a 30 m TG-5SilMS column with 5 m guard column was used (Thermo, 0.25 mm I.D., 0.25 µm film thickness). The GC oven started at 40 °C for 1.5 min, followed by 10 °C min^{-1} up to 210°C and 30 °C min^{-1} to 300 °C for a final hold time of 1.5 min. Mass-spectral resolution was set at 120000, full scan range was m/z 50-750, electron energy was 40 eV. 3-point calibration curves (5 ng/ml to 20 ng/ml) were used for quantification. There was no quantification standard available for phenylheptamethylcyclotetrasiloxane (Ph-D4), however, a qualitative authentic specimen was prepared in house.

Samples for volatile fluorinated and chlorinated substances, "other" brominated FRs, $CHBr_3$, $CHBrCl_2$, CH_2ClBr, MeFOSEA, chlorendic anhydride and PPUs were spiked with internal standards containing perdeuterateddiisopropylbenzene and deuterated 2,2-dimethylpropan-1-ol, tribromo derivative and 2,3,5,6-Tetrabromo-p-xylene. Then the cartridge was eluted slowly with ca 4 mL of ethylacetate. 200 uL was

removed and then used for analysis of VFCs and $CHBr_3$, the remaining extracts were concentrated to 100 µL prior to instrumental analysis. The extracts were analyzed using Q Exactive GC (Orbotrap, Thermo). The GC oven started at 40 °C for 1 min, followed by 30 °C min^{-1} up to 300°C for a final hold time of 5.33 min. Mass-spectral resolution was set at 60000, mass range was optimized for different analytes (m/z 180-300, 300-500 or 205-225), electron energy was 40 eV. 4-point calibration curves (0.2 ng/ml to 25 ng/ml) were used for quantification.

FBSA, MeFBSA, EtFBSA and TFA (for gas phase measurement) were analyzed on TSQ Vantage triple-quad mass-spectrometer connected to Accela liquid chromatograph (ThermoScientific), equipped with 100 mm long, 2.1 mm. i.d. C18 BCC column. Gradient eluent (water-methanol) was employed in the same way as for analysis of ionic PFAS. Mass-spectrometer was operated in multiple reaction monitoring mode (MRM). MRM transitions were optimised with the help of authentic standards.

Analysis and quantification of HCB, OCPs, PCBs, S/MCCPs, dechloranes and other chlorinated FRs

Samples were spiked with 20 µL of internal standards (IS) containing ^{13}C-labelled PCB congeners (~230 pg/µL), 20 µL IS containing ^{13}C-labelled OCP congeners (~100-2500 pg/µL), 50 µL IS containing ^{13}C-labelled hexachlorodecane (~1000 pg/µL) for SCCP, 20 µL IS containing ^{13}C-labelled trans-CD (~500 pg/µL) for MCCP, 20 µL ^{13}C-labelled Dechlorane plus syn (~100 pg/µL) for dechloranes, before being Soxhlet extracted for 8h in diethylether/*n*-hexane (10:90, v:v). The filters and the corresponding PUF plugs were extracted separately, but in the same solvent in order to aggregate the sample. All the extracts were concentrated and treated with sulphuric acid followed by SPE clean-up with silica. Before quantitative analysis, 20 µL of unlabelled tetrachloronaphthalene (TCN, 100 pg/µL) was added as recovery standard (RS).

Identification and quantification of HCB, PCBs and OCP were carried out using a gas chromatography coupled to a high-resolution mass spectrometer as detector (GC/HRMS). The analyses were performed in Electron Impact Ionisation (EI) mode for PCBs, HCB, HCHs and DDTs using selected ion monitoring (SIM) for the respective compound groups. Identification and quantification of chlordanes, SCCP, MCCP, dechloranes and some “other” chlorinated FRs (chlordene plus, dechlorane plus Cl10, dechlorane plus axx Cl10, dechlorane plus ax Cl11, dechlorane plus Cl11 and chlorendic anhydride) were carried out using GC coupled to an Agilent HR qToF (time of flight) in Negative Chemical Ionisation (NCI) mode. A mass window of ± 20 ppm were used for extraction of the ions for quantification. For chlorendic anhydride, only a native standard was available which resulted in a rather semi-quantitative determination.

Analysis and quantification of PAHs

Samples were spiked with 20 µL of IS containing deuterated PAH congeners (10 ng/µL) and then soxhlet extracted for 8h in cyclohexane. The filters and the corresponding PUF plugs were extracted separately, but in the same solvent in order to unify the sample. The extract was then concentrated and cleaned by SPE with deactivated silica (8% water). Before quantitative analysis, 20 µL RS containing deuterated PAH congeners (1.5 ng/µL) was added.

Identification and quantification of the PAHs was carried out using a high-resolution gas chromatography coupled to a low-resolution mass spectrometer as detector (GC/LRMS). The analyses were performed in EI mode using SIM.

Analysis and quantification PBDEs, TBA, HBCDDs, nBFRs and TBBPA

Samples were spiked with 20 µL of IS containing ^{13}C-labelled PBDE congeners (~270-2500 pg/µL), 20 µL IS containing ^{13}C-labelled HBCDD congeners (α-, β-, γ-HBCDD, ~100 pg/µL), 20 uL of IS containing ^{13}C-labelled nBFR congeners (~1000 pg/µL), and 20 uL of IS containing ^{13}C-labelled TBBPA. The samples were then Soxhlet extracted for 8h in diethylether/*n*-hexane (10:90, v:v). The filters and the corresponding PUF plugs were extracted separately, but in the same solvent in order to aggregate the sample. The extract was then concentrated, treated with acid, and cleaned by SPE with silica. The extract was spiked with 20 µL of unlabelled TCN (100 pg/µL) and 20 µL RS containing deuterated (d18-α,β,γ) HBCDD (~130 pg/µL). Before quantitative analysis, aliquots for PBDE/TBA and nBFRs were analysed directly. Identification and quantification of the PBDEs, nBFRs and TBA was carried out using a HRGC/HRMS operating in EI mode using SIM for the respective compound groups. From 2022, the number of PBDEs analysed were increased from 17 to 26 PBDEs.

For identification and quantification of HBCDDs and TBBPA, an aliquot of the final sample extract was solvent exchanged into methanol. The extract was then analysed using high performance liquid chromatography system in combination with a time-of-flight high resolution mass spectrometer as detector (HPLC/MS-TOF). The analyses were performed with Electrospray ionisation (ESI) in negative ion mode using full scan mass detection (R=10 000 FWHM). In total, three HBCDDs (α, β, γ) were quantified. TBBPA was also quantified on the HBCDD extract, by using ^{13}C-labelled β-HBCDD as internal standard and compensating for approximately 88% loss during acid treatment.

Analysis and quantification OPFRs

All glass equipment were wrapped in aluminium foil and heated to 450°C for 8h and rinsed with solvent before use. All lids lined with PTFE and metal was ultrasonicated for 10 min in acetonitrile before use. The Soxhlet units are further cleaned by a pre-extraction with acetone without samplers.

Samples (PUF-filters and GFFs) were spiked with 10ng IS containing deuterium labelled OPFRs (d15-TEP, d12-TCEP, d18-TCPP, d27-TNBP, d15-TPP, d15-TDCPP, d51-TEHP, d31-TIPPP), and then Soxhlet extracted for 8h in acetone/hexane (1:1, v:v). The extract was solvent exchanged to acetonitrile before clean-up.

All clean-up of samples was performed in a laminar flow clean cabinet fitted with HEPA and charcoal filter to remove dust and air contaminants of the laboratory air. SPE (solid phase extraction) columns were used prepacked with a mixture Z-sep and C18 silica and Florisil on top (EZ-POP from Supelco) which was washed with acetonitrile and dried at -15mmHg for 10min before use. After adding the extract onto the column, acetonitrile was used to elute out all the OPFRs. Samples was concentrated using centrifugal vacuum evaporation and transferred to analytical glass and 50uL of 0.2% formic acid in Milli-Q water.

Analysis and quantification of OPFRs was performed using LC-Orbitrap high-resolution accurate mass (HRAM) with negative electrospray ionisation (ESI-) (Thermo Scientific). The analyses were performed using full scan. Before quantitative analysis, 10 ng of d27-TDMPP was added as RS.

