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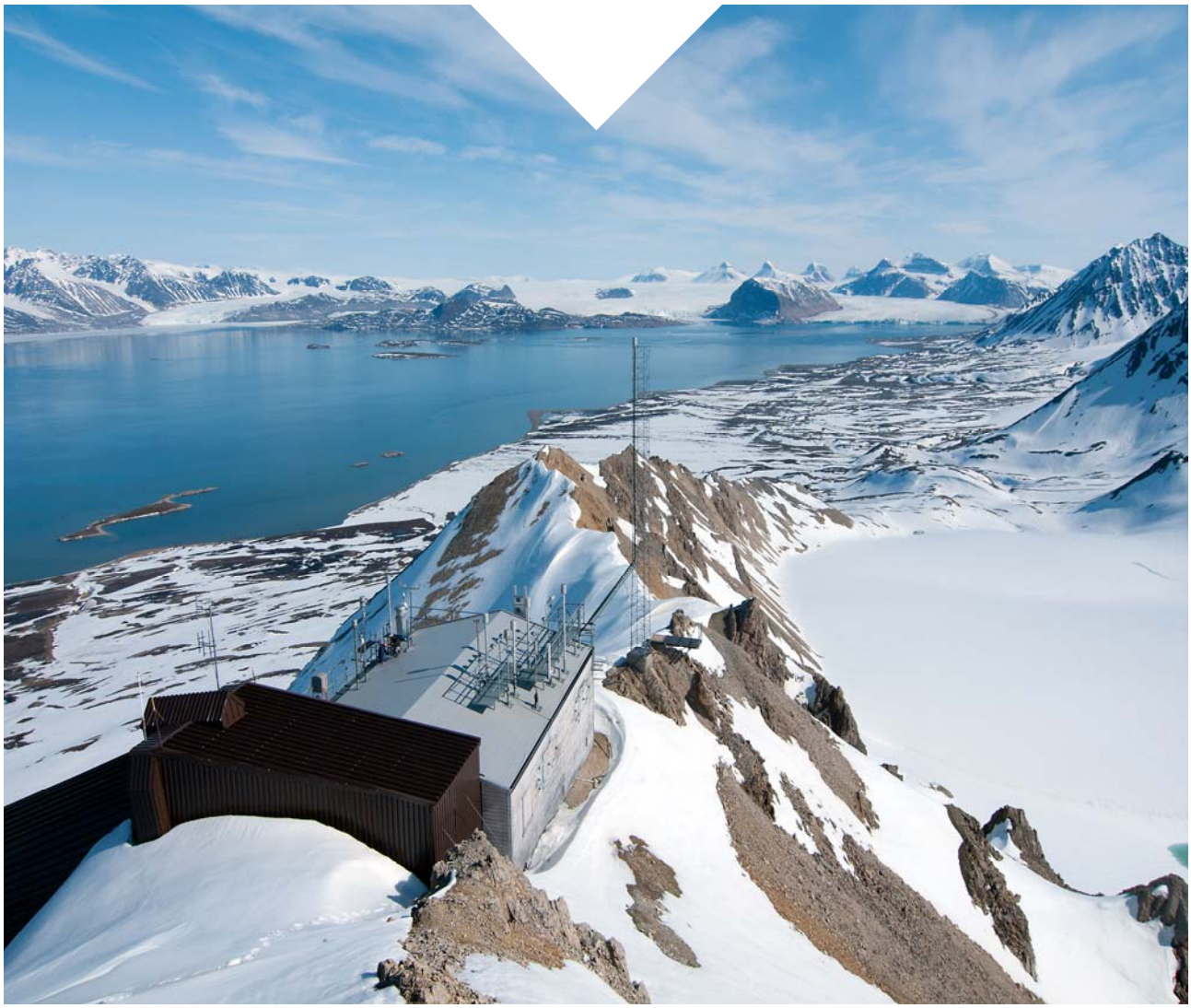
Monitoring of environmental contaminants in air and precipitation, annual report 2013



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Monitoring of environmental contaminants in air and precipitation, annual report 2013

Summary – sammendrag

This report presents results from 2013 for persistent organic pollutants (POPs) and heavy metals from the rural air- and precipitation chemistry monitoring network in Norway. These results are compared to previous years.
Denne rapporten beskriver resultater fra overvåkingen av miljøgifter i luft og nedbør på norske bakgrunnsstasjoner i 2013, og disse er sammenlignet med tidligere år.

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Miljøkjemi
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Miljøovervåkning

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Front page photo

Zeppelin Observatory

Preface

This report presents results of environmental contaminants in air and precipitation from the annual monitoring in Norwegian rural background environments for 2013. The results are part of the national monitoring programme of long-range transported air pollutants, which is conducted by NILU on behalf of The Norwegian Environment Agency, and the Ministry of Climate and Environment.

This report includes heavy metals in precipitation from four sites, persistent organic pollutants (POPs) and heavy metals in air from three sites, and POPs in precipitation from one site.

The present report is one of four reports, which cover the national monitoring of atmospheric composition in the Norwegian rural background environment. The other three reports are published separately; i) inorganic compounds, particulate and carbonaceous matter and ground level ozone; ii) ozone layer and UV; and iii) the influence of climate gases and aerosol particles on climate.

Data and results from the national monitoring program are also reported and used in several international fora, including: EMEP (European Monitoring and Evaluation Programme) under the CLTRAP (Convention on Long-range Transboundary Air Pollution), CAMP (Comprehensive Atmospheric Monitoring Programme) under OSPAR (the Convention for the Protection of the marine Environment of the North-East Atlantic) and AMAP (Arctic Monitoring and Assessment).

All measurement data presented in the current report can be received by contacting NILU, or downloaded directly from the database: http://ebas.nilu.no/.

A large number of persons have contributed to the current report, including those responsible for sampling, technical maintenance, chemical analysis and quality control. Kristine Aasarød is especially acknowledged for compiling this report. Further, the constructive contribution and review of the draft report by the contact persons at the Norwegian Environment Agency, is greatly appreciated.

Kjeller, June 2014

Pernilla B. Nizzetto and Wenche Aas
Project leaders
Environmental Chemistry (MILK) and Atmospheric and Climate Research (ATMOS)

Content

Summary

This report presents the results for 2013 from the Norwegian rural air- and precipitation chemistry monitoring network. The purpose of the monitoring is to increase the knowledge on long-range transported contaminants in Norway. The monitoring network includes monitoring of: i) persistent organic pollutants (POPs) and heavy metals including mercury in air at three sites (i.e. Birkenes, Andøya and Zeppelin), ii) heavy metals in precipitation at four sites (i.e. Birkenes, Hurdal, Kårvatn and Svanvik), and iii) mercury and POPs in precipitation at one site (i.e. Birkenes). In addition, this year two classes of emerging organic pollutants (i.e. siloxanes and chlorinated paraffins) were included at one site (i.e. Zeppelin).

The highest annual mean concentrations of heavy metals measured in precipitation were found at Svanvik in Sør-Varanger due to emissions from smelters in Russia. The wet deposition, however, was generally highest in Southern Norway. In general, the air concentrations of heavy metals was 2-3 times higher at the Birkenes in southern Norway than those observed at Andøya and Zeppelin. The same was seen for polycyclic aromatic hydrocarbons (PAHs) and per- and polyfluorinated alkyl substances (PFAS). This is related to Birkenes being closer to the emission sources at the European Continent. For mercury and legacy POPs, there were no large differences between the sites. This is a result of their large potential to be transported far from emission sources, and indicates a lack of regional primary sources.

There has been a substantial reduction of heavy metals in precipitation in Norway since 1980; i.e. more than 90% reduction for lead at Birkenes and Kårvatn. From 1990, the reductions of lead has been between 50-65%, except at Svanvik where no significant trend for this period has been observed. Similar reductions have been observed for cadmium in precipitation while somewhat less for zinc. The levels of mercury, HCB and HCHs in precipitation have significantly been reduced since the beginning of the monitoring in 1990 when combining the datasets from the linked observatories at Lista and Birkenes.

At Lista/Birkenes there has been a significant reduction in air concentration for almost all heavy metals (As, Cd, Co, Cr, Pb, Ni and V) for the period 1991 to 2013. At Zeppelin, there has also been a significant reduction since 1994 for several heavy metals (As, Cd, Cu, Pb, Ni and V). The reduction of lead has been 62% and 44%, respectively at Birkenes and Zeppelin. For cadmium, similar trends have been observed, 56% and 49% reductions respectively. Significant trends for mercury in air could not be found at any of the sites within the measurement periods.

POPs in air do not show as significant decreasing trends as the heavy metals. The largest reduction in concentration has been observed for HCHs both at the Birkenes and Zeppelin. Reduced concentrations are also observed for DDTs, chlordanes (CHLs), and polychlorinated biphenyls (PCBs) but not as significant due to more fluctuating concentrations. In contrast, an increase in concentrations during the last 10 years has been observed for hexachlorobenzene (HCB) at Zeppelin. The other POP classes are either stable during the last years or monitored too shortly to make any conclusions.

For 2013, PCBs and all pesticides except HCB, were similar or just slightly lower than previous years, supporting a declining trend but also indicates that the declining trends may have

reached a plateau. Surprisingly, the levels of polybrominated diphenyl ethers (PBDEs) and PAHs were up to 2.5 times higher than previous years at Zeppelin and even the highest since 2007 for PBDEs and since 2001 for PAHs. At Birkenes, higher levels than previous years were observed for PBDEs, tribromanisol (TBA) and PFAS and the levels for PBDEs and TBA were the highest since 2007. In contrast the levels of PFAS at Zeppelin supported decreasing trends. Decreasing concentrations of PFAS at Birkenes indicate ongoing emission from primary sources in populated areas.

To date there is still a lack of air monitoring data on both siloxanes (cVMS) and chlorinated paraffins (SCCP/MCCP) and the measurements at Zeppelin during 2013 have helped to fill this gap. Although there is still uncertainties related to the sampling and analysis, a general conclusion is that these pollutants are found at the same levels as PAHs which in turn are up to three orders of magnitude higher than the concentrations of legacy POPs (i.e. PCBs, OCPs, PBDEs, PFAS). This emphasizes the importance of continuous monitoring of these emerging POPs to follow their emission trends.

Sammendrag

Denne rapporten presenterer resultater fra det nasjonale overvåkningsprogrammet for atmosfæriske tilførsler av miljøgifter for 2013. Formålet med overvåkningen er å fremskaffe kunnskap om langtransport av miljøgifter som kilde til forurensning i Norge og ivareta rapportering til internasjonale konvensjoner, programmer og nettverk. Overvåkings-programmet inkluderer observasjoner av i) organiske miljøgifter, tungmetaller og kvikksølv i luft på tre stasjoner (Birkenes, Andøya og Zeppelin), ii) organiske miljøgifter og kvikksølv i nedbør på en stasjon (Birkenes), samt iii) tungmetaller i nedbør på fire stasjoner (Birkenes, Hurdal, Kårvatn og Svanvik). To klasser av nye miljøgifter (siloksaner og klorparafiner) er inkludert 2013 på én lokalitet (Zeppelin).

Den høyeste årlige gjennomsnittskonsentrasjonen for de fleste tungmetallene målt i nedbør ble funnet på Svanvik i Sør-Varanger på grunn av utslipp fra smelteverkene i Russland. Våtavsetning er derimot generelt høyest i Sør-Norge. Generelt er konsentrasjonen målt i luft på Birkenes 2-3 ganger høyere enn det som er observert ved Andøya og Zeppelin. Det samme er også tilfellet for de organiske miljøgiftene PAHs og PFAS. Dette er fordi Birkenes er nærmere utslippskildene på det europeiske kontinentet. For kvikksølv og de fleste internasjonalt regulerte organiske miljøgifter er det ikke store forskjeller mellom stasjonene da de har stort potensiale for langtransport og det indikerer at det ikke er dominerende primære utslippskilder i regionen.

Det har vært en betydelig reduksjon av tungmetaller i nedbør i Norge siden 1980; for bly mer enn 90% på Birkenes og Kårvatn. Fra 1990 har det vært en reduksjon av bly mellom 50-65%, unntatt på Svanvik der det ikke er noen signifikant trend for denne perioden. Det er tilsvarende reduksjoner for kadmium i nedbør, mens noe mindre for sink. For kvikksølv, HCB og HCH i nedbør, har det vært en signifikant reduksjon siden 1990 hvis man kombinerer datasettene fra de nærliggende observatoriene Lista og Birkenes.

På Lista/Birkenes har det vært en betydelig reduksjon i luftkonsentrasjon for nesten alle tungmetaller som er målt (As, Cd, Co, Cr, Pb, Ni og V) for perioden 1991 til 2013. På Zeppelinobservatoriet, har det også vært en betydelig reduksjon siden 1994 for flere tungmetaller (As, Cd, Cu, Pb, Ni, V). Reduksjonen av bly har vært på 62% og 44% hhv. på Birkenes- og Zeppelinobservatoriet. For kadmium er det lignende reduksjoner, hhv. 56% og 49%. Det er ingen signifikante trender for elementært kvikksølv i luft på noen av stasjonene.

De organiske miljøgiftene i luft har ikke så tydelig nedadgående trend som tungmetallene. Den største reduksjonen observeres for HCH'ene. Det er også en reduksjon i de observerte luftkonsentrasjonene for DDT, klordaner og PCB, men før disse observeres også store årlige variasjoner. For HCB er det derimot observert en økning i luftkonsentrasjonen på Zeppelinobservatoriet de siste ti årene. For andre miljøgifter har overvåkningen pågått i for få år til å si noe om trender.

I 2013 er nivået av PCB og alle pesticider utenom HCB, på samme nivå eller lavere enn tidligere år, som bekrefter den generelle nedadgående trend for disse komponentene. Mer overaskende så er nivået av PBDE og PAH på Zeppelinobservatoriet opp til 2.5 ganger høyere enn tidligere år. For PBDE er det høyeste nivå som er observert siden 2007 og for PAH høyeste

siden 2001. På Birkenes er nivået av PBDE, og TBA det høyeste nivå observert siden 2007. For PFAS er det høyere nivå på Birkenes enn tidligere år i motsetning til Zeppelin hvor årsgjennomsnittet er lavere. Høye konsentrasjoner av PFAS på Birkenes kan indikere at det er påvirkning fra primære utslippskilder i bebygde områder.

For å øke kunnskapen om nivået av nye miljøgifter som siloksaner og klorinerte parafiner har disse komponentene blitt inkludert i overvåkingsprogrammet på Zeppelin. Selv om måle- og analysemetodene er usikre kan man observere at nivåene av disse miljøgiftene er på samme konsentrasjonsnivå som PAH, men opp til en faktor tusen høyere enn de regulerte POPene (PCB, OCP, PBDE, PFAS). Dette viser at det er viktig å fortsatt overvåke disse nye stoffene for å følge utviklingen fremover.

1. The monitoring programme

Heavy metals and Persistent Organic Pollutants (POPs) are identified as being toxic, bio-accumulative, persistent and prone to long-range transport. Due to the contaminants' threat against health and environment, monitoring of these pollutants has been of high priority for the government. Long-range transport of air pollution is, for several compounds, the most important source in remote areas where there are few or no local sources. Recognition of long-range atmospheric transport of environmental contaminants to remote areas, such as the Arctic, has contributed to the regulation of several of these compounds both on a regional and global scale.

The Aarhus protocol on heavy metals signed in 1998 (UN/ECE, 1998a), targets three particularly harmful metals: cadmium, lead and mercury. Parties will have to reduce their emissions of these three metals below their levels in 1990. The Protocol was amended in 2012, to adopt more stringent controls of heavy metals. Emissions of POPs in Europe are regulated in the Aarhus Protocol on POPs from 1998 (UN/ECE, 1998b), and initially it included sixteen substances/substance groups. In 2009, seven additional substances were amended to the Protocol (UN/ECE, 2010). The use and production of POPs is also regulated or banned on a global scale by the Stockholm Convention on POPs (SC). The SC currently includes 23 compounds (Stockholm Convention, 2007; Stockholm Convention, 2011).

The purpose of this monitoring programme is to obtain information of atmospheric contribution of both regulated and new emerging contaminants to the Norwegian environment, and to monitor any changes in the contaminants' levels in time and space. This documentation is essential for compliance monitoring of existing abatement strategies, and to develop new policy for emerging contaminants. To document the long-range transport of air pollution, the locations of the monitoring stations/observatories are selected, as far as possible, in areas which are not influenced by any local sources. Further, the number of observatories and the geographical distribution are selected in order to represent different parts of Norway. The observatories in the monitoring programme are to a large extent part of the long-term national measurement programme of atmospheric composition.

Monitoring of heavy metals in precipitation has been part of the Norwegian national monitoring programme since 1980, while POPs were included in 1991. Air measurements of heavy metals and POPs started in 1991 at Lista in south of Norway as part of the CAMP Programme (The Comprehensive Atmospheric Monitoring Programme) under the OSPAR Convention (The Convention for the Protection of the Marine Environment of the North-East Atlantic), (http://www.ospar.org). Lista closed down in 2004, but the extended measurement programme continued at the nearby observatory in Birkenes. In 1994, air measurements of heavy metals and POPs were included at the Zeppelin Observatory as part of the Arctic Monitoring and Assessment Programme (AMAP, http://www.amap.no). Both sites became part of the EMEP Programme (European Monitoring and Evaluation Programme, http://www.emep.int) under The Convention on Long-range Transboundary Air Pollution (LRTAP, http://www.unece.org/env/lrtap) in 1999, (Tørseth et al, 2012). In the end of 2009, a new monitoring station was established at Andøya as part of the national Marine Pollution Monitoring Programme (Green et al., 2011). It included measurements of heavy metals and POPs in air. This site was after a couple of years incorporated in the regular national

programme, and data are reported to AMAP, EMEP and CAMP. A subset of the data are also reported to the European Commission as defined in the air quality directive (EU, 2008)

The 2013 measurements presented in this report is a compilation of results from three different national projects and programs:

- Heavy metals and POPs (except PAH) in air at Birkenes, Andøya and Zeppelin, and heavy metals in precipitation at Birkenes are part of the national monitoring programme of environmental contaminants on behalf of The Norwegian Environment Agency
- Heavy metals in precipitation at Svanvik is part of the Norway-Russia measurement programme on behalf of The Norwegian Environment Agency
- POPs in precipitation at Birkenes, heavy metals in precipitation at Hurdal and Kårvatn and PAH in air at Zeppelin are part of the long-term dataseries programme on behalf of the Ministry of Climate and Environment, as well as NILUs internal monitoring programme.

In 2013, the monitoring of Environmental contaminants involved six observatories whereof three includes POPs. The locations of the observatories are illustrated in Figure 1.1, and the measurement programme is described in Table 1.1. Information of sampling and analytical methods are given in Annex 3. Further information of the sites, site descriptions are available at http://www.nilu.no/projects/ccc/sitedescriptions/). All the data presented in this report are available at http://ebas.nilu.no/.

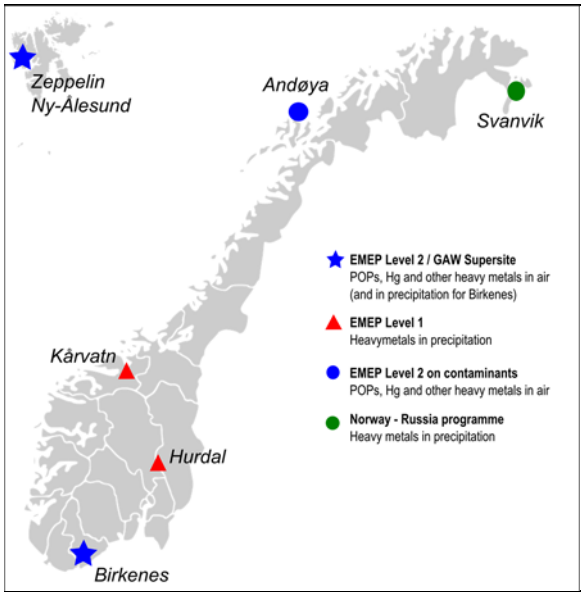

Figure 1.1: Norwegian background stations measuring environmental contaminates in 2013.

Table 1.1: Norwegian monitoring stations and the sampling programme of heavy metals and persistent organic pollutants (POPs), 2013.

Station code and name		Lat	Long	hasl	Heavy metals		Persistent Organic Pollutants (POPs)*	
					precipitation	air and aerosols	precipitation	air and aerosols
NO0001-2R	Birkenes	58 23 N	8 15 E	190 / 219	As, Cd, Cr, Co, Cu, Pb, Hg, Mn, Ni, V, Zn	As, Cd, Cr, Co, Cu, Pb, Hg, Ni, V, Zn	HCB, HCHs, PCBs	HCB, HCHs, DDTs, CHLs, PCBs, PBDEs, HBCD, PAHs, PFAS
NO0056R	Hurdal	60 22 N	11 4 E	300	Cd, Pb, Zn			
NO0039R	Kårvatn	62 47 N	8 53 E	210	Cd, Pb, Zn			
NO0047	Svanvik	69 27 N	30 2 E	30	Al, As, Cd, Cr, Co, Cu, Pb, Mn, Ni, V, Zn			
NO0090R	Andøya	69 16 N	16 0 E	380		As, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, V, Zn		HCB, HCHs, DDTs, PCBs, PBDEs, PFAS
NO0042G	Zeppelin	78 54 N	11 53 E	474		As, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, V, Zn		HCB, HCHs, DDTs, CHLs, PCBs, PBDEs, HBCD, PAHs, PFAS, Siloxanes, SCCP, MCCP

* Full names given in Chapter 3.1.

2. Heavy metals

Heavy metals have been part of the Norwegian national monitoring programme since 1980. Measurements of lead, zinc and cadmium in weekly precipitation samples were initiated in February 1980 at Birkenes and Kårvatn, in October 1986 at Nordmoen Hurdal, and in March 1987 at Svanvik. Heavy metals in air was included in the programme in 1991 at Lista and 1994 at Zeppelin, while 2010 at Andøya.

There were no changes in the monitoring programme from 2012 to 2013.

2.1 Heavy metals in precipitation

Annual mean volume weighted concentrations and total wet deposition of heavy metals are given in Table 2.1 and Table 2.2. These show that the highest annual mean concentrations are, except for zinc, observed at Svanvik. This is due to high emissions from the smelters in Nikel (Russia) close to the Norwegian border. When there is easterly wind from Russia and the Kola Peninsula the levels of contaminants increase significantly at the Norwegian side of the border. Further details and discussion of these data can be found in the annual report for the Norway-Russia programme (Berglen et al., 2014). The levels are comparable at Hurdal and Birkenes while lowest at Kårvatn, which is also furthest away from the main emission sources in continental Europe. For wet deposition, the highest levels are in general seen at Birkenes, though some exceptions like Ni, As, Cu which has very high levels in Svanvik.

Table 2.1: Annual average volume weighted mean concentrations of heavy metals (µg/L) and mercury (ng/L) in precipitation in 2013.

Site	Pb	Cd	Zn	Ni	As	Cu	Co	Cr	Mn	V	Al	Hg
Birkenes	0.60	0.02	5.3	0.21	0.05	1.0	0.02	0.06	1.92	0.21	-	5.50
Hurdal	0.41	0.02	8.0	-	-	-	-	-	-	-	-	-
Kårvatn	0.16	0.01	6.5	-	-	-	-	-	-	-	-	-
Svanvik	1.09	0.06	3.9	26.0	1.7	51.1	0.78	0.23	-	0.79	22.50	-

Table 2.2: Total wet deposition of heavy metals (µg/m^2) and mercury (ng/m^2) in 2013.

Site	Pb	Cd	Zn	Ni	As	Cu	Co	Cr	Mn	V	Al	Hg
Birkenes	872	22	7634	301	77	1444	23	85	2780	301	-	7812
Hurdal	435	18	8485	-	-	-	-	-	-	-	-	-
Kårvatn	185	7	7633	-	-	-	-	-	-	-	-	-
Svanvik	317	17	1121	7555	489	14859	226	67	-	229	6558	-

The calculated monthly means and depositions for all the elements are found in Annex A.1.1-A.1.24. The monthly mean concentration for lead, cadmium and mercury are shown in Figure 1.1. There is no clear seasonal variation for lead and cadmium. The peak in July is probably because of little precipitation this month (Table A1.13). This is in contrast to

previous years when elevated levels during wintertime have been observed. For mercury, somewhat higher concentrations and wet deposition were found during the summer months compared to winter.