Analysis and quantification of ionic PFAS

Filters (two filters from the same month for Zeppelin and Birkenes) were spiked with 20 µL of IS containing ^{13}C-labelled PFAS congeners (0.5 ng/µL) and then extracted using sonication bath for 3x10 min in methanol. The extract was then concentrated and cleaned with acidified Envi-Carb. Before quantitative analysis, 10 µL

of unlabelled 3,7-dimethyl PFOA (0.1 ng/µL) was added as recovery standard. For samples from Sofienbergparken $^{13}C_8$-PFOS and $^{13}C_8$-PFOA were added as recovery standards.

Identification and quantification of the PFASs was carried out using LC Orbitrap-HRMS in ESI- mode. The analyses were performed in full scan mode.

Analysis and quantification of volatile PFAS

PUF/XAD/PUF (two sets from the same month for Zeppelin and Birkenes) were spiked with 50 µL of IS containing ^{13}C-labelled FTOH/FOSE/FOSA congeners (0.1 ng/µL). The PUFs and XAD were then extracted in acetone:MTBE (1:1 v/v) using a cold extraction technique based on (Dreyer et al., 2008). The solvent mix was added and left for one hour then replaced by new solvent mix that was left for 30 min. The extracts were concentrated, solvent exchanged to ethyl acetate and cleaned with Envi-Carb. Before quantitative analysis, 20 µL of unlabelled 9:1 FTOH (0.1 ng/µL) was added as recovery standard.

Sampling, analysis and quantification of POPs in precipitation

Precipitation samples were collected at Birkenes using bulk samplers. This sampler consists of a glass cylinder (60 mm height, 285 mm inner diameter), a glass funnel and a Pyrex glass bottle (1-2 L). The sampler is installed on a supporting system about 2 m above the ground level. Samples are collected on a weekly basis starting on Mondays, resulting in samples composed of one or more bottles depending on the amount of rain. The samplers are continuously open, both during dry and wet periods. It may result in non-wanted dry deposition in some samples.

The precipitation samples were spiked with 20 µL of IS containing ^{13}C-labelled PCB/HCB/HCH congeners (0.1 ng/ µL) and then liquid extracted in cyclohexane for 4h. After separation and removal of the water phase the solvent extract is solvent exchanged to hexane before acid treatment and clean-up by SPE with silica.

Identification and quantification of the PCBs, HCB and HCHs was carried out using a HRGC/HRMS, as described above.

Sampling and analysis of POPs, PAHs and BFRs in passive air samples

POPs, PAHs and BFRs were sampled with a passive air sampler with a pre-cleaned PUF as adsorbent (Kalina et al., 2017). The PUF-samplers for POPs and BFRs were deployed outdoors at the Zeppelin station 09.10.24-18.12.24, and indoors at two locations (i.e. NILU-room and Cleanroom) 05.11.24-18.12.24 and 10.10.24-18.12.24 for POPs and BFRs respectively. The PUF-samples for PAHs were collected outdoor only, 05.11.24-18.12.24.

Figure B.2. The passive PUF-sampler deployed indoors at the Zeppelin station

The PUF samples were analysed as described above. Semi-quantitative air concentrations were obtained from the amounts in the samplers and air volumes estimated from days deployed and sampling rates derived from the template of Harner (2017), i.e. accounting for the ambient temperature.

Sampling and analysis of cVMS in passive air samples

Siloxanes were sampled with a passive air sampler with XAD-2 as adsorbent (Krogseth et al., 2013). The XAD-samplers were deployed at four locations; two outdoor (09.10.24-18.12.24), one at the NILU-room (13.10.24-18.12.24) and one at the Cleanroom (10.10.24-18.12.24). 0,5g XAD was added internal standard and extracted with 4 mL of Hexane by shaking for 1 hour (300 rpm). An aliquot of 200 µL was analysed as described above. Semi-quantitative air concentrations were obtained from the amounts in the samplers and air volumes estimated from days deployed and a sampling rate of 0.045 m^3/day.

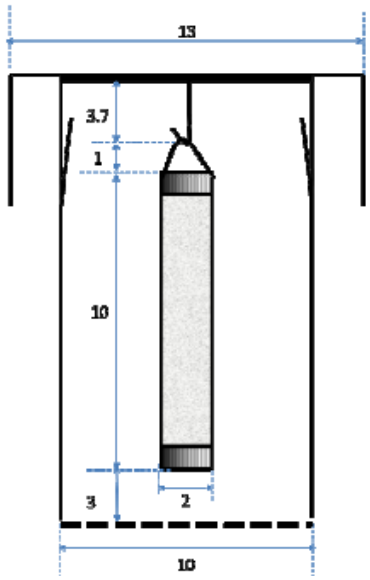

Figure B.3. A schematic illustration of the passive XAD-sampler deployed at the Zeppelin station

Sampling and analysis of PFAS in passive air samples

PFAS was sampled with passive air sampler with XAD as adsorbent, as described for cVMS. Approximately 3 g of XAD was spiked with internal standard and extracted with 10 mL of Methanol by shaking for 24 hours. The methanol extract was evaporated to near dryness under gentle flow of nitrogen and resuspended in 200uL methanol , followed by 50uL of water. An aliquot was analysed on LC-HRMS (PFCAs/PFSAs) and GC-MS (FTOHs) as described above. Semi-quantitative air concentrations were obtained from the amounts in the samplers and air volumes estimated from days deployed and sampling rates derived from Karásková et al. (2018).

Sampling and analysis of VOCs in passive air samples

VOCs were collected using so-called Tenax tubes. These are small metal tubes that contain a sorbent called Tenax™. Tenax has the ability to sorb VOCs directly from the air through diffusion and holds them in its structure on the inside of the metal tube. After 14 days, the tubes have captured a representative amount of VOCs from the air (Figure B.4). The samplers were deployed at different sampling sites indoor/outdoor at the Zeppelin Observatory in three periods between 05.11.24-18.12.24, when there was a lot of activity at the station. For comparison, samplers were also deployed after renovation (28.03.25-14.04.25).

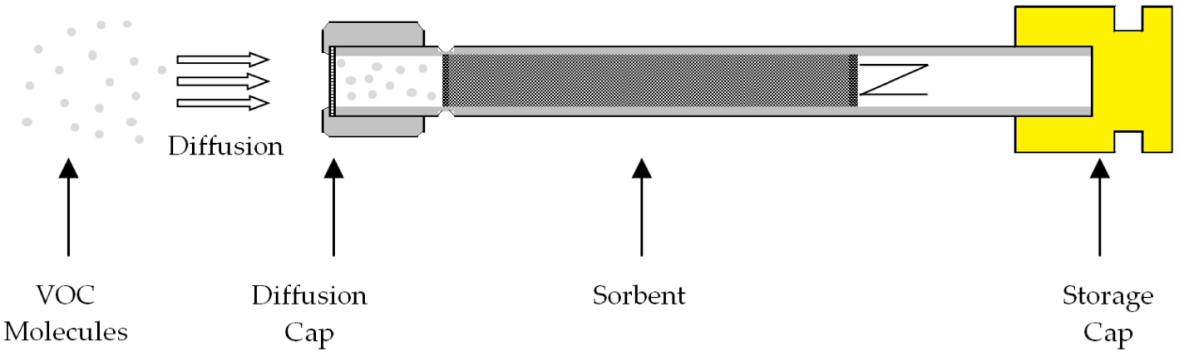

Figure B.4: Illustrates a Tenax tube and how VOCs diffuse from air (approximately 0,4 ml/min).

VOCs were analyzed using a high-resolution mass spectrometer, so-called "Thermal Desorption Gas Chromatography Quadrupole interfaced Time-of-Flight Mass Spectrometry", TD-GC-QiToF-MS.

Non-target analysis of dust samples

Non-Target Analysis (NTA) was carried out by gas chromatography coupled to high-resolution mass spectrometer (GC-MS). Extracts were injected (3 µL) using a programmable temperature vaporizer (PTV) inlet going from 50 to 300°C. The chromatographic separation was carried out using a TG-5SILMS GC column from Thermo Scientific (30m length, 0.25mm internal diameter). The GC separation was performed between 40 and 320°C for 40 min. Fragmentation of the detected ions was carried out using a 7200 Accurate-Mass Quadrupole Time-of-Flight from Agilent (at 70 eV collision energy). Data-processing of acquired NTA raw files was performed using MzMine software (version 4.7.3). The software performed peak-picking, deconvolution, alignment, grouping, and blank filtering of all chemical features. The blank filtration was performed by removing all features detected in both the field blanks and samples with an intensity in the blanks lower than 10 times than in the samples. Database search was performed using the NIST2023 spectral library with a cut-off score of 0.7 and Kovats retention index lower than 50.

B4. Quality assurance/Quality control (QA/QC)

Detailed information about the QA/QC routines at NILU's laboratories is presented in an internal technical report for monitoring programmes (Enge et al., 2022). In short, the organic and inorganic chemical analyses are accredited in accordance to NS-EN ISO/IEC 17025. The accredited analytical methods are to be found under accreditation number TEST 008 and include P12 chemical analysis and P3002 air sampling. The accredited chemical analyses include heavy metals, mercury, PCBs, organochlorine pesticides (HCB, HCHs, chlordanes, and DDTs), and PAHs. These are in-house methods that are based on the EMEP manual , and were the reference methods when the manual was developed. Methods, for e.g. PBDEs and HBCDDs, are not included in the manual, but the methods correspond to the POP-method. Tables B.3-B.4 shows an overview of the methods used for all analytes included in the monitoring programme, together with relevant references where the methods have been utilised. Numerous analytical methods for POPs have been published over the past 30-40 years, and Muir et al. (2006) summarised the commonly used analytical methods. They concluded that methods best suited for the situation in a given laboratory should be adapted, and that participation in interlaboratory comparisons is more important, rather than standardisation of methodology.

Table B.3 summarises the methods used for the organic contaminants of emerging concern and lists the references where the most common analytical methods are described. NILU strives to use the methods that is expected to currently give the best results, and the methods are under continuous development. For example, is ABN under testing as a replacement sampling material for the determination of S/MCCP and OPFR, which is expected to lower the blank contributions.

All sampling equipment at the monitoring stations undergoes routine controls and calibration of flow rates.

The analytical procedure is accompanied by a comprehensive quality control programme based on the requirements of NILU's accreditation.

Field blank samples and method blank samples are routinely included to control for unintended contamination during storage, transport, and analytical steps. The number of blank samples depends on the total number of samples per year, but typically there are 3-4 field blanks and 12 lab blanks. Field blanks, consisting of the sampling material (e.g. pre-cleaned PUF plugs, filters, XAD, ABN), are sent to each station where they are handled and exposed as the real samples during assembly and retrieval. They are then transported, stored, extracted, cleaned, and analysed in the same way as, and in parallel with, the real samples. The method blanks are obtained by extracting pre-cleaned sampling material (e.g. PUFs, filters, XAD, ABN) in solvent and using the same clean-up and analytical procedures as real samples and field blanks.

Based upon the method blanks, the method detection limit (MDL) is calculated for all compounds, given as the average plus 3 times the standard deviation of the concentrations of target analytes in the blank. When no target compound is detected in the blank samples, the instrumental detection limit (IDL), defined as 3 times the noise level, is used in the calculation of MDL. Concentrations below MDL are set to MDL/2 in further statistical treatment (e.g. calculation of mean and median).

Table B 3: Overview of methods used for organic contaminants in the monitoring programme, performed by NILU.

	Sampling material:	Sampling reference	Extraction method:	Clean-up method:	Instrumental method:	Analytical method reference:
POPs:						
HCB	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014; Muir, Sverko 2006; Halse et al. 2011
HCHs	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014; Halse et al. 2011
DDTs	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014; Muir, Sverko 2006; Halse et al. 2011
Chlordanes	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC-QTOF HRMS NCI (full scan)	EMEP 2014; Muir, Sverko 2006; Halse et al. 2011
PCBs	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014; Muir, Sverko 2006; Halse et al. 2011
POPs in precipitation (PCB, HCB, HCH)	Bulk (wet+dry deposition)	EMEP 2014	Liquid extraction, cyclohexane	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014
PAH	PUF/GFF	EMEP 2014; Yu et al. 2019	Soxhlet extraction, cyclohexane	silica fractionation	GC/LRMS EI (SIM)	EMEP 2014; Halse et al. 2011
S/MCCP	PUF/GFF	EMEP 2014*	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC-QTOF HRMS NCI (full scan)	EMEP 2014*; Yuan, Muir, MacLoed 2019; Nipen et al. 2022
Dechloranes	PUF/GFF	EMEP 2014*	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC-QTOF HRMS NCI (full scan)	EMEP 2014*; Sverko et al. 2011
BFRs:						
PBDEs	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014*; de Wit 2002
HBCD	PUF/GFF	EMEP 2014; Hung et al. 2016	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	LC-Orbitrap HRMS (full scan)	EMEP 2014*; de Wit 2002
TBA	PUF/GFF	EMEP 2014*	Soxhlet extraction, diethylether/n-hexane (10:90, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014*
nBFRs	PUF/GFF	EMEP 2014*	Soxhlet extraction, acetone/hexane (1:1, v:v)	sulphuric acid+silica fractionation	GC/HRMS EI (SIM)	EMEP 2014*; Covaci et al. 2011
OPFRs	PUF/GFF	EMEP 2014*	Soxhlet extraction, acetone/hexane (1:1, v:v)	SPE Z-sep/C18 silica/Florisil (EZ-POP)	LC-Orbitrap HRAM ESI+ (full scan)	SPE from Stenerson et al. 2015
PFAS ionic	GFF	Hung et al 2016	Sonication bath, methanol	Acidified Envi-Carb	LC-Orbitrap HRMS ESI- (full scan)	Amin et al. 2020
PFAS volatile	PUF/XAD/PUF	Hung et al 2016	Cold-extraction, acetone:MTBE (1:1, v/v)	Envi-Carb	GC/LRMS EI (SIM)	Dreyer et al. 2008
cVMS	ABN	Warner et al. 2020	On column, hexane	None	GC/LRMS EI (SIM)	Warner et al. 2020
lVMS	ABN	Warner et al. 2020*	On column, hexane	None	GC-Orbitrap HRMS EI (full scan)	Warner et al. 2020*
Volatile fluorinated and chlorinated substances	ABN	Warner et al. 2020*	On column, ethylacetate	None	GC-Orbitrap HRMS EI (full scan)	Warner et al. 2020*

*Substance not included in the publication, but is based on the same method.

Table B 4: Overview of methods used for heavy metals and mercury in the monitoring programme, performed by NILU.

	Sampling material:	Sampling reference:	Sample preparation	Extraction method	Instrumental method:	Analytical method reference:
Elemens in particles						
V, Cr, Mn, Co, Ni, Cu, Zn, As, Cd and Pb	PTFE filters (Birkenes and Svanvik)	Based on NS-EN 12341:2014, NS-EN 14902:2005; EMEP 2014.	Filter extracted in HNO3/H2O 1:2	UltraClave, Max temperature of 250 oC in 15 min	ICP-MS	EMEP 2014 and NS-EN 14902:2005
V, Cr, Mn, Co, Ni, Cu, Zn, As, Cd and Pb	Whatman 41 cellulose filter (Zeppelin and Sofienberparken)	Based on NS-EN 12341:2014, NS-EN 14902:2005; EMEP 2014.	1/4 filter extracted in HNO3/H2O 1:2	UltraClave, Max temperature of 250 oC in 15 min	ICP-MS	EMEP 2014 and NS-EN 14902:2005
Elements in precipitation:						
V, Cr, Mn, Co, Ni, Cu, Zn, As, Cd and Pb	Acid washed PE bulk collectors	Based on NS 4864:1983; EMEP 2014; Berg et al., 1997.	Sample preservation 1% HNO3	Not applicable	ICP-MS	EMEP 2014
Mercury in air						
GEM	Gold traps	NS-EN 15852:2010 and SOPs from NADP-AMNet and GMOS	Not applicable	Not applicable	CVAFS	NS-EN 15852:2010 and SOPs from NADP-AMNet and GMOS
Mercury species in air						
GOM	KCl impregnated denuder	SOPs from NADP-AMNet and GMOS	Not applicable	Thermal desorption	CVAFS	SOPs from NADP-AMNet and GMOS
PBM	Quartz filter	SOPs from NADP-AMNet and GMOS	Not applicable	Thermal desorption	CVAFS	SOPs from NADP-AMNet and GMOS
Mercury in precipitation						
Hg-tot	Borosilicate glass bulk collector	NS-EN 15853:2010 and EMEP 2014.	Pre-sampling preservation using HCl	Not applicable	CVAFS	NS-EN 15853:2010, US-EPA 1631 and EMEP 2014

The laboratory routinely participates in laboratory performance studies for POPs and heavy metals through QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe).

All raw data for POPs and heavy metals are openly accessible from the NILU database (ebas.nilu.no) for thorough examinations.