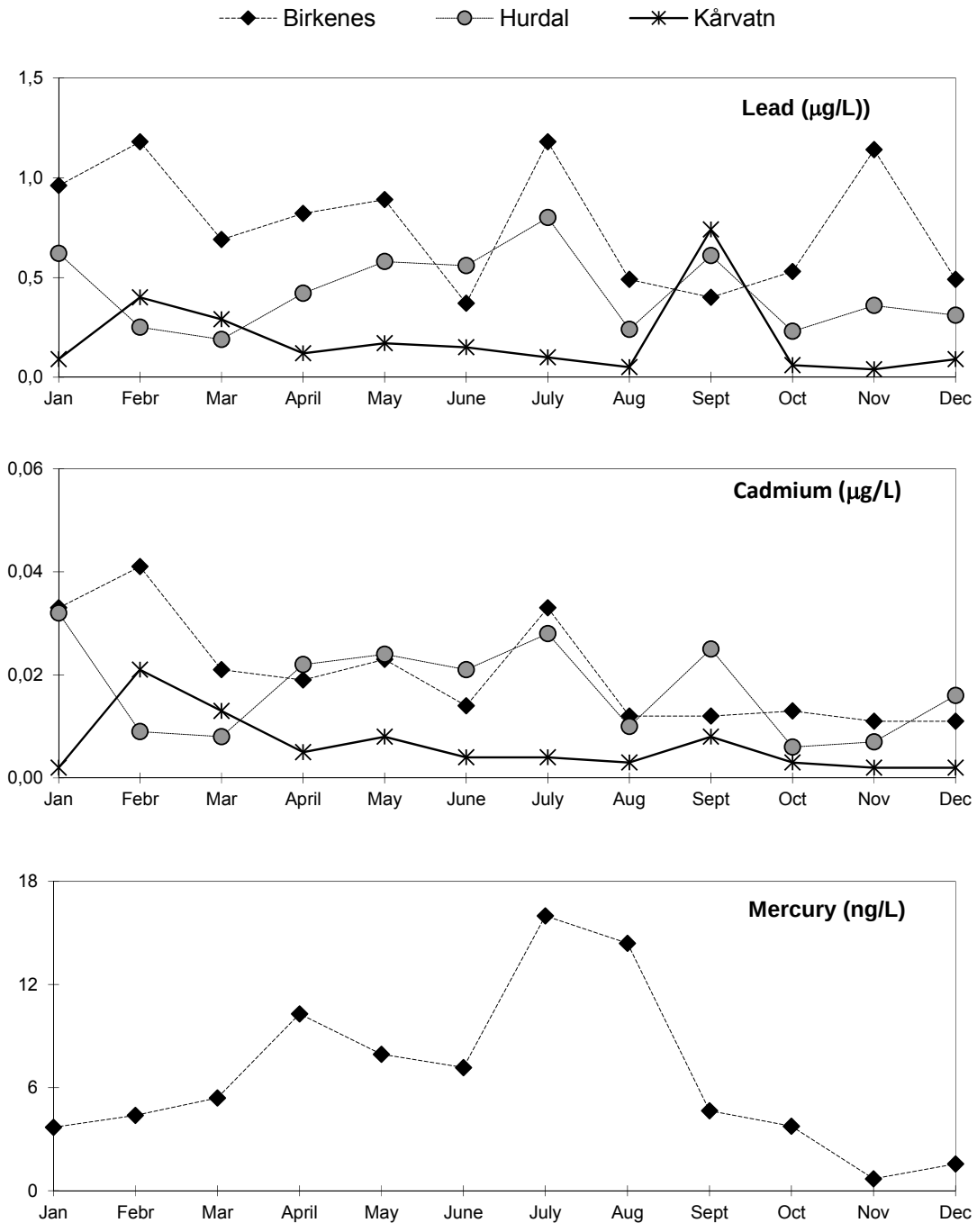

Figure 2.1: Monthly average volume weighted mean concentrations of lead, cadmium and mercury in precipitation in 2013.

Figure 2.2 and Table A.1.25 shows volume weighted annual mean concentrations from 1980-2013. Compared to 2012, the level in 2013 are slightly higher with some exceptions. It is, however, a clear reduction in a long time perspective. For example, the levels of lead at

Birkenes and Kårvatn has been reduced with more than 90% between 1980 and 2013 and between 50-65% since 1990. In contrast, at Svanvik, no significant trend has been observed for the same periods. The levels of cadmium at Birkenes and Kårvatn has also been reduced with more than 90% since 1980, and between 35% and 55% since 1990. A similar significant trend has not been observed at Svanvik.

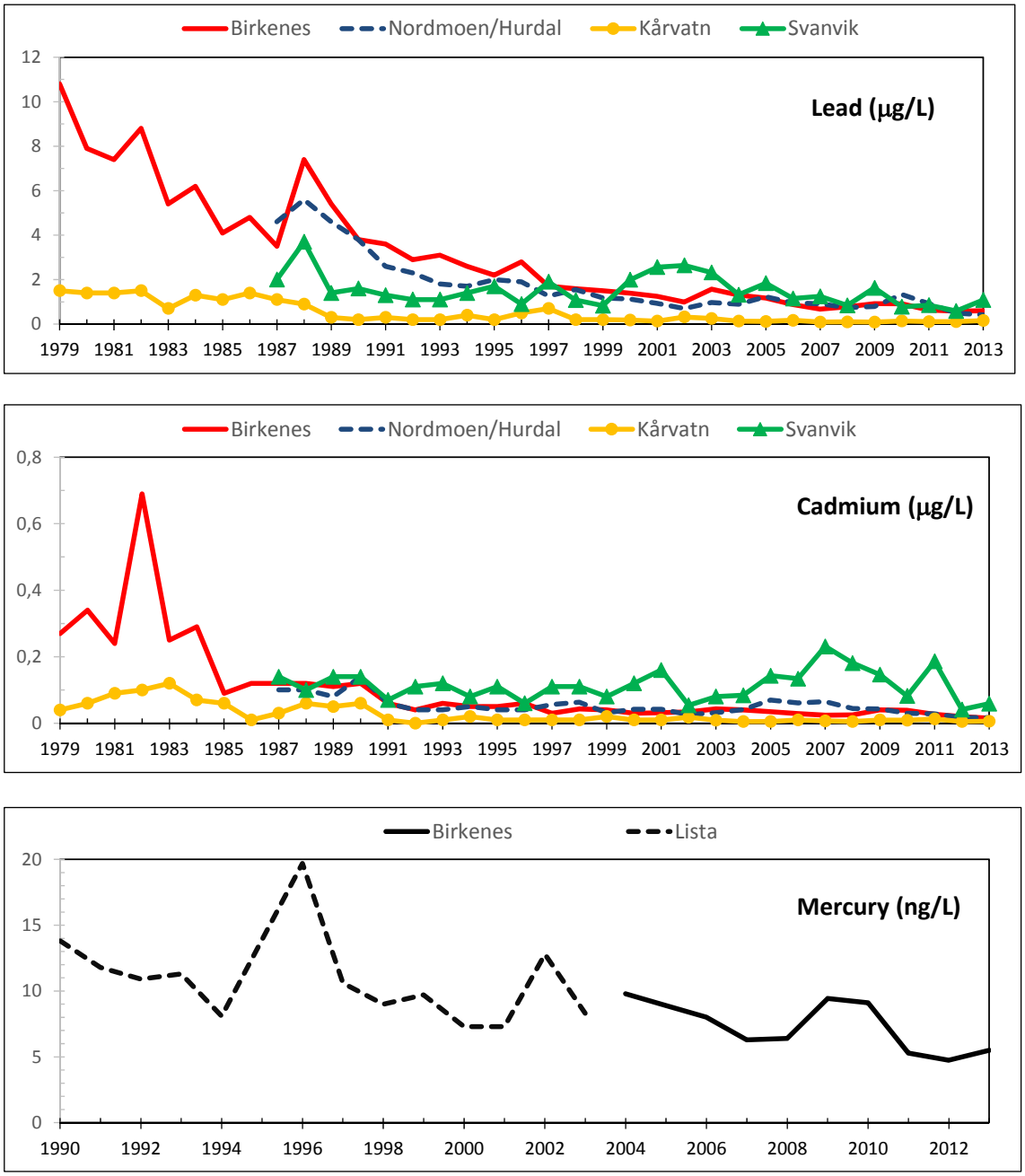

Figure 2.2: Time series of annual volume weighted mean of lead, cadmium and mercury in precipitation at Norwegian background stations.

The concentrations of zinc in precipitation have been reduced by 60-70% since 1980 and approximately by 40% since 1990 at Birkenes and Kårvatn.

The concentrations of zinc decreased at all sites up to 1992. After that there have been large annual variations, with increases at some sites for some years. This can be due to the fact that zinc is easily influenced of contamination.

For mercury in precipitation, there has been a significant reduction of 45% since 1990 when combining the Lista and Birkenes datasets. It is believed that Lista, which was closed down after 2003 was influenced by similar air masses as Birkenes, both situated at the south coast of Norway. However the precipitation amount and deposition rates may differ between these sites and combining the datasets for trend analysis is therfore uncertain

For the other elements, such as nickel, cobalt and copper, there has been an increase in concentrations at Svanvik since the monitoring started in 1987. There are large annual variations in the concentration levels, and this may be due to meteorological variations as well as changes in the composition of the ore used at the smelters in the Kola Peninsula. For further discussion, it is referred to the report by Berglen et al. (2014).

2.2 Heavy metals in air

The annual mean concentrations of the heavy metals measured in air in 2013 are given in Table 2.3, and the weekly concentrations of lead and cadmium are illustrated in Figure 2.3. The monthly mean concentrations can be found in Annex 1, tables A.1 26-28.

In general, the air concentrations of most heavy metals at Birkenes are 2-3 times higher than those observed at Andøya and Zeppelin. This is because Birkenes is closer to the emission sources at the European Continent For mercury, there were only minor differences in air concentrations between the sites. A reason may be that the gaseous mercury has a longer residence time in the atmosphere than the particulate bound heavy metals, and therefore has larger potential to be transported far from emissions sources. As a consequence, mercury is a global pollutant while the other heavy metals originate more from regional pollution emissions.

In 2013, the annual mean concentrations of most heavy metals except mercury, nickel and vanadium are somewhat higher at Zeppelin than those observed at Andøya. This is due to individual episodes with high concentrations of heavy metals at Zeppelin during the winter in 2013 (Figure 2.3).

At all the sites, the episodes of cadmium and lead are well correlated (Figure 2.3).This not necessarily because they have similar emission sources, but because the polluted air is well mixed, and the high episodes are happening when the meteorology favors long range transport.

Table 2.3: Annual mean concentrations of heavy metals in air and aerosols in 2013. Unit: ng/m^3.

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
Birkenes II	0.15	0.027	0.33	0.026	0.52	0.73		0.38	0.39	3.9	1.56
Andøya	0.04	0.008	0.11	0.011	0.24	0.24	0.41	0.14	0.12	1.4	1.54
Zeppelin	0.10	0.012	0.16	0.012	0.25	0.46	0.62	0.12	0.07	2.3	1.47

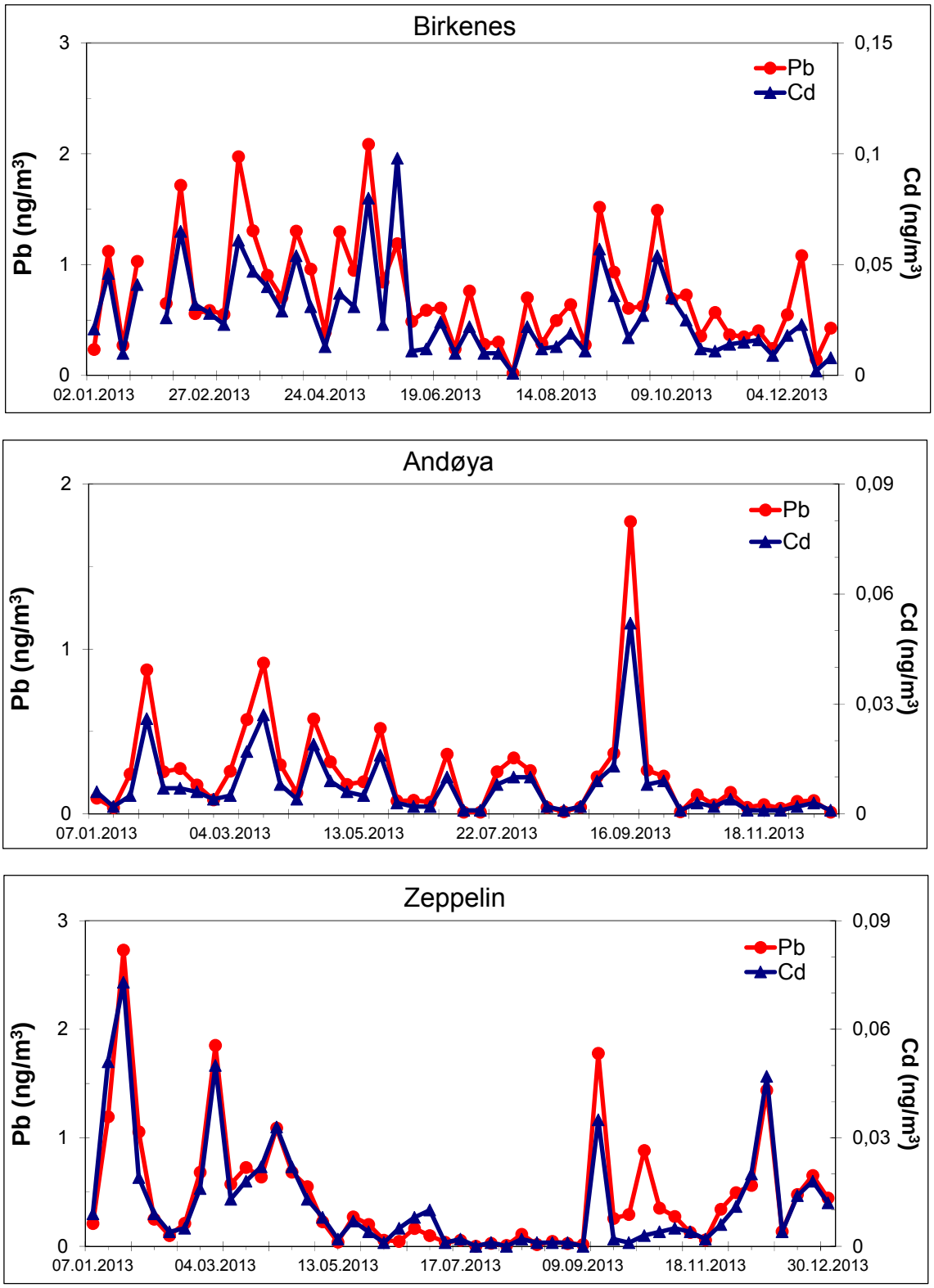

Figure 2.3: Weekly concentrations of lead and cadmium at Norwegian background stations in 2013, Unit: ng/m³.