Sampling and analysis of the organic contaminants of emerging concern (i.e. volatile siloxanes/fluorinated/chlorinated substances, S/MCCPs, nBFRs, OPFRs, dechloranes and PFAS) are associated with a bigger uncertainty than the well-established POPs. This is due to more diffuse sources in laboratories and sampling facilities (e.g., the use of CPs has increased again in a lot of different industrial, household products and consumer goods during the last few years) that results in a larger risk for contamination. NILU is continuously taking actions to minimize this influence. Examples of such measures are improved pre-cleaning of analytical equipment, isolated work in clean cabinet facilities and removal of some materials and products where the chemicals are in use. However, samples cannot be sampled, stored, extracted, and prepared for analysis without any physical contact with a lot of different materials and instruments. This causes a raising number of blank samples exceeding the acceptance level, which in consequence raises the method detection limit (MDL) for samples analysed in parallel with those blank samples. Therefore, for most of the emerging contaminants we adopt a sample blank treatment commonly used for non-regulated contaminants. The mass of the target compounds in each sample is compared to the average mass in the field blanks (on a site-specific basis) and treated as follows: If the blank level is <20% of the measured level, no correction is done. If the blank level is 20–100% of the measured level, the blank level is subtracted from the measured level. In this case, the MDL is calculated as 3 times the standard deviation only.

The quality and uncertainty of the analysis of the different compound classes is described in the internal technical report for monitoring programmes (Enge et al., 2022). The report classifies the compound classes in three categories as given below. For practical reasons, one additional category has been introduced in this report.

Category 1: The methods are accredited according to EN ISO/IEC 17025 or could easily be included into this system. The analysis is well proven with available relevant interlaboratory studies and/or certified reference material.

Category 2: The methods are not accredited according to EN ISO/IEC 17025. Either reference material or interlaboratory studies are available and the methods are well proven.

Category 3: None or few reference material or satisfying interlaboratory studies available. The methods are less reproducible, and the results have higher uncertainty.

Category 4 (extra): No standard available to be purchased and it is only possible to investigate the samples based on the m/z of the compounds. Resultingly, it is not possible to predict a concentration and these compounds are reported as detected/non-detected only.

Appendix C The monitoring programme and the datasets

Air measurements of heavy metals and POPs started in 1991 at Lista observatory in southern Norway as part of a government programme on environmental monitoring and were reported to the Comprehensive Atmospheric Monitoring Programme (CAMP) under the Convention for the Protection of the marine Environment of the North-East Atlantic (OSPAR) (http://www.ospar.org). Lista was closed in 2004, but the extended measurement programme continued at the nearby observatory in Birkenes. From 2009, the measurements were done at a new location (i.e. Birkenes II). In 1993, air measurements of heavy metals and POPs were included at the Zeppelin Observatory on Svalbard as part of the Arctic Monitoring and Assessment Programme (AMAP) (http://www.amap.no). Birkenes and Zeppelin became part of EMEP (http://www.emep.int) under the LRTAP (http://www.unece.org/env/lrtap) in 1999, (Tørseth et al., 2012). From 2009-2021 a monitoring station for heavy metals and POPs also was located at Andøya as part of the national Marine Pollution Monitoring Programme for the Norwegian Environment Agency (Green et al., 2011). The urban monitoring station was established in Sofienbergparken (Oslo) in 2022 (for environmental contaminants), primarily aiming at early detection of CECs in air.

Table C.2: Site locations and station keepers for the monitoring sites in 2024.

Station code (EBAS)	Station	Fylke	m.a.s.l.	Latitude N	Longitude E	Established	Station keepers	Adress
NO0001R NO0002R	Birkenes Birkenes II	Aust-Agder	190 219	58° 23'	8° 15'	1971	Olav Lien	4760 Birkeland
NO0056R	Hurdal	Akershus	300	60° 22’	11° 04’	1997	Thomas Sørlien	2090 Hurdal
NO0039R	Kårvatn	Møre og Romsdal	210	62° 47'	8° 53'	1978	Erik Kårvatn	6645 Todalen
NO0073U	Sofienbergparken	Oslo	24	59° 55'	10° 46'	2021	NILU	0558 Oslo
NO0047R	Svanvik	Finnmark	27	69°27'	30°02’	1986	NIBIO	9900 Kirkenes
NO0042G	Zeppelin		475	78° 54'	11° 53'	1989	Norsk Polarinstitutt	9173 Ny-Ålesund

* Osen (forest) is part of the national forest damage monitoring conducted by NIBIO

Table C.2: A list of contaminants measured at each station in 2024.

Monitoring station	Birkenes	Zeppelin	Hurdal	Kårvatn	Svanvik	Sofienberg-parken
Organic contaminants – Air	HCB, HCH, DDTs, PCBs, PBDEs, HBCDDs, PAHs, PFAS (ionic + volatile), cVMS, S/MCCPs, HCBD, vol. F+Cl substances.	HCB, HCH, DDTs, chlordanes, PCBs, PBDEs, HBCDDs, PAHs, PFAS (ionic + volatile), cVMS, S/MCCPs, nBFRs, dechloranes, HCBD, vol. F+Cl substances.				PBDEs, HBCDDs, PFAS (ionic + volatile), cVMS, lVMS, S/MCCPs, nBFRs, OPFRs, dechloranes, PCP/PCA, UV-substances, HCBD, vol. F+Cl substances.
Organic contaminants – Precipitation	HCB, HCHs, PCBs					
Heavy metals – Air	Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Ti, V, Zn, Hg	Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Ti, V, Zn, Hg + Hg-species			Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Ti, V, Zn	Al, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Ag, Ti, V, Zn, Hg
Heavy metals – Precipitation	As, Cd, Cr, Co, Cu, Pb, Mn, Ni, V, Zn, Hg		As, Cd, Cr, Co, Cu, Pb, Mn, Ni, V, Zn, Hg	As, Cd, Cr, Co, Cu, Pb, Mn, Ni, V, Zn, Hg	Al, As, Cd, Cr, Co, Cu, Pb, Mn, Ni, V, Zn	

Table C.3: The 2024 datasets used in this report and their associated doi's

Site	Name	Components	DOI's and their landing web pages
NO0001R	Birkenes	HMs in precipitation	https://doi.org/10.48597/Y3JQ-MFDT
NO0001R	Birkenes	Mercury in precipitation	https://doi.org/10.48597/GDTW-Z354
NO0002R	Birkenes II	Mercury in air	https://doi.org/10.48597/3YB3-DTGD
NO0002R	Birkenes II	HMs in air/aerosol	https://doi.org/10.48597/BBQ2-Q5TM
NO0002R	Birkenes II	HCB/PCBs in air/PM10	https://doi.org/10.48597/WY7Q-G8HE
NO0002R	Birkenes II	HCHs/DDTs in air/PM10	https://doi.org/10.48597/F6T8-KV4B
NO0002R	Birkenes II	PBDEs in air/PM10	https://doi.org/10.48597/DK7X-VG8A
NO0002R	Birkenes II	HCBDDs in air/PM10	https://doi.org/10.48597/CCX3-XS6K
NO0002R	Birkenes II	PAHs in air/PM10	https://doi.org/10.48597/7AT2-6C4W
NO0001R	Birkenes	POPs in precipitation	https://doi.org/10.48597/9QCT-E72T
NO0039R	Kårvatn	HMs in precipitation	https://doi.org/10.48597/UKBA-VZEP
NO0039R	Kårvatn	Mercury in precipitation	https://doi.org/10.48597/BMSF-X6HU
NO0042G	Zeppelin	HMs in air/aerosol	https://doi.org/10.48597/6PXH-3ESD
NO0042G	Zeppelin	Mercury in air	https://doi.org/10.48597/RKPP-ZA3R
NO0042G	Zeppelin	GOM and PBM in air	https://doi.org/10.48597/FK9Z-4NZ4
NO0042G	Zeppelin	HCB/PCBs in air/aerosol	https://doi.org/10.48597/TXXS-WB2D
NO0042G	Zeppelin	HCHs/DDTs in air/aerosol	https://doi.org/10.48597/9RHM-VA28
NO0042G	Zeppelin	CHLs in air/aerosol	https://doi.org/10.48597/4RRE-TCGA
NO0042G	Zeppelin	PBDEs in air/aerosol	https://doi.org/10.48597/YZH3-SYED
NO0042G	Zeppelin	HBCDDs in air/aerosol	https://doi.org/10.48597/XRRU-5B48
NO0056R	NO0056R	Mercury in precipitation	https://doi.org/10.48597/ZPWB-QAKP
NO0056R	NO0056R	HMs in precipitation	https://doi.org/10.48597/X9XC-HZSM
NO0047R	Svanvik	HMs in air/aerosol	https://doi.org/10.48597/P2VK-KQ3S
NO0047R	Svanvik	HMs in precipitation	https://doi.org/10.48597/Q9YY-8UMB

NO0073U	Sofienbergparken	PBDEs in air/PM10	https://doi.org/10.48597/A4U4-C6TY
NO0073U	Sofienbergparken	HBCDs in air/PM10	https://doi.org/10.48597/UM7D-P65X
NO0073U	Sofienbergparken	HMs in air/PM10	https://doi.org/10.48597/XPYV-29XW
NO0073U	Sofienbergparken	Mercury in air	https://doi.org/10.48597/KFET-UY8C
NO0059	Troll	Mercury in air	https://doi.org/10.48597/6FFJ-BV27

Appendix D Summary of results from measurements during renovation at Zeppelin

New building materials such as wood, glue, paint, joint foam and insulation foam are sources of many different chemical compounds that easily evaporate into the air and may increase the concentration of volatile organic compounds (VOC) in both indoor and outdoor air.

The VOCs detected indicate which sources that are the most likely. The results from indoor air clearly show the presence of humans at the station. This is evident from the high concentrations of D-Limonene, isopropyl alcohol, benzaldehyde, (Z)-(Z)-Hex-3-en-1-yl 2-methylbut-2-enoate and acetone which are typical from cosmetics, soaps and other types of cleaning agents. The high concentrations of 1-butanol is expected as this solvent is used in one of the measuring instruments.

There were also some amounts of glycol ethers such as Ethanol, 2-(2-butoxyethoxy)-, 2-Propanol, 1-(2-butoxy-1-methylethoxy)- and Ethanol, 2-phenoxy- in the air which are typical from paint products. These are added to water-based paint, often together with dimethyl esters such as dimethylester adiapate and dimethyl ester glutarate, as well as 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate, better known as Texanol™, which also clearly emerges from the dataset.

There is also some ethanediol in the air. This is typically used as antifreeze in, for example, liquid putty, liquid concrete and other liquid materials when it is cold outside to ensure the correct consistency.

Other substances include phenol, as well as benzene, toluene, ethylbenzene and xylene (so-called BTEX). These are suspected to come from outdoor air. Phenol is typically from burning wood, while BTEX gases come from combustion engines such as snowmobiles, cars, boats and diesel generators.

*Table D.1: Gives an overview of the most abundant compounds in air in different locations at the Zeppelin station. TVOC is the calculated Total amount of Volatile Organic Compounds, given in µg/m³. Normal air should not exceed 400 µg/m³. The TVOC-concentrations are calculated using toluene equivalents.**

Sampling site:	Sampling time:	TVOC:	Most abundant compounds:						Abundance:						Total of TVOC:
Cleanroom	30.10-20.11	841	Heptane	Cyclohexane	Cyclohexane, methyl-				20%	16%	15%				52%
Roof 1	30.10-20.11	42	Nonanal	Acetophenone					13%	11%					24%
Roof 2	30.10-20.11	141	n-Hexane	Dodecane	Toluene	Ethyl Acetate			14%	14%	7%	6%			42%
NILU-room 1	30.10-20.11	797	Hexane, 3-methyl-	Cyclohexane, methyl-	Hexane, 2-methyl-				22%	16%	8%				47%
NILU-room 2	05.11-20.11	1383	Cyclohexane	Heptane					8%	5%					13%
Hybrid-room	05.11-20.11	891	D-Limonene	Nonane	1-Butanol	1-Hexanol, 2-ethyl-			6%	5%	4%	4%			19%
Campaign-room	05.11-20.11	1012	1-Butanol	D-Limonene	Nonane				6%	5%	5%				16%
Cable car 1	05.11-20.11	157	Isopropyl Alcohol	1-Butanol	Carbon dioxide				6%	5%	5%				16%
Cable car 2	05.11-20.11	76	Carbon dioxide	Acetonitrile	Acetophenone	Isopropyl Alcohol	1-Butanol	Benzaldehyde	10%	6%	5%	5%	5%	5%	36%
Roof 1	20.11-04.12	9	n-Hexane	Acetophenone	Benzaldehyde				20%	20%	14%				54%
Roof 2	20.11-04.12	24	n-Hexane	Ethyl Acetate					31%	18%					49%
NILU-room 1	20.11-04.12	869	D-Limonene	1-Butanol	Nonane				7%	6%	6%				19%
Hybrid-room	20.11-04.12	1100	Limonene	1-Butanol	Hexane, 2,4-dimethyl-				6%	6%	5%				17%
Campaign-room	20.11-04.12	911	D-Limonene	1-Butanol	Pentane, 2,2,3,4-tetramethyl-				6%	6%	5%				18%
Cable car 1	20.11-04.12	76	Toluene	Methyl nitrate	Benzene, 1,3-dimethyl-	n-Hexane			10%	6%	5%	5%			26%
Cable car 2	20.11-04.12	32	Toluene	Benzene, 1,3-dimethyl-	n-Hexane	Acetophenone			15%	7%	7%	7%			35%
Roof 1	04.12-18.12	81	Pentane, 3-methyl-	Ethyl Acetate	3-Methoxy-3-methylbutanol	Acetonitrile			21%	12%	11%	9%			52%
Roof 2	04.12-18.12	89	n-Hexane	Ethyl Acetate	Acetonitrile				22%	15%	9%				46%
NILU-room 1	04.12-18.12	115	1-Butanol	n-Hexane	Nonane				14%	5%	5%				24%
Hybrid-room	04.12-18.12	266	3-Methoxy-3-methylbutanol	n-Hexane					9%	8%					16%
Campaign-room	04.12-18.12	136	Nonane	n-Hexane	1-Butanol				6%	5%	4%				15%
Cable car 1	04.12-18.12	59	1-Butanol	Ethanol, 2-phenoxy-	3-Methoxy-3-methylbutanol	n-Hexane			15%	9%	8%	8%			41%
Cable car 2	04.12-18.12	111	3-Methoxy-3-methylbutanol	n-Hexane					19%	13%					32%
Cleanroom	28.03-14.04	17	Acetophenone	1-Butanol	Phenacylidene diacetate	Benzaldehyde			21%	19%	13%	11%			64%
Roof 1	28.03-14.04	14	Toluene	Acetophenone	Benzaldehyde	Benzoyl isothiocyanate			25%	21%	16%	10%			
Roof 2	28.03-14.04	15	Acetophenone	Benzaldehyde	Benzoyl isothiocyanate				28%	17%	14%				59%
NILU-room 1	28.03-14.04	51	1-Butanol						71%						71%
Cable car 1	28.03-14.04	29	1-Butanol	Acetophenone	Benzaldehyde				55%	11%	8%				74%
Cable car 2	28.03-14.04	23	1-Butanol						68%						68%

*Toluene equivalents is when the calibration for toluene is used to calculate the concentration for all the detected compounds in the sample. This is standard practice in non-target VOC-analysis.

Appendix E Summary of results from parallel measurements at Zeppelin

The custom-made NILU sampler for POP, PAH and BFH (so-called “NILU-PUR”) used at the Zeppelin Observatory (Table B.1), are planned to be replaced by the conventional Digitel Hi-vol in 2025. The Digitel sampler utilizes the same sampling principles, i.e. a pump draws air through a filter and an adsorbent (PUF/PUF), and gives an accurate and automatically volume estimate based on the flow and ambient temperature. The same sampler is currently used for heavy metals and PFAS, and also at Birkenes and Sofienbergparken. In 2024, a number of samples were therefore taken with Digitel in parallel with the NILU sampler, to assess the difference between the two samplers.

While air was sampled simultaneously with the two samplers at the monitoring site, and the samples were transported together to the laboratory, the preparation and analysis of the Digitel samples were done on different days than the original samples, meaning measurement uncertainty (25-35% for PCBs, 40% for HCHs, 30-35% for DDTs, 35% for Chlordanes and HCB, 35-50% for PBDEs and 35-100% for PAHs) also needs to be taken into account in the comparison.