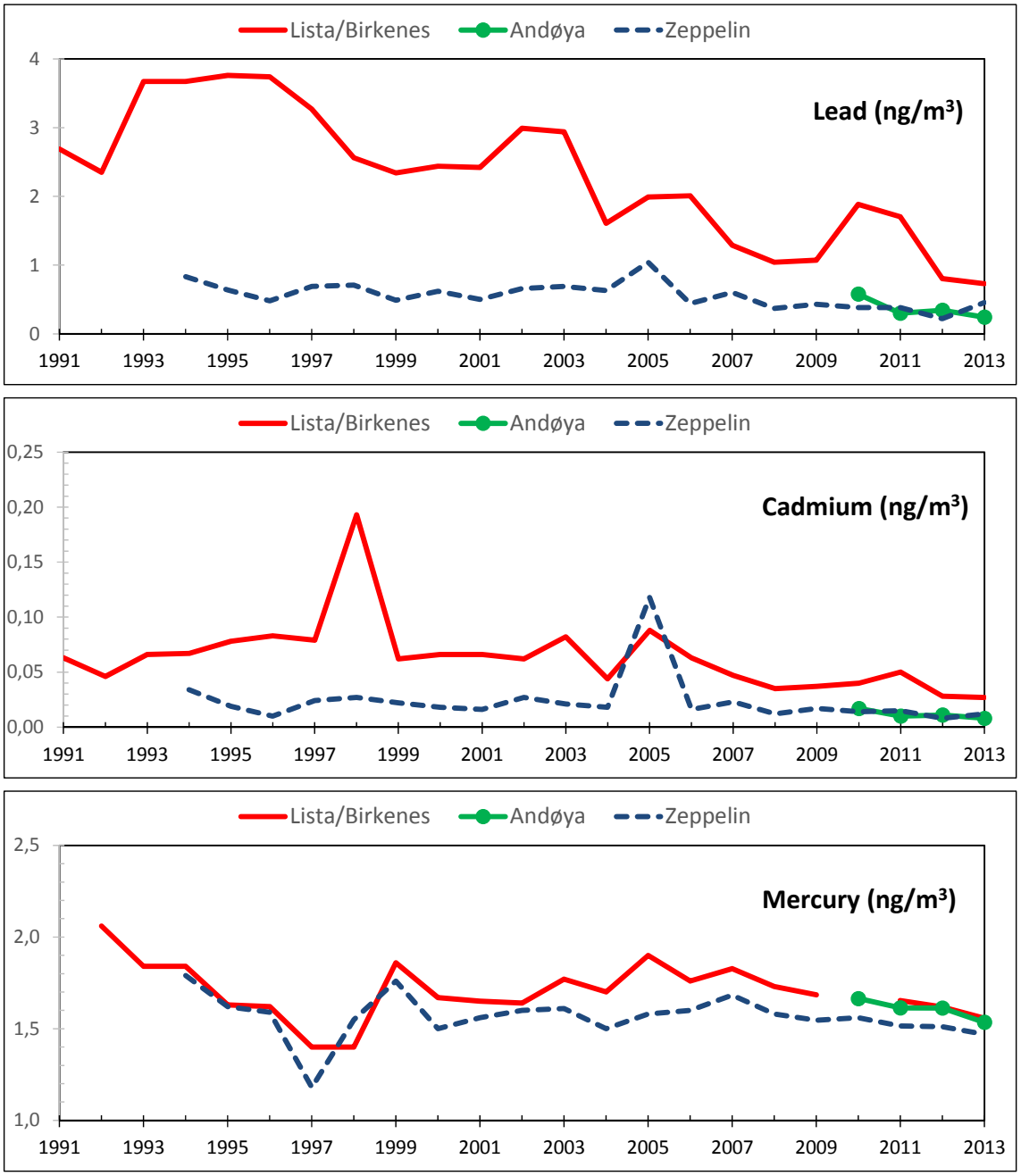

Figure 2.4: Time series of annual mean average concentrations of lead, cadmium and mercury in air and aerosols, 1991-2013, Unit: ng/m³ (note that the y-axis for mercury begins at 1.0 ng/m³).

The long-term time series of the annual mean concentrations of lead, cadmium and mercury are shown in Figure 2.4. The annual concentrations for all the elements for all years and sites can be found in Annex Table A.1.29.

At Lista/Birkenes there has been a significant reduction in air concentration for almost all the elements (As, Cd, Co, Cr, Pb, Ni and V) for the period 1991 to 2013. At Zeppelin, there has also been a significant reduction since 1994 for several elements (As, Cd, Cu, Pb, Ni, V). The reduction for lead has been 62% and 44% respectively at Birkenes and Zeppelin. For cadmium, there were similar trends, 56% and 49% reductions respectively. No significant trends were found for mercury at any of the sites within their measurement periods.

3. Persistent organic pollutants (POPs)

Organic pollutants in air have been monitored at Zeppelin since 1991, while the monitoring started later at Birkenes and Andøya. The components included in the monitoring at each observatory are presented in Table 1.1. In general, HCB, HCHs, DDTs, PCBs, PBDEs and PFAS are monitored at all three observatories while chlordanes (CHLs), HBCD and PAHs are only monitored at Birkenes and Zeppelin. In addition, two new groups of emerging organic pollutants were included at Zeppelin for 2013; i.e. siloxanes (cVMS) and chlorinated paraffins (SCCP, MCCP) (see Chapter 4).

Sampling was done continuously throughout the year with specific sampling frequencies and lengths for each station and class of pollutants. For example, PCB, HCB, DDT, HCH were sampled on a weekly basis at all three stations but with different sampling length at the individual stations (e.g. 24-72 h). Details are given in Annex 3, Table A.3.4.

Data for the individual POP classes at each observatory are presented as annual mean concentrations in Table 3.1-3.10, and as monthly mean concentrations in Figure 3.1-3.9. Detailed data (monthly mean concentrations for individual components within each class) are presented in Annex 2. The results are presented below on POP class basis due to the high amount of POP classes and individual components within each class.

3.1 Persistent organic pollutants in air

3.1.1 Hexachlorobenzene (HCB)

The use and production of HCB has been regulated by the Aarhus Protocol on POPs (1998a) under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (UN/ECE, 1998b) and the Stockholm Convention on POPs (SC) (Stockholm Convention, 2007). It is, however, still released as a by-product during manufacturing of other chemicals as well as through incomplete combustion from old dumpsites.

The annual mean concentrations of HCB were, as previous years, 1.5-3 times higher at Zeppelin than at Birkenes and Andøya. The differences may be influenced by an artifact related to sampling (i.e. breakthrough of HCB during sampling) which may result in underestimations of the true air concentrations. The amount of this artifact is not yet fully characterized but significant breakthrough is estimated at high sample volumes and may also be enhanced by higher temperatures. More research on this subject is needed.
The annual mean concentrations at each observatory did not differ from those measured in 2012 (Table 3.1) and are in line with typical European levels (Halse 2011, Jaward 2004). In fact, stable concentrations have been observed at all observatories during the last 3-4 years but long-term measurements at Zeppelin show a trend of increasing levels from about 55 pg/m^3 in the beginning of 2000 to about 80 pg/m^3 from 2010 to today (Table 3.1). The reason for this trend has been suggested to depend on increased re-emissions from deposited HCB due to higher temperature and ice-free winters, or to a continuous use of pesticides containing HCB in some parts of the world (Hung et al., 2010). Despite the increasing trend the levels are still below those observed in the 1990s. In contrast, the long-term observations at Birkenes indicate continuous declining concentrations during the last 10 years, although the decline seem to have flattened out during the last four years (Table 3.1). The decline

may indicate ongoing reduction of primary emissions, as Birkenes is closer to potential primary emission sources in western and central Europe, but more research is needed before any conclusion can be drawn.

The concentrations at Zeppelin did not show any seasonal variations, with weekly measurements (excluding a single outlier) ranging from 68-97 pg/m^3. A strong seasonality was however found at Andøya and Birkenes, with up to a factor of 3-4 lower concentrations in summer time (June-August) than in winter time (October-March) (Figure 3.1).

Table 3.1: Annual mean concentrations of HCB (pg/m^3) in air.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes*	161	95	95	89		93	83	54	51	57	65	64	64	64	64	86	63	51	47	53	52
Andøya																	88	29	24	28	27
Zeppelin	93	116	98	92	99	82	88	56	55	56	54	65	67	71	67	73	76	79	81	83	81

*Includes data from Lista (1993-2003) and Birkenes observatory (2004-2013).

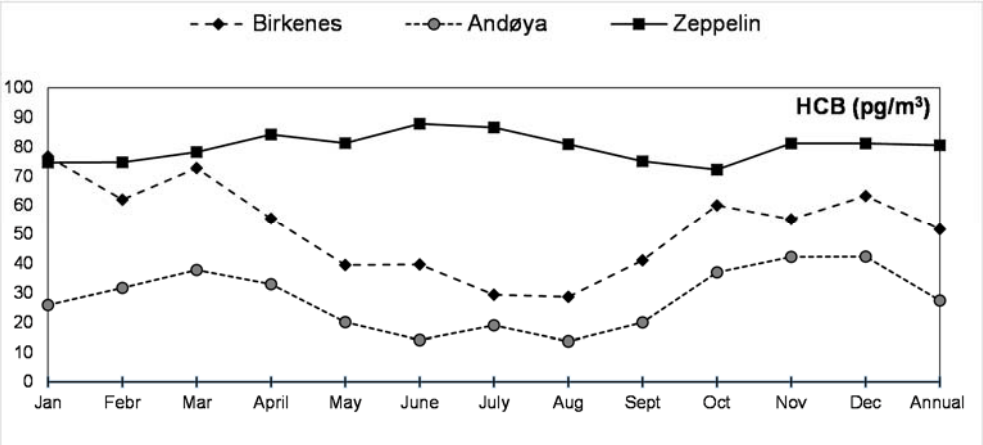

Figure 3.1: Monthly and annual mean concentrations (pg/m^3) of HCB in air for 2013.

3.1.2 Hexachlorohexanes (HCHs)

HCHs have been and are to some extent still used as insecticides. The Aarhus protocol on POPs (UN/ECE, 2010) and the SC on POPs (Stockholm Convention, 2011) has implemented international regulations on the use and production of HCHs with exception for the use of γ-HCH for pharmaceutical control of head lice and scabies. Production is therefore still ongoing in a few countries.

Two isomers; α- and γ-HCHs, were measured at all observatories. The annual mean concentrations of sum HCH (α+γ) and the individual isomers for 2013 were in the same range at all observatories and followed the decreasing trends from previous years (Table 3.2). Overall, HCHs are the compounds that have shown the largest decrease since the beginning of the air monitoring at Zeppelin and Birkenes (a factor of 15 and 25). Both isomers are found to be declining with similar pattern at both observatories although a somewhat larger reduction is observed for γ-HCH than for α-HCH. The ratio of α-/γ-HCH was found to be higher at Zeppelin (6.8 in 2013) than Birkenes (1.8 in 2013). The same has been observed since the beginning of the monitoring. The ratio has increased with a factor of 1.5 at both

observatories during 2000s compared to the 1990s as a result of the larger reduction of γ-HCH in the air. No conclusion on trends can be drawn for Andøya since monitoring data are available only for five years.

The monthly mean concentrations did not show any strong seasonality but a tendency of lower concentrations in winter time (December-March) (Figure 3.2) was observed. The highest individual concentrations were observed in summer time (May-October) at Birkenes (2-3 times higher than winter time concentrations). This may be due to revolatilisation from soil or other environmental surface media during warmer periods (i.e. secondary emissions) or may in part also be due to remaining applications during summer months (i.e. primary emission) (Halse, 2012).