In general, the air concentrations of organic contaminants obtained from the Digitel sampler were comparable to the NILU-sampler (Table E.1-E.4), with the highest deviations (dev%) when the concentrations were below or close to the method detection limit. Furthermore, elevated deviations were observed for some of the sampling dates for the most volatile PAHs. For these compounds, occasionally high field blanks were observed at the station and e.g. the concentrations of Naphtalene have been flagged in EBAS (in 2024) with higher uncertainty. Further investigations are therefore needed for these compounds. High deviations are also observed for some of the BDEs (e.g. BDE-209), which might be related to possible blank contributions and higher uncertainty in the analytical determination.

Table E.1: PCBs

	NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%	
Start:	11.03.24	11.03.24			06.05.24	06.05.24			01.07.24	01.07.24			29.07.24	29.07.24			24.08.24	26.08.24		
Stop:	13.03.24	13.03.24			08.05.24	08.05.24			03.07.24	03.07.24			31.07.24	31.07.24			26.08.24	28.08.24		
PeCB	32.9	33.7	2%		21.9	18.5	-16%		7.1	7.13	0%		7.61	7.12	-6%		10.2	10.3	1%	
HCB	46.3	46.2	0%		47.8	60.1	26%		42.7	42.7	0%		44.2	47.2	7%		55.8	56	0%	
18	0.536	0.579	8%		0.438	0.421	-4%		1.04	1.29	24%		0.574	0.348	-39%		0.657	0.725	10%	
28	0.379	0.32	-16%		0.418	0.237	-43%		0.948	0.502	-47%		0.651	0.157	-76%		0.602	0.336	-44%	
31	0.338	0.301	-11%		0.404	0.232	-43%		0.881	0.527	-40%		0.634	0.191	-70%		0.564	0.35	-38%	
33	0.238	0.185	-22%		0.277	0.13	-53%		0.695	0.335	-52%		0.49	0.106	-78%		0.434	0.224	-48%	
37	0.0546	0.0246	-55%		0.0802	0.0129	-84%		0.172	0.0344	-80%		0.152	0.0169	-89%		0.118	0.0247	-79%	
47	0.159	0.151	-5%		0.144	0.111	-23%		0.255	0.129	-49%		0.194	0.104	-46%		0.18	0.099	-45%	
52	0.323	0.301	-7%		0.256	0.207	-19%		0.365	0.246	-33%		0.284	0.176	-38%		0.285	0.193	-32%	
66	0.0916	0.0612	-33%		0.0521	0.036	-31%		0.162	0.0416	-74%		0.128	0.0295	-77%		0.121	0.0378	-69%	
74	0.0579	0.0432	-25%		0.0519	0.0267	-49%		0.101	0.0287	-72%		0.0901	0.0244	-73%		0.0746	0.0251	-66%	
99	0.0557	0.0478	-14%		0.0583	0.0429	-26%		0.0622	0.0295	-53%		0.0541	0.031	-43%		0.0549	0.0297	-46%	
101	0.154	0.116	-25%		0.162	0.0975	-40%		0.186	0.0694	-63%		0.178	0.0847	-52%		0.168	0.0712	-58%	
105	0.0138	0.0064	-54%		0.0137	0.0057	-58%		0.0173	0.0064	-63%		0.0146	0.0044	-70%		0.0183	0.0055	-70%	
114	0.0012	0.001	-17%	*	0.002	0.001	-50%	*	0.001	0.001	0%	*	0.002	0.0018	-10%	*	0.001	0.001	0%	*
118	0.0466	0.0252	-46%		0.049	0.0246	-50%		0.0551	0.0202	-63%		0.0454	0.0163	-64%		0.0552	0.019	-66%	
122	0.001	0.001	0%	*	0.002	0.001	-50%	*	0.001	0.001	0%	*	0.002	0.001	-50%	*	0.001	0.001	0%	*
123	0.0011	0.001	-9%	*	0.0038	0.001	-74%	*	0.001	0.001	0%	*	0.002	0.0021	5%	*	0.001	0.001	0%	*
128	0.0071	0.003	-58%		0.0089	0.001	-89%	*	0.008	0.001	-88%	*	0.0067	0.0038	-43%		0.0071	0.0033	-54%	
138	0.0407	0.0204	-50%		0.0453	0.0254	-44%		0.0471	0.021	-55%		0.0417	0.0272	-35%		0.043	0.0214	-50%	
141	0.0107	0.0062	-42%		0.0085	0.0045	-47%		0.0128	0.0054	-58%		0.0104	0.0087	-16%		0.0125	0.0059	-53%	
149	0.0726	0.0533	-27%		0.0931	0.055	-41%		0.0907	0.0471	-48%		0.0934	0.0691	-26%		0.0836	0.0506	-39%	
153	0.0638	0.0436	-32%		0.0615	0.0415	-33%		0.0699	0.04	-43%		0.057	0.0578	1%		0.0613	0.0394	-36%	
156	0.0028	0.0012	-57%		0.002	0.001	-50%	*	0.0029	0.001	-66%	*	0.0023	0.001	-57%	*	0.0028	0.0011	-61%	
157	0.001	0.001	0%	*	0.002	0.001	-50%	*	0.0011	0.001	-9%	*	0.001	0.001	0%	*	0.001	0.001	0%	*
167	0.0013	0.001	-23%	*	0.002	0.001	-50%	*	0.0018	0.001	-44%	*	0.001	0.001	0%	*	0.001	0.001	0%	*
170	0.0032	0.0017	-47%		0.0065	0.002	-69%	*	0.0043	0.0021	-51%		0.003	0.0022	-27%		0.0041	0.00137	-67%	*
180	0.0103	0.0056	-46%		0.0095	0.007	-26%		0.0095	0.0068	-28%		0.0081	0.008	-1%		0.0092	0.0069	-25%	
183	0.0044	0.0031	-30%		0.0057	0.001	-82%	*	0.005	0.0031	-38%		0.0051	0.0044	-14%		0.0049	0.0036	-27%	
187	0.0125	0.0088	-30%		0.0085	0.00255	-70%	*	0.0145	0.0087	-40%		0.0147	0.0136	-7%		0.0133	0.0108	-19%	
189	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*
194	0.0011	0.001	-9%	*	0.001	0.001	0%	*	0.0011	0.001	-9%	*	0.001	0.001	0%	*	0.001	0.001	0%	*
206	0.00111	0.001	-10%	*	0.014	0.003	-79%	*	0.0024	0.00102	-58%	*	0.001	0.001	0%	*	0.0011	0.00104	-5%	*
209	0.0019	0.001	-47%	*	0.003	0.001	-67%	*	0.0027	0.0016	-41%		0.0015	0.0012	-20%		0.0012	0.001	-17%	*
Sum 7 PCB	1.0174	0.8318	-18%		1.0013	0.64	-36%		1.6806	0.9054	-46%		1.2652	0.527	-58%		1.2237	0.6869	-44%	
Sum PCB	4.48621	3.8855	-13%		3.7043	2.2926	-38%		7.7964	5.21222	-33%		5.5713	2.292	-59%		5.4139	3.62794	-33%	
Median:			-23%				-45%				-45%				-36%				-37%	
Min:			-58%				-89%				-88%				-89%				-79%	
Max:			8%				26%				24%				7%				10%	

*The concentration from either NILU-PUR or Digitel is below the method detection limit

Table E.2 HCHs, DDTs and Chlordanes

	NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%	
Start:	11.03.24	11.03.24			06.05.24	06.05.24			01.07.24	01.07.24			29.07.24	29.07.24			24.08.24	26.08.24			10.03.25	10.03.25		
Stop:	13.03.24	13.03.24			08.05.24	08.05.24			03.07.24	03.07.24			31.07.24	31.07.24			26.08.24	28.08.24			12.03.25	12.03.25		
a-HCH	1.55	1.66	7%		2.16	2.01	-7%		2.23	2.2	-1%		2.72	2.96	9%		3.13	3.61	15%	*	1.40	1.51	8%	
g-HCH	0.331	0.443	34%		0.383	0.548	43%		0.387	0.343	-11%		0.537	0.502	-7%		0.508	0.551	8%		0.361	0.324	-10%	
o,p'-DDE	0.0334	0.0313	-6%		0.0117	0.0109	-7%		0.009	0.00202	-78%	*	0.0085	0.0075	-12%		0.0096	0.0087	-9%		0.0428	0.0382	-11%	
p,p'-DDE	0.229	0.218	-5%		0.0549	0.0581	6%		0.0385	0.0451	17%		0.0391	0.0403	3%		0.0545	0.0494	-9%		0.257	0.229	-11%	
o,p'-DDD	0.0034	0.00253	-26%	*	0.0037	0.00282	-24%		0.0029	0.003	3%	*	0.0037	0.0046	24%		0.00288	0.0054	88%		0.005	0.0027	-46%	
p,p'-DDD	0.00291	0.00253	-13%	*	0.00294	0.0025	-15%	*	0.0029	0.004	38%	*	0.00262	0.00257	-2%	*	0.00288	0.00271	-6%	*	0.00264	0.00249	-6%	*
o,p'-DDT	0.0387	0.0334	-14%		0.0187	0.0206	10%		0.0128	0.006	-53%	*	0.0267	0.027	1%		0.0316	0.0342	8%	*	0.055	0.0423	-23%	
p,p'-DDT	0.0238	0.015	-37%		0.00545	0.00745	37%	*	0.0105	0.007	-33%	*	0.0118	0.0113	-4%		0.0235	0.0219	-7%		0.0258	0.0157	-39%	
Sum DDT	0.33121	0.30276	-9%		0.09739	0.10237	5%		0.0766	0.06712	-12%		0.09242	0.09327	1%		0.12496	0.12231	-2%		0.38824	0.33039	-15%	
trans-Chlordane	0.101	0.0994	-2%		0.0631	0.0851	35%		0.0254	0.0418	65%		0.0451	0.0632	40%		0.0454	0.0495	9%					
cis-Chlordane	0.181	0.171	-6%		0.235	0.299	27%		0.152	0.215	41%		0.257	0.339	32%		0.224	0.255	14%					
trans-Nonachlor	0.16	0.151	-6%		0.232	0.288	24%		0.131	0.185	41%		0.208	0.276	33%		0.189	0.207	10%					
cis-Nonachlor	0.00749	0.00651	-13%	*	0.022	0.0293	33%		0.02	0.0293	47%		0.0321	0.0428	33%		0.0289	0.036	25%					
Median:			-6%				10%				3%				3%				8%				-11%	
Min:			-37%				-24%				-78%				-12%				-9%				-46%	
Max:			34%				43%				65%				40%				88%				8%	

*The concentration from either NILU-PUR or Digitel is below the method detection limit

Table E.3 PBDEs

	NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%	
Start:	08.04.24	08.04.24			03.06.24	03.06.24			23.09.24	23.09.24			16.12.24	16.12.24			27.01.25	27.01.25		
Stop:	11.04.24	11.04.24			06.06.24	06.06.24			26.09.24	26.09.24			19.12.24	19.12.24			30.01.25	30.01.25		
TBA	1.62	1.91	18%		3.48	2.28	-34%		19.5	15.1	-23%		7.62	14.8	94%		11.3	12.5	11%	
17[1]	0.00396	0.00346	-13%	*	0.0041	0.00358	-13%	*	0.0042	0.00345	-18%	*	0.00387	0.00348	-10%	*	0.0032	0.0029	-9%	
28[1]	0.0058	0.0049	-16%		0.0068	0.0058	-15%		0.0108	0.00304	-72%	*	0.008	0.00726	-9%		0.0086	0.0051	-41%	
47[1]	0.0826	0.106	28%		0.15	0.286	91%		0.16	0.0914	-43%		0.143	0.287	101%		0.235	0.152	-35%	
49[1]	0.0034	0.0035	3%	*	0.0065	0.007	8%		0.0067	0.00297	-56%	*	0.0044	0.00863	96%		0.0076	0.0079	4%	
66[1]	0.00204	0.0018	-12%	*	0.0034	0.0038	12%		0.0032	0.00178	-44%	*	0.0026	0.00555	113%		0.00384	0.0035	-9%	*
71[1]	0.00146	0.00127	-13%	*	0.00151	0.00132	-13%	*	0.00138	0.00127	-8%	*	0.00143	0.00128	-10%	*	0.00142	0.001	-30%	*
77[1]	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*
85[1]	0.00465	0.00407	-12%	*	0.00482	0.00421	-13%	*	0.00439	0.00406	-8%	*	0.00456	0.00409	-10%	*	0.00178	0.00115	-35%	*
99[1]	0.0155	0.0135	-13%	*	0.0733	0.0344	-53%		0.0233	0.017	-27%		0.0208	0.0576	177%		0.0314	0.0121	-61%	
100[1]	0.00537	0.00469	-13%	*	0.0201	0.0167	-17%		0.0158	0.009	-43%		0.0134	0.0202	51%		0.0142	0.0067	-53%	
119[1]	0.00128	0.00112	-13%	*	0.00133	0.00116	-13%	*	0.00121	0.00112	-7%	*	0.00125	0.00113	-10%	*	0.00128	0.001	-22%	*
126[1]	0.00138	0.0012	-13%	*	0.00143	0.00125	-13%	*	0.0013	0.0012	-8%	*	0.00135	0.00121	-10%	*	0.001	0.001	0%	*
138[1]	0.00759	0.00663	-13%	*	0.00786	0.00687	-13%	*	0.00716	0.00662	-8%	*	0.00743	0.00668	-10%	*	0.00758	0.00488	-36%	*
153[1]	0.00499	0.00436	-13%	*	0.00517	0.00452	-13%	*	0.00471	0.00435	-8%	*	0.00489	0.00439	-10%	*	0.00448	0.00289	-35%	*
154[1]	0.00259	0.00226	-13%	*	0.0038	0.00235	-38%	*	0.00244	0.00226	-7%	*	0.00254	0.00256	1%	*	0.00256	0.00165	-36%	*
156[1]	0.00769	0.00672	-13%	*	0.00796	0.00696	-13%	*	0.00725	0.0067	-8%	*	0.00753	0.00676	-10%	*	0.00834	0.00537	-36%	*
183[1]	0.00975	0.00852	-13%	*	0.0101	0.00883	-13%	*	0.0092	0.00851	-8%	*	0.00955	0.00858	-10%	*	0.00448	0.00289	-35%	*
184[1]	0.00321	0.0028	-13%	*	0.00332	0.0029	-13%	*	0.00302	0.0028	-7%	*	0.00314	0.00282	-10%	*	0.00217	0.0014	-35%	*
190[1]	0.00619	0.00541	-13%	*	0.0064	0.0056	-13%	*	0.00583	0.00539	-8%	*	0.00606	0.00544	-10%	*	0.0048	0.00309	-36%	*
191[1]	0.00799	0.00699	-13%	*	0.00828	0.00724	-13%	*	0.00754	0.00697	-8%	*	0.00783	0.00704	-10%	*	0.00426	0.00274	-36%	*
196[1]	0.00643	0.00562	-13%	*	0.00665	0.00582	-12%	*	0.00606	0.0056	-8%	*	0.00629	0.00566	-10%	*	0.00368	0.00237	-36%	*
197[1]	0.00608	0.00531	-13%	*	0.00629	0.0055	-13%	*	0.00573	0.0053	-8%	*	0.00595	0.00535	-10%	*	0.00433	0.00279	-36%	*
202[1]	0.0154	0.0135	-12%	*	0.016	0.014	-13%	*	0.0146	0.0135	-8%	*	0.0151	0.0136	-10%	*	0.00959	0.00618	-36%	*
206[1]	0.392	0.0454	-88%		0.0284	0.0252	-11%	*	0.0258	0.0239	-7%	*	0.0268	0.0557	108%	*	0.0114	0.0126	11%	*
207[1]	0.145	0.0247	-83%	*	0.0293	0.0256	-13%	*	0.0267	0.0247	-7%	*	0.0277	0.0249	-10%	*	0.0107	0.0111	4%	*
209	23.2	2.54	-89%		0.212	1.19	461%		2.76	1.37	-50%		0.343	0.859	150%		0.895	0.16	-82%	
[1]Sum 25 BDE	0.743	0.285	-62%		0.414	0.488	18%		0.359	0.254	-29%		0.336	0.548	63%		0.389	0.255	-34%	
Median:			-13%				-13%				-8%				-10%				-35%	
Min:			-89%				-53%				-72%				-10%				-82%	
Max:			28%				461%				0%				177%				11%	

*The concentration from either NILU-PUR or Digitel is below the method detection limit