Table 3.2: Annual mean concentrations of sum HCH (pg/m³) in air.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes	178.9	178.3	133.6	189.8	118.9	121.4	112.4	92.8	58.9	43.4	32.7	29.1	20.7	26.7	20.9	17.7	12.8	14.0	11.3	9.8	9.6	7.4	7.5
Andøya																				6.3	5.9	5.4	5.1
Zeppelin			93.6	79.7	75.9	73.1	66.0	47.4	42.8	26.5	27.3	34.1	23.2	19.8	17.8	12.7	11.1	10.5	9.6	8.7	7.2	6.5	6.1

*Includes data from Lista (1993-2003) and Birkenes observatory (2004-2013).

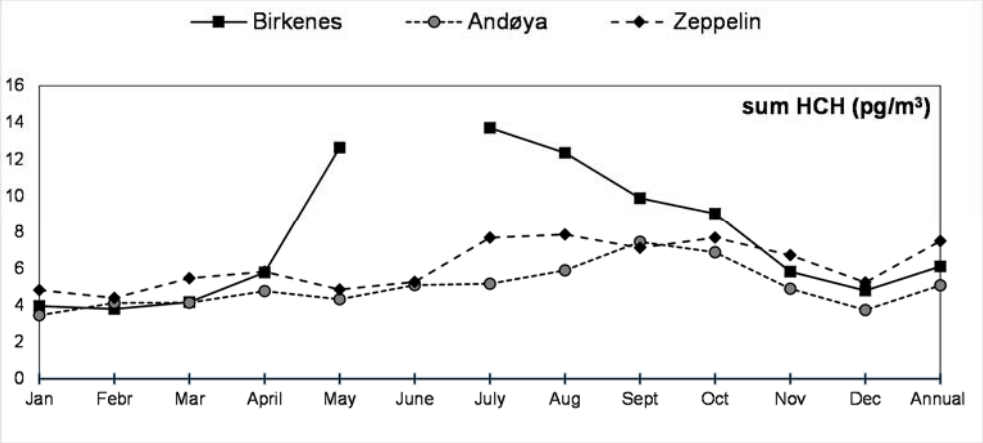

Figure 3.2: Monthly and annual mean concentrations (pg/m³) of sum HCH in air for 2013.

3.1.3 DDTs

The production and usage of DDTs was banned in Europe, US and Canada during 1970 to 2000 and is further regulated by the Aarhus protocol (UN/ECE, 1998b) and the SC on POPs (Stockholm Convention, 2007), but is still in use in some parts of the world for disease (primarily malaria) vector control.

The six DDT congeners; o,p'- and p,p'- DDT, DDD, and DDE, were measured at all three observatories. The annual mean concentrations of sum DDT and the individual congeners for 2013 were as previous years up to three times higher at Birkenes compared to Andøya and Zeppelin (Table 3.3). The annual mean concentration of sum DDT for 2013 at Birkenes was higher than the previous two years while the concentrations at Andøya and Zeppelin was similar or slightly lower than previous years. This was also consistent for all congeners. Although the concentrations were higher at Birkenes, they were still 10-100 times lower than the concentrations found on the European continent (Halse 2011, Pribylova 2012). The reason

for higher concentrations at Birkenes may be explained by its closeness to the continent but more research is needed before any conclusions can be drawn.

The long-term monitoring at Zeppelin shows a significant reduction of the air concentrations.

A strong seasonality was found at Zeppelin with 3-6 times higher concentrations in winter time (December-January) compared to warmer months (April-September) (Figure 3.3). This seasonality was seen for sum DDTs as well as o,p'- and p,p'-DDE and DDT but not for DDD. A similar trend was found at Andøya with slightly different time frames; highest concentrations in January-February and September-December, and lowest concentration in May-August. In contrast, at Birkenes the highest levels were found in August-October and May and the lowest concentrations in January-March.

The most abundant congener was p,p'-DDE (50-60%) at all sites. The ratio p,p'-DDE/p,p'-DDT was consistently 5.3 at all sites indicating no recent use of technical DDT.

Table 3.3: Annual mean concentrations of sum DDT (pg/m^3) in air.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes																	1.81	1.61	1.37	1.74
Andøya																	0.82	0.68	0.69	0.68
Zeppelin	4.27	1.01	1.74	1.82	2.88	2.27	1.59	1.45	1.47	1.46	1.03	1.01	1.87	3.17	0.80	0.72	0.65	0.49	0.61	0.55

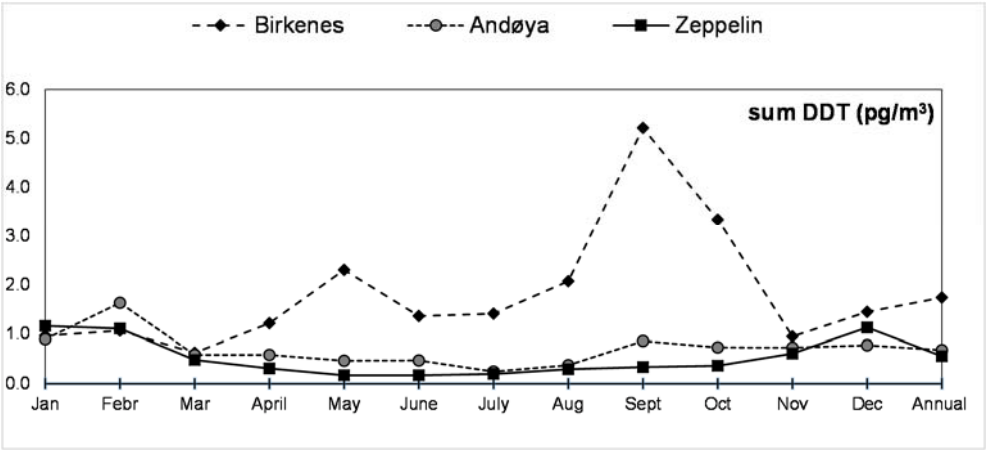

Figure 3.3: Monthly and annual mean concentrations (pg/m^3) of sum DDT in air for 2013.

3.1.4 Chlordanes (CHLs)

The use and production of chlordanes has been banned under the Aarhus protocol (UN/ECE, 1998b) and the SC on POP (Stockholm Convention, 2007). They were previously primarily used as pesticides (insecticides).

The four stereoisomers of chlordane (i.e. cis- and trans-chlordane (CD), and cis- and trans-nonachlor (NO)) were measured at Birkenes and Zeppelin. The annual mean concentrations of sum chlordanes (CHL) for 2013 was 0.92 pg/m^3 at Zeppelin and 1.15 pg/m^3 at Birkenes. The

levels of sum CHL and the individual stereoisomers at Zeppelin are in line with the small decreasing trend observed during the last years as well as the significant reduction of air concentrations since the beginning of 1990s (Table 3.4). The ratio of trans-CD and cis-CD was low at both observatories (0.2-0.6 compared to 1.17 in technical mixture). This indicates that chlordanes have been aged in the atmosphere, since trans-CD degrades faster than cis-CD in the environment.

No seasonality was observed for sum CHL at Zeppelin, instead the concentrations were consistent over the year (0.8-1.1 pg/m^3) (Figure 3.4). Two of the individual isomers, however, showed seasonality although contrary to each other; cis-NO was a factor of 5-6 higher in summer time (May-September) than in winter time (November-April), and trans-NO was a factor of 3-4 lower in summer time than in winter time. The range of concentrations was larger at Birkenes and a seasonality with higher concentrations in summer time (May-August) and lower concentrations in winter time (January-March) was observed. A similar trend was seen for the individual isomers with exception of trans-CD that were constant over the year.

Table 3.4: Annual mean concentrations of sum chlordanes (pg/m^3) in air.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes																		1.22	1.20	1.14	1.15
Zeppelin	2.69	3.13	2.38	2.91	1.76	1.74	1.91	1.49	1.99	1.98	1.69	1.55	1.47	1.54	1.39	1.05	1.12	1.11	0.98	0.98	0.92

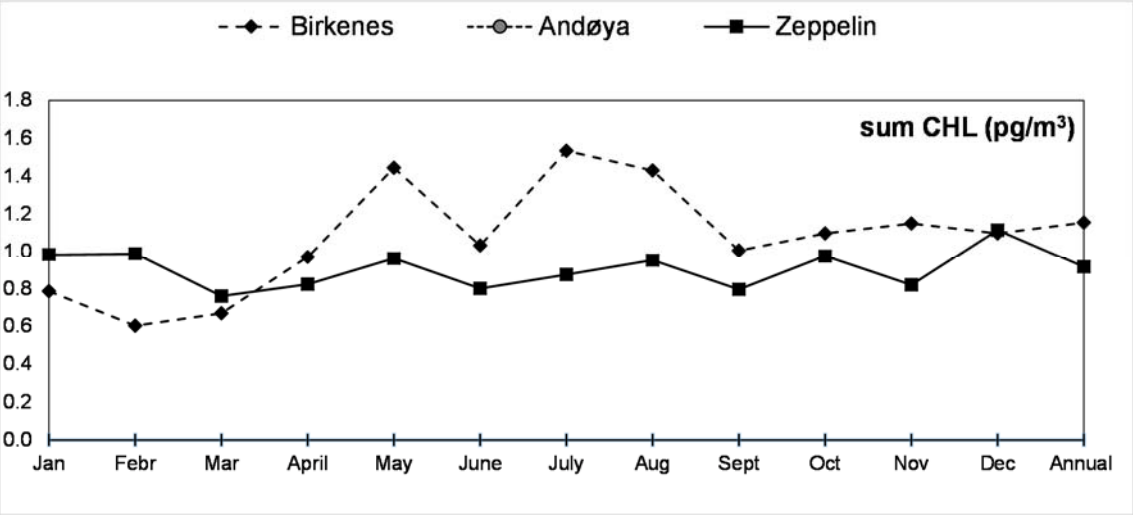

Figure 3.4: Monthly and annual mean concentrations sum chlordanes (pg/m^3) in air.

3.1.5 Polychlorinated biphenyls (PCBs)

PCBs have been removed from active use in most countries since the mid 1970s and were further banned by the Aarhus protocol (UN/ECE, 1998b) and the SC on POPs (Stockholm Convention, 2007). Current sources of emissions to the environment are mainly from places where they have been disposed or stored, such as landfills or exposed soils, or from open burning of products containing PCBs, waste incinerations and accidental fires (Breivik et al., 2002; Cousins and Jones, 1998).

The PCBs theoretically consists of a group of 209 congeners. 32 of these (=sum PCB) were measured at all three stations. These 32 congeners in turn include the seven European indicator congeners (PCB-7); PCB 28, 52, 101, 118, 138, 153, 180, as well as the 12 dioxin-like and most toxic congeners according to WHO; PCB 77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167, 189.

The annual mean concentrations of both sum PCB and PCB-7 for 2013 were a factor of 2 higher at Birkenes and Zeppelin than at Andøya (Table 3.5). Reason for this is unknown. The annual mean concentrations for 2013 are similar or slightly lower than in 2012 at all observatories. Stable concentrations have been observed at Zeppelin and Birkenes during the last 3 years but the concentrations have decreased with about a factor of 2-3 during the previous 5-10 years. The concentrations at Andøya follow a declining trend also during the last years which result in larger differences compared to Zeppelin and Birkenes. As previous years, the tri- and tetra-PCBs were the most common PCBs, comprising 80-90% of sum PCB.

The monthly concentrations varied to a small extent for both sum PCBs and sum PCB-7 and as a consequence no strong seasonality was observed at any of the observatories. Only at Birkenes a tendency of higher concentration during summer time was observed. The same pattern was seen for both sum PCB and sum PCB-7.

Table 3.5: Annual mean concentrations of sum PCB and sum PCB-7 (pg/m^3) in air.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
sum PCB (pg/m^3)													
Birkenes										13.72	10.42	10.05	9.78
Andøya									19.53	11.85	7.58	7.07	5.10
Zeppelin	37.09	27.70	19.77	18.15	25.67	28.26	30.83	29.27	19.26	13.14	10.04	10.77	10.07
sum PCB-7 (pg/m^3)													
Birkenes				5.39	7.21	6.80	4.79	6.15	4.23	3.14	2.88	2.56	2.72
Andøya									7.37	2.20	1.67	1.66	1.50
Zeppelin	6.57	5.47	4.33	3.88	4.75	9.34	6.09	6.03	4.17	2.64	2.29	2.64	2.62

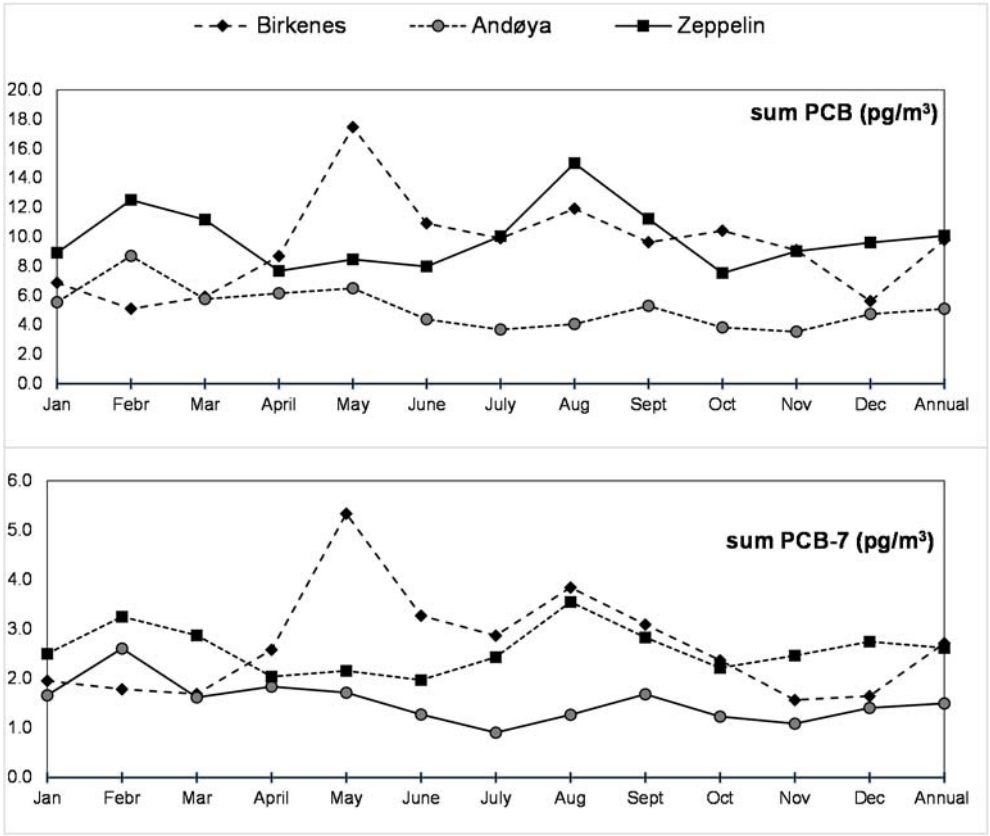

Figure 3.5: Monthly and annual mean concentrations (pg/m³) of sum PCB and sum PCB-7 in air for 2013.

3.1.6 Polybrominated diphenyl ethers (PBDEs)

The production and use of the commercial PBDE mixtures: Penta- and Octa-BDE, are regulated by Aarhus protocol (UN/ECE, 2010) and the SC on POPs (Stockholm Convention, 2011) and are today banned in most countries world wide. On the other hand, the commercial PBDE mixture: Deca-BDE, has not yet been subjected to the same restrictions and is still in use on a global scale. Steps to limit or ban the use have been taken in some countries and regions including Norway where it is banned and the EU where it is banned in electrical products.

PBDEs theoretically comprise 209 congeners with different degrees of bromination from tetra- to deca-BDE. 17 of these congeners (=sum PBDE) were measured at all three sites.

The annual mean concentrations of sum PBDEs were highest at Zeppelin and lowest at Andøya (Table 3.6). Higher concentrations at Zeppelin were found for BDE-100, -28, -47, -49, -66, -71, and -99 while the others including BDE-209 were found at similar concentrations at all observatories. The concentrations of sum PBDEs and the individual congeners were higher than 2012 at all observatories. The concentration of sum PBDE at Birkenes was the highest since the start of the monitoring (in 2008) and at Zeppelin it was the highest since 2007. The high annual mean of sum PBDE at Zeppelin and Birkenes was mainly due to higher concentrations (a factor 2) for BDE-209, -47, and -206 in 2013 compared to previous years. No significant long term trends of sum PBDE or BDE-209 can be seen at any of the observatories.

Instead the annual mean concentrations of both sum PBDEs and the individual congeners tend to fluctuate year by year.

The most abundant congeners were BDE-209 and BDE-47 representing 45-65% and 9-27% of sum BDEs.

No clear seasonal variations were seen for sum PBDEs nor the individual congeners (including BDE-209) at any observatory, instead the concentrations fluctuated from month to month (Figure 3.6). High levels at Zeppelin in May and October and at Birkenes in August and December are due to individual high measurements during these months and not a trend for the whole month. The reason for these individual high levels are not known. High levels at Zeppelin station during October 2013 may have been caused by ongoing construction work during this period.

Table 3.6: Annual mean concentrations of sum PBDE and BDE-209 (pg/m^3) in air.

	2006	2007	2008	2009	2010	2011	2012	2013
				PBDE (pg/m^3)				
Birkenes			1.06	0.75	0.83	0.78	0.54	1.10
Andøya				2.44	0.84	0.63	0.57	0.81
Zeppelin	7.54	5.19	0.91	1.04	1.34	0.98	0.64	1.53
				BDE-209 (pg/m^3)				
Birkenes			0.37	0.34	0.42	0.46	0.25	0.66
Andøya				1.70	0.48	0.39	0.39	0.50
Zeppelin	6.46	0.98	0.29	0.53	0.67	0.42	0.30	0.70

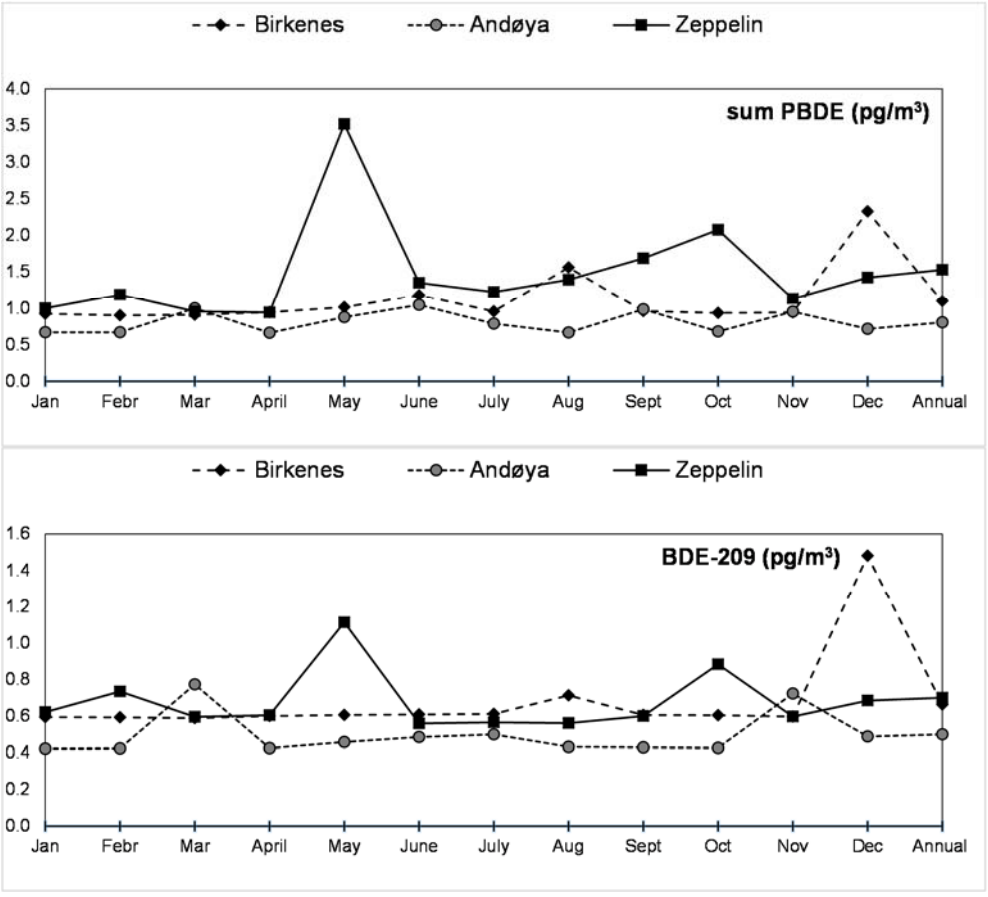

Figure 3.6: Monthly and annual mean concentrations (pg/m^3) of sum PBDE and BDE-209 in air for 2013.

3.1.7 Tribromanisol (TBA)

TBA is produced naturally by marine algae/sponges or by microbial degradation of tribromophenol (used for wood preservation and as a fire retardant additive). It show POP characteristic behaviors and have similar structure to other brominated pollutants.

The annual mean concentrations of TBA were 6.33, 6.56, and 4.94 pg/m^3 at Zeppelin, Andøya, and Birkenes respectively (Table 3.7). The level at Zeppelin was similar to previous years while higher concentrations were observed at both Andøya and Birkenes. At Andøya the concentrations were almost double compared to 2012 and the highest observed since the start of the monitoring (in 2010). The concentration at Birkenes was the second highest since 2007. The reason for this is unknown but may be due to ongoing applications. More research and continuous monitoring is needed to clarify this.

The lowest monthly mean concentrations at Birkenes and Zeppelin were observed during spring/summer while highest concentrations were seen during autumn (Figure 3.7). The same trend was also observed at Andøya although to a less extent.

Table 3.7: Annual mean concentrations of TBA (pg/m^3) in air.

	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes		5.02	3.32	3.93	4.24	3.78	3.70	4.94
Andøya					5.66	4.79	3.42	6.56
Zeppelin		7.50	4.56	6.94	7.59	7.76	6.37	6.33

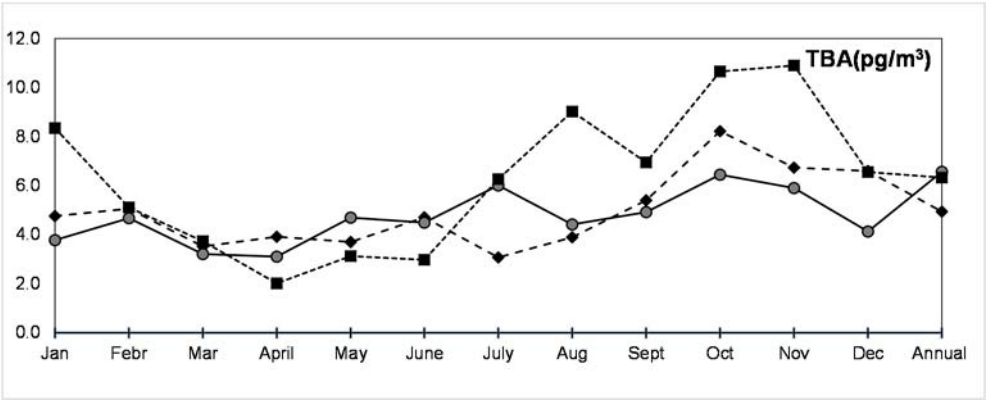

Figure 3.7: Monthly and annual mean concentrations (pg/m^3) of TBA in air for 2013.

3.1.8 Hexabromocyclododecane (HBCD)

HBCD is a brominated flame retardant often used in thermal insulation in building and construction materials. The HBCD was included in the SC on POPs in 2013 with a time-limited exception for production and use in some polystyrene applications. The global ban will enter into force in November 2014 (Stockholm Convention, 2012).

The three main diastereomers: α-, ß-, and γ-HBCD (=sum HBCD) were sampled at Zeppelin and Birkenes together with PBDEs. High levels were observed during the first two years of monitoring (2006-2007). Since 2008 the HBCD levels have significantly decreased but the levels are fluctuating from year to year so that no clear time trend can be seen for 2008-2013. Continuous monitoring are needed.

Overall the individual HBCD diastereomers were only detected in less than 10% of the measurements and the annual mean concentrations for HBCD should therefore be taken with care and regarded as an upper limit of concentrations. No monthly mean concentrations and no seasonal trends could be obtained for 2013 due to low level of detection.

Table 3.8: Annual mean concentrations of sum HBCD (pg/m^3) in air.

	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes	7.85	4.15	0.39	0.67	0.19	0.84	0.20	0.11
Zeppelin	7.07	6.64	1.68	0.29	0.34	0.84	0.13	0.19

3.1.9 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are mainly produced through incomplete combustion of organic materials, both through industrial and domestic use. They are regulated in the Aarhus protocol on POPs (UN/ECE, 1998b) and the EU air quality directive (AQD) (EU, 2004).

7 methyl-PAH and 38 PAHs (=sum PAH) including the 16 EPA-PAHs (=sum PAH-16) were measured at Birkenes and Zeppelin during 2013. The measurements of PAHs at Andøya ended in 2012. The annual mean concentrations for 2013 were up to two times higher at Birkenes than at Zeppelin (Table 3.9). The concentrations at Birkenes were similar to 2012 while the concentrations at Zeppelin was more than a factor of 2 higher than 2012, and cut the decreasing trend observed since 2009. The levels of benzo(a)pyrene are up to three orders of magnitude below the European Air Quality Standard (1 ng/m^3) (EEA) as defined by the 4th daughter directive (EU, 2004).

A strong seasonality was observed at Zeppelin with up to one order of magnitude higher concentrations in winter time (November-March) than in summer time (Figure 3.8). The same seasonality was also seen at Birkenes but with a smaller variation in concentrations during the seasons as well as individual elevated levels during May and June. The same seasonalities were seen both for sum PAHs and the individual PAHs.

Table 3.9: Annual mean concentrations of sum PAH and sum PAH-16 (ng/m^3) in air.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
sum PAH (ng/m^3)																				
Birkenes																5.57	5.54	4.52	4.70	4.62
Andøya																3.01	2.15	1.27	1.32	-
Zeppelin	8.34	4.31	3.08	6.21	7.41	5.23	3.87	3.19	2.51	2.87	2.07	2.16	1.94	2.74	2.63	2.74	2.69	2.20	1.33	2.89
sum PAH-16 (ng/m^3)																				
Birkenes													1.54		3.00	2.51	2.51	2.30	2.34	2.53
Zeppelin	3.53	1.14	1.50	3.25	3.06	1.56	1.87	1.39	1.06	1.14	0.81	0.82	0.84	1.05	0.97	1.11	1.01	0.83	0.50	1.25

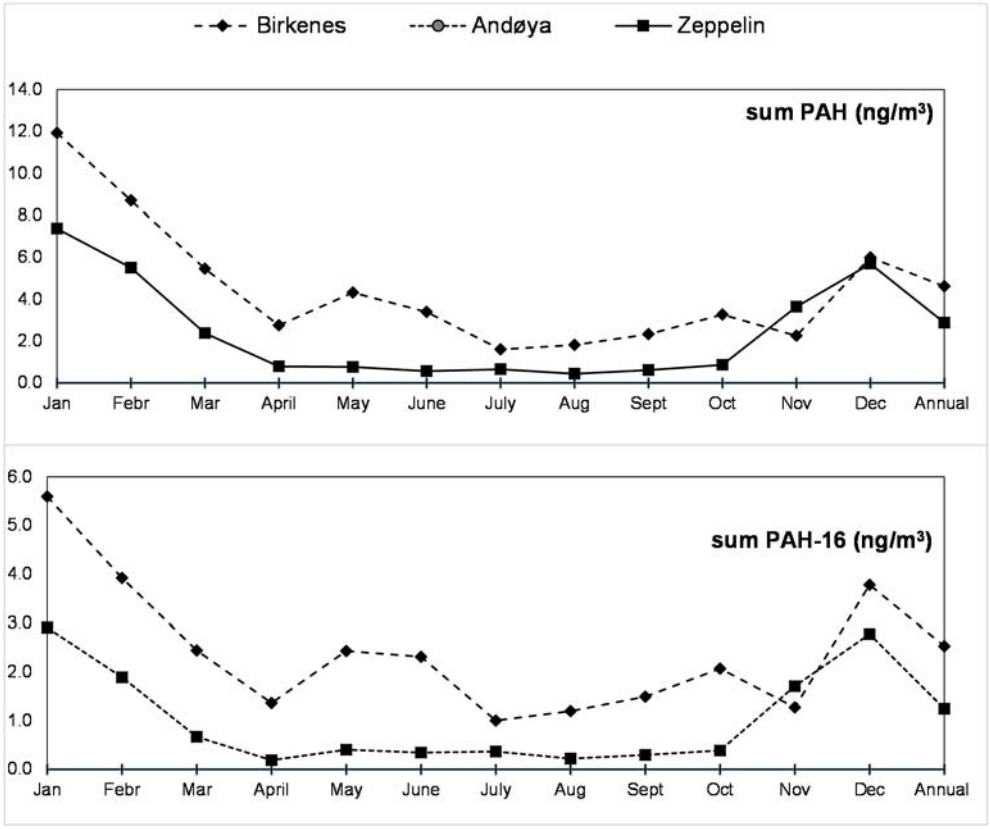

Figure 3.8: Monthly and annual mean concentrations (pg/m³) of sum PAH and sum PAH-16 in air for 2013.

3.1.10 Per- and Polyfluorinated Alkyl Substances (PFAS)

PFAS comprise a large and complex group of chemicals: ionic compounds like perfluoroalkyl sulfonates (PFOS) and perfluoroalkyl carboxylates (PFCAs); and neutral, volatile compounds like fluorotelomer alcohols (FTOHs) and N-alkylated fluorooctane sulphonamides and sulfonamidoethanols (FOSAs/FOSEs). During the last 50 years the PFAS, such as perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and their related products, have been widely used in consumer products. The only PFAS that is regulated by the Aarhus protocol (UN/ECE, 2010) and the SC on POPs (Stockholm Convention, 2011) is perfluorooctane sulfonic acid (PFOS) together with its salt and perfluorooctane sulfonyl fluoride (PFOS-F). In Norway, both PFOS and PFOA are banned.

13 PFAS were measured at all three stations: FTS 6-2 (6:2 Fluorotelomer Sulfonate), PFBA (Perfluorobutyric acid), PFBS (Perfluorobutane sulfonate), PFDcA (Perfluorodecanoic acid), PFDcS (Perfluorodecane sulfonate), PFHpA (Perfluoroheptanoic acid), PFHxA (Perfluoro-hexanoic acid), PFHxS (Perfluorohexane sulfonate), PFNA (Perfluorononanoic acis), PFOA, PFOS, PFOSA (Perfluorooctane sulphonamide), PFUnA (Perfluoroundecanoic acid). PFBA was excluded due to analytical problems. Sum PFAS therefore includes 12 compounds.

The compounds observed with high detection frequency was PFOA, PFOS, PFOSA, PFDcA, PFHpA, PFHxA, and PFNA. The others were below detection limit in more than 60% of the measurements and the provided concentrations in Annex 3 should be considered as the upper levels. The most abundant compounds at all observatories were PFOA (19-26% of sum PFAS), and PFNA (8-12% of sum PFAS) while PFOSA was high at Zeppelin (16%) and PFDcA was high at Andøya (18%).

The annual mean concentrations of sum PFAS at Birkenes and Andøya were higher in 2013 compared to 2012 and 2011, while the concentrations at Zeppelin was the lowest since the start of the monitoring in 2006. Highest annual mean concentrations were observed at Birkenes while the lowest at Zeppelin. This correspond to their anthropogenic applications, current use and thereby a strong contribution of ongoing emission from primary sources. There is a big variability in levels from year to year and not a strong evidence of decreasing trends.

The monthly mean concentrations at Zeppelin are stable throughout the year and show no seasonal trend. A bigger variability in monthly mean concentrations were observed at Birkenes and Andøya but no strong seasonality was seen as the concentrations fluctuate from month to month.

Table 3.10: Annual mean concentrations of sum PFAS (pg/m³) in air.

	2006	2007	2008	2009	2010	2011	2012	2013
Birkenes	11.18	2.34	3.07	10.63	7.66	3.62	2.56	5.12
Andøya				2.62	8.06	1.64	1.28	2.05
Zeppelin	2.04	1.47	1.48	1.84	3.82	1.73	1.31	1.25

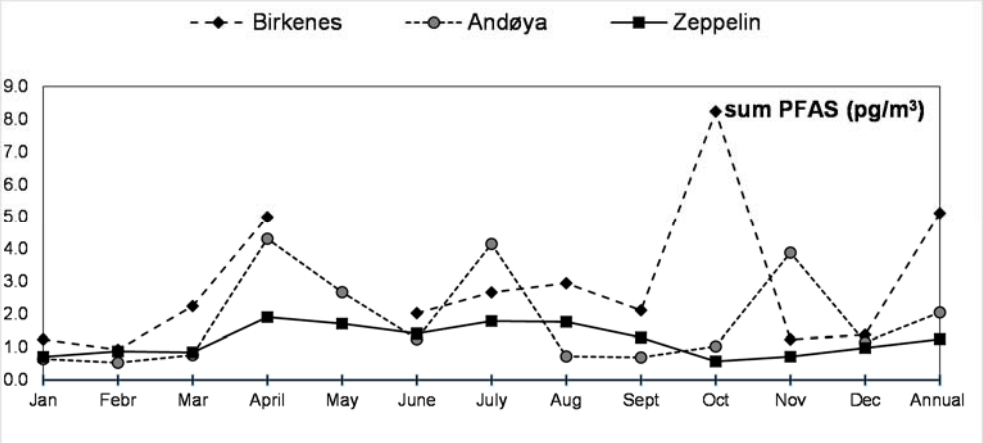

Figure 3.9: Monthly and annual mean concentrations (pg/m³) of sum PFAS in air for 2013 (excluding one outlier at Birkenes in May).

3.2 Persistent organic pollutants in precipitation

Precipitation samples were as previous years collected at Birkenes and analysed for HCHs, HCBs, and PCB-7 (Annex 3, and Table A.2.6).

The annual mean concentrations of HCB in precipitation were similar to those observed during the last 6 years. A significant reduction of concentrations has been observed since the 1990s and the beginning of 2000 while the concentrations seem to have reached a plateau during

the last five years. The same results have been observed for the air concentrations. HCB showed small seasonal variations but higher concentrations were observed during January-July than August-December, Figure 3.10.

The annual mean concentration for sum HCH was the lowest since the beginning of the monitoring (in 1992) and as in air they followed the decreasing trend. The monthly mean concentrations showed lowest concentrations in January-March and highest in April-July. This seasonality is similar to that found for air concentrations at Birkenes.

The annual mean concentration of PCB-7 was a factor of 4-6 higher than the previous four years and the highest since the start of the monitoring (in 2006). This was influenced by very high levels during June-October. The same was not observed in air samples. As a consequence a pronounced seasonality was observed with higher concentrations in summer time than in winter/spring time.

Table 3.11: Annual mean concentrations of HCB, sum HCH and sum PCB-7 (ng/l) in precipitation.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
HCB	0.14	0.40	0.57	0.80	1.42	0.90	0.68	0.55	0.49	0.34	0.34	0.43	0.12	0.12	0.14	0.18	0.09	0.06	0.09	0.08	0.10	0.08
sum HCH	7.09	10.52	12.31	7.24	10.44	6.08	5.64	4.95	3.65	2.86	2.10	1.30	1.26	0.99	0.68	0.58	0.63	0.47	0.43	0.46	0.60	0.40
sum PCB-7															0.17	0.18	0.23	0.06	0.06	0.04	0.07	0.26

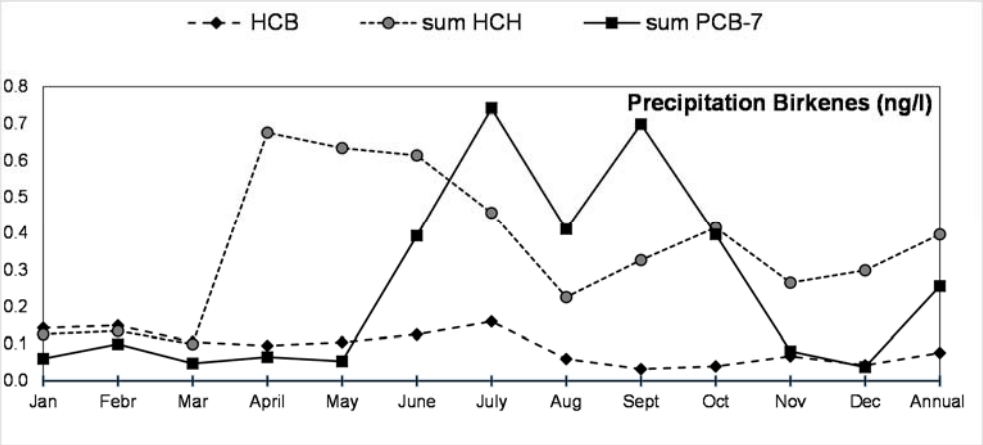

Figure 3.10: Monthly and annual mean concentrations (ng/l) of HCB, sum HCH and sum PCB-7 in precipitation at Birkenes, 2013.

4. Emerging contaminants

4.1 Cyclic volatile methyl siloxanes (cVMS)

cVMS are used in production of silicone polymers, in personal care products, and in various technical applications (Wang et al., 2013). The main environmental emissions are to the atmosphere through volatilization, and they are also emitted to aquatic environments through wastewater effluents. There are no regulations on the production and use of cVMS, but concern has been raised over the congeners octamethylcyclotetrasiloxane (D4), ecamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) due to their possible potential for bioaccumulation, persistence, toxicity, and long-range atmospheric transport (Brooke et al., 2009a; Brooke et al., 2009c; Brooke et al., 2009b). D4 and D5 are included on Norway's list of priority substances with the aim to stop the emissions of these compounds within 2020 (Environment.no, 2013). Measurements of environmental trace levels are challenging due to a high potential of contamination of samples from indoor air, personal care products, and laboratory equipment (Varaprath et al., 2006). To our knowledge, cVMS levels in Arctic air have only been reported in two studies so far (Genualdi et al., 2011; Krogseth et al., 2013a).

Measurements of cVMS were included at Zeppelin in 2013. Samples were collected in two sampling campaigns using the same sampling design as in Krogseth et al. (2013a). Details are given in Annex 3.

Due to storage artifacts and subsequent corrections, the reported concentrations should be considered semi-quantitative. All cVMS congeners in all samples were above LOD and LOQ. The mean concentrations of D5 and D6 were 0.72 ± 0.23 ng/m^3 and 0.87 ± 0.26 ng/m^3 in summer, and 2.83 ± 0.27 ng/m^3 and 0.42 ± 0.12 ng/m^3 in winter, respectively. For D4, the average upper limit of the concentration windows was 0.95 ± 0.32 ng/m^3 in summer and 1.27 ± 0.11 ng/m^3 in winter. However, no conclusion can be drawn about the presence of D4 in air from Zeppelin due to the storage artefacts (Table 4.1, Figure 4.1).

In the winter samples, D5 was the dominating congener, followed by D4 and D6. This is the same profile as observed at Zeppelin in 2011 (Krogseth et al., 2013a). However, in summer 2013, the concentrations of D4 and D6 often exceeded the concentrations of D5. A pronounced seasonality was observed at Zeppelin for D5, with higher concentrations in winter than in summer. Both the seasonality and the absolute concentrations of D5 in 2013 corresponded well with the results from 2011 (Figure 4.1). D6 displayed higher concentrations in summer than in winter, which is opposite of what was observed in 2011 and what is expected from theoretical considerations (Whelan et al., 2004; Krogseth et al., 2013a; McLachlan et al., 2010). The results for D4 indicated the same tendency as for D6, with higher upper limits of the concentration windows in summer of 2013 than in 2011, and with a less pronounced seasonality in 2013 than in 2011 (Figure 4.1). However, no conclusions can be drawn for D4 as the results could possibly be non-detects.

The concentrations of cVMS at Zeppelin are much lower than in air from typical source areas such as urban centers (Krogseth et al., 2013b; Genualdi et al., 2011; Buser et al., 2013;

Yucuis et al., 2013; Companioni-Damas et al., 2014) or close to wastewater treatment plants and landfills (Cheng et al., 2011; Krogseth et al., 2013b).

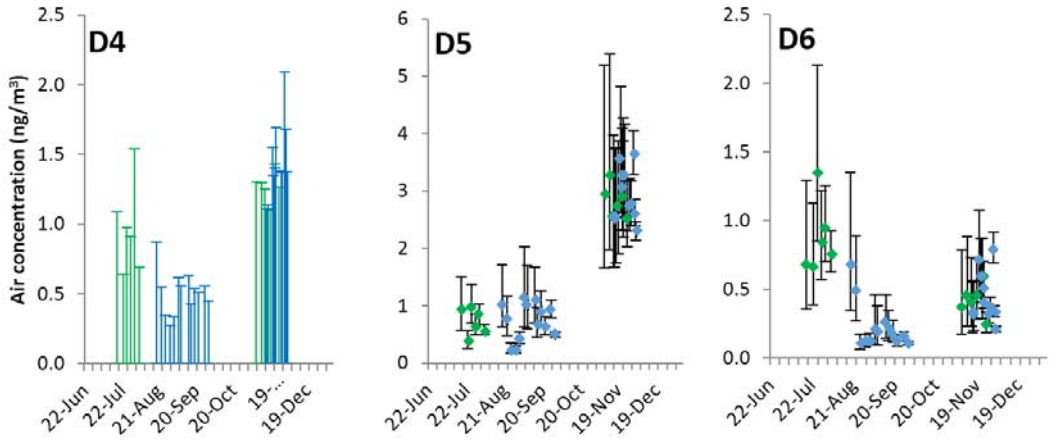

Figure 4.1: Concentrations of cVMS on Zeppelin in 2013 (green) compared to in 2011 (blue) (Krogseth et al., 2013a). Results for D4 are reported as a range from non-detected to an upper limit. Results for D5 and D6 are reported as a storage-corrected point-estimate with a range representing the 95 % confidence interval of the storage correction (Krogseth et al., 2013a).

Table 4.1: Concentrations of cVMS on Zeppelin in 2013, as the average of two parallel samples. Unit: ng/m³.

Date		D4		D5			D6		
Start	End	Lower boundary	Upper boundary	Point estimate	Low estimate	High estimate	Point estimate	Low estimate	High estimate
18.07.2013	23.07.2013	n.d.	0.97	0.93	0.58	1.51	0.68	0.36	1.29
23.07.2013	26.07.2013	n.d.	0.64	0.38	0.25	0.57	0.66	0.38	1.13
26.07.2013	29.07.2013	n.d.	0.97	0.98	0.69	1.38	1.34	0.85	2.13
29.07.2013	01.08.2013	n.d.	0.91	0.64	0.48	0.85	0.83	0.57	1.22
01.08.2013	05.08.2013	n.d.	1.54	0.83	0.67	1.03	0.94	0.70	1.25
05.08.2013	08.08.2013	n.d.	0.69	0.57	0.50	0.67	0.76	0.63	0.93
08.11.2013	12.11.2013	n.d.	1.31	2.94	1.67	5.19	0.37	0.17	0.79
12.11.2013	15.11.2013	n.d.	1.30	3.27	1.98	5.39	0.45	0.23	0.89
15.11.2013	19.11.2013	n.d.	1.25	2.58	1.68	3.97	0.41	0.23	0.73
19.11.2013	23.11.2013	n.d.	1.10	2.72	1.91	3.87	0.45	0.28	0.73
23.11.2013	26.11.2013	n.d.	1.43	2.92	2.20	3.88	0.60	0.41	0.87
26.11.2013	29.11.2013	n.d.	1.27	2.54	2.03	3.19	0.25	0.18	0.33

4.2 Short and medium chained chlorinated paraffins (SCCP, MCCP)

Chlorinated paraffins (CPs), also referred to as polychlorinated n-alkanes, are semivolatile chemicals (SOCs) that have been used in large amounts for several decades in commercial products such as plasticizers, flame retardants, sealants and paints, and in industrial processes such as metalworking fluids and drilling (UNEP, 2010). Commercial mixtures of CPs are usually classified into three groups according to their carbon chain length (Cx); short chained chlorinated paraffins (SCCPs) with C10-C13, medium chain chlorinated paraffins (MCCPs) with C14-C17, and long chain chlorinated paraffins (LCCPs) with C18-C30. Some of the CPs have been found to be persistent in the environment, subject to long-range transport and show bioaccumulation potential in aquatic food chains. In addition, SCCPs in particular have been receiving wide attention due to their higher toxicity to certain aquatic organisms and rodents (UNEP, 2010). As a consequence, SCCPs are included in the Aarhus protocol on POPs (UN/ECE, 2010) and on Norway's list of priority substances (Environment.no, 2013). They are currently also being reviewed by the SC on POPs for a possible inclusion into their list of POPs (Stockholm Convention, 2012). Information regarding levels and distribution of SCCPs in the environment remain limited, mainly due to analytical challenges and blank problems (Tomy et al., 1997). The atmosphere is usually considered to be the main transport medium, but very few studies have been conducted to investigate the atmospheric levels and distribution of SCCPs.

SCCPs and MCCP were included in the monitoring at Zeppelin for 2013. Sampling was done on a weekly basis together with sampling of PCBs, and OCPs (Annex 3). As in other published studies, the blank levels for the SCCPs and MCCPs were variable and high which resulted in relatively high LOD values (10-50% of detected masses). Despite this only 3% of the measurements for SCCPs were below LOD. Lower detection was found for the MCCPs where one third of the measurements were below LOD. More knowledge and studies are needed on blank problems and how to deal with blanks. The presented data should therefore be handled with care.

The annual mean concentrations for 2013 were 360 pg/m^3 for SCCPs and 23 pg/m^3 for MCCPs (Table 4.2). These concentrations are similar to rural air in Canada but almost three orders of magnitude lower than recent results from China. The monthly mean concentrations fluctuated from month to month, Figure 4.2.

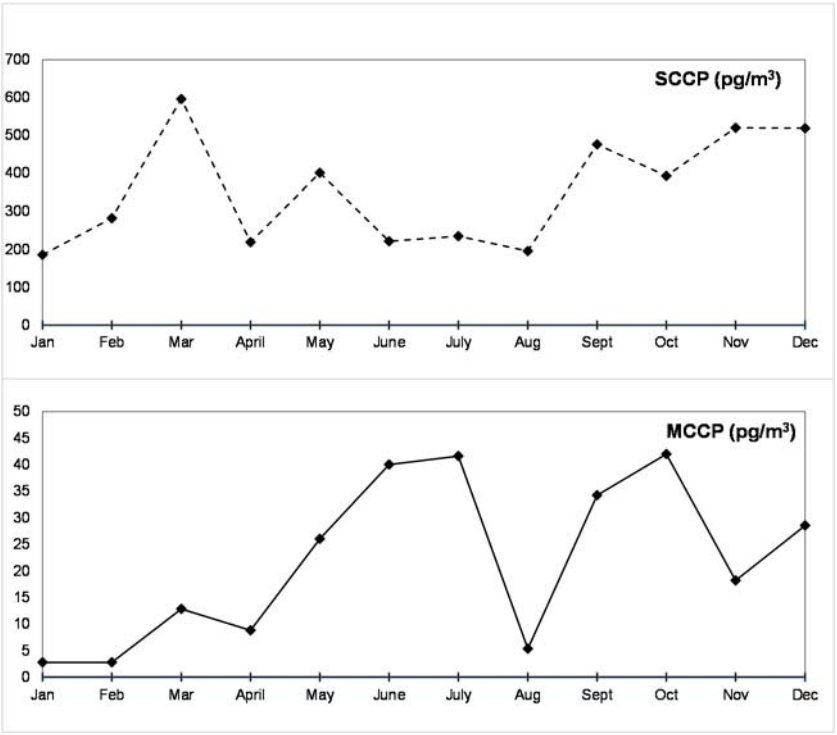

Figure 4.2: Monthly mean concentrations (pg/m^3) of short- and medium chained chlorinated paraffins (S/MCCP) in air at Zeppelin, 2013.

Table 4.2: Annual mean concentrations of SCCp and MCCP (pg/m^3) in air.

2013	SCCP	MCCP
Zeppelin	361	23

5. Summary organic pollutants

The overall annual mean concentrations for each compound class and observatory are presented in Table 5.1. It shows that HCB was found at highest levels at Zeppelin while DDTs, PAHs and PFAS were found at highest levels at Birkenes and lowest levels at Zeppelin. The levels of PCBs and PBDEs were generally lowest at Andøya while the other classes (i.e. HCHs, CHLs) were observed in similar levels at all observatories. Interestingly, the siloxanes (cVMS) and chlorinated paraffins (SCCP/MCCP) were found at similar levels as the PAHs and up to three orders of magnitude higher levels than the legacy POPs (i.e. PCBs, OCPs, PBDEs, PFAS). This emphasizes the importance of continuous monitoring of these emerging POPs to follow their emission trends.

Table 5.1: Annual mean concentrations (pg/m^3) for all studied organic pollutants in air, 2013.

	HCB	sum HCH	sum DDT	sum CHL	sum PCB	sum PCB-7	sum PBDE	TBA	sum PAH	sum PAH16	sum PFAS	SCCP	MCCP	cVMS (D5)	cVMS (D6)
Birkenes	52	7.5	1.7	1.2	9.8	2.7	1.1	4.9	4600	2530	5.1				
Andøya	27	5.1	0.7		5.1	1.5	0.8	6.6			2.1				
Zeppelin	81	6.1	0.6	0.9	10.1	2.6	1.5	6.3	2900	1200	1.2	360	20	1780	640

6. References

Berglen, T.F., Dauge, F., Andresen, E., Haugsbakk, I., Nilsson, L.O., Ofstad, T., Tønnesen, D., Vadset, M., Våler, R.L. (2013) Grenseområdene Norge - Russland. Luft- og nedbørkvalitet, april 2012 - mars 2013. Kjeller, NILU (Statlig program for forurensningsovervåking. Rapport 1153/2013. M 41-2013) (NILU OR 42/2013) (in Norwegian).

Breivik, K., Sweetman, A., Pacyna, J.M., Jones, K.C. (2002) Towards a global historical emission inventory for selected PCB congeners – a mass balance approach 2. Emissions. *Sci. Total Environ., 290*, 199-224.

Brooke, D., Crookes, M., Gray, D., Robertson, S. (2009a) Environmental risk assessment report: Decamethylcyclopentasiloxane. Bristol, Environment Agency.

Brooke, D., Crookes, M., Gray, D., Robertson, S. (2009b) Environmental risk