Table E.4 PAHs

	NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%		NILU-PUR	Digitel	Dev%	
Start:	13.03.24	13.03.24			08.05.24	08.05.24			03.07.24	03.07.24			31.07.24	31.07.24			28.08.24	28.08.24			15.01.25	15.01.25		
Stop:	15.03.24	15.03.24			10.05.24	10.05.24			05.07.24	05.07.24			02.08.24	02.08.24			30.08.24	30.08.24			17.01.25	17.01.25		
Naphtalene[1]	0.711	0.755	6%		0.0259	0.245	846%	*	0.435	0.447	3%		0.0943	0.251	166%		0.143	0.0645	-55%		1.51	0.821	-46%	
2-Methylnaphtalene	0.0591	0.14	137%		0.0091	0.0761	736%	*	0.143	0.143	0%		0.0283	0.102	260%		0.057	0.0259	-55%		0.402	0.202	-50%	
1-Methylnaphtalene	0.0631	0.101	60%		0.00634	0.04	531%	*	0.072	0.0736	2%		0.0146	0.0539	269%		0.0305	0.0136	-55%		0.326	0.192	-41%	
Biphenyl	0.542	0.571	5%		0.0191	0.0349	83%		0.0534	0.0456	-15%		0.0164	0.0345	110%		0.0663	0.0354	-47%		1.31	0.853	-35%	
Acenaphthylene[12]	0.0021	0.012	471%	*	0.00216	0.00355	64%	*	0.0055	0.0066	20%		0.002	0.006	200%	*	0.0035	0.00186	-47%	*	0.0102	0.0038	-63%	
Acenaphthene[12]	0.00506	0.0195	285%	*	0.00521	0.0133	155%	*	0.0163	0.0246	51%		0.00482	0.0217	350%	*	0.0115	0.0052	-55%		0.0378	0.0063	-83%	
Dibenzofuran	0.564	0.562	0%		0.0512	0.0737	44%		0.0527	0.0575	9%		0.0204	0.0527	158%		0.251	0.147	-41%		1.5	0.857	-43%	
Fluorene[12]	0.108	0.103	-5%		0.0133	0.0205	54%		0.0202	0.0193	-4%		0.0057	0.0152	167%		0.028	0.0177	-37%		0.837	0.497	-41%	
Dibenzothiophene	0.0023	0.00181	-21%	*	0.00215	0.00186	-13%	*	0.00203	0.00189	-7%	*	0.00198	0.00188	-5%	*	0.00197	0.00185	-6%	*	0.0055	0.0058	5%	
Phenanthrene[12]	0.0187	0.043	130%		0.00899	0.0078	-13%	*	0.0212	0.0126	-41%		0.0163	0.0105	-36%		0.0123	0.0093	-24%		0.101	0.0856	-15%	
Anthracene[12]	0.00137	0.0022	61%	*	0.00141	0.00122	-13%	*	0.00133	0.00124	-7%	*	0.0013	0.00123	-5%	*	0.0013	0.00121	-7%	*	0.002	0.002	0%	*
3-Methylphenanthrene	0.002	0.0019	-5%	*	0.00143	0.00124	-13%	*	0.0023	0.0017	-26%		0.0017	0.00125	-26%	*	0.0018	0.00123	-32%	*	0.0081	0.0062	-23%	
2-Methylphenanthrene	0.00356	0.00309	-13%	*	0.00367	0.00318	-13%	*	0.00347	0.00324	-7%	*	0.00339	0.00321	-5%	*	0.00337	0.00316	-6%	*	0.0101	0.0079	-22%	
2-Methylanthracene	0.0042	0.00364	-13%	*	0.00432	0.00375	-13%	*	0.00409	0.00381	-7%	*	0.004	0.00378	-6%	*	0.00398	0.00372	-7%	*	0.00258	0.0025	-3%	*
9-Methylphenanthrene	0.00165	0.00143	-13%	*	0.00169	0.00147	-13%	*	0.0016	0.00149	-7%	*	0.00157	0.00148	-6%	*	0.0017	0.00146	-14%	*	0.0044	0.0034	-23%	
1-Methylphenanthrene	0.002	0.002	0%	*	0.00148	0.00129	-13%	*	0.0015	0.00131	-13%	*	0.00137	0.0013	-5%	*	0.0014	0.00128	-9%	*	0.0086	0.007	-19%	
Fluoranthene[12]	0.0109	0.0122	12%		0.00286	0.00248	-13%	*	0.008	0.00253	-68%	*	0.0071	0.0028	-61%		0.00263	0.00246	-6%	*	0.11	0.0685	-38%	
Pyrene[12]	0.0064	0.0072	13%		0.00138	0.00119	-14%	*	0.0039	0.0015	-62%		0.0034	0.0034	0%		0.00126	0.00118	-6%	*	0.0656	0.0317	-52%	
Benzo(a)fluorene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0086	0.005	-42%	
Retene	0.00269	0.00233	-13%	*	0.00277	0.0024	-13%	*	0.00262	0.00244	-7%	*	0.00256	0.00242	-5%	*	0.00254	0.00238	-6%	*	0.0128	0.0092	-28%	
Benzo(b)fluorene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0047	0.0027	-43%	
Benzo(ghi)fluoranthene	0.0016	0.002	25%		0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0146	0.0118	-19%	
Cyclopenta(cd)pyrene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0035	0.0034	-3%	
Benz(a)anthracene[12]	0.001	0.0011	10%	*	0.001	0.001	0%	*	0.0013	0.001	-23%	*	0.0012	0.001	-17%	*	0.001	0.001	0%	*	0.0135	0.0098	-27%	
Triphenylene	0.001	0.0035	250%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0063	0.0057	-10%	
Chrysene 1	0.0024	0.0036	50%		0.001	0.001	0%	*	0.0022	0.001	-55%	*	0.0019	0.001	-47%	*	0.001	0.001	0%	*	0.0274	0.0228	-17%	
Benzo(b)fluoranthenes[12]	0.0027	0.0027	0%		0.001	0.001	0%	*	0.0025	0.001	-60%	*	0.0021	0.001	-52%	*	0.001	0.001	0%	*	0.034	0.0271	-20%	
Benzo(k)fluoranthenes[12]	0.001	0.001	0%		0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0143	0.0119	-17%	
Benzo(j)fluoranthenes	0.0012	0.0012	0%		0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0163	0.0129	-21%	
Benzo(a)fluoranthene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0033	0.0027	-18%	
Benzo(e)pyrene	0.0014	0.0015	7%		0.001	0.001	0%	*	0.0012	0.001	-17%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0185	0.015	-19%	
Benzo(a)pyrene[12]	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0133	0.0104	-22%	
Perylene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0018	0.0014	-22%	
Indeno(1,2,3-cd)pyrene[12]	0.0016	0.0015	-6%		0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0221	0.0193	-13%	
Dibenzo(ac)anthracene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0015	0.0012	-20%	
Dibenzo(ah)anthracene[12]	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0027	0.0022	-19%	
Benzo(ghi)perylene[12]	0.0014	0.0014	0%		0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0188	0.0159	-15%	
Anthanthrene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0014	0.0011	-21%	
Coronene	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.001	0.001	0%	*	0.0082	0.0081	-1%	
Dibenzo(ae)pyrene	0.00114	0.001	-12%	*	0.00118	0.00102	-14%	*	0.00111	0.00104	-6%	*	0.00109	0.00103	-6%	*	0.002	0.00101	-50%	*	0.0029	0.0026	-10%	
Dibenzo(ai)pyrene	0.00104	0.001	-4%	*	0.00107	0.001	-7%	*	0.00101	0.001	-1%	*	0.001	0.001	0%	*	0.002	0.001	-50%	*	0.001	0.001	0%	*
Dibenzo(ah)pyrene	0.00108	0.001	-7%	*	0.00112	0.001	-11%	*	0.00105	0.001	-5%	*	0.00103	0.001	-3%	*	0.002	0.001	-50%	*	0.001	0.001	0%	*
Sum 42 PAH	2.14	2.38	11%		0.19	0.56	197%		0.88	0.87	0%		0.26	0.59	131%		0.65	0.36	-44%		6.50	3.86	-41%	
[1]Sum 16 PAH	0.876	0.967	10%		0.069	0.303	338%		0.522	0.523	0%		0.145	0.320	120%		0.211	0.111	-47%		2.820	1.635	-42%	
[2]Sum 15 PAH	0.165	0.212	29%		0.043	0.058	34%		0.087	0.076	-13%		0.051	0.069	35%		0.068	0.047	-32%		1.310	0.814	-38%	
Median:			0%				0%				0%				0%				-6%				-21%	
Min:			-21%				-14%				-68%				-61%				-55%				-83%	
Max:			471%				846%				51%				350%				0%				5%	

*The concentration from either NILU-PUR or Digitel is below the method detection limit

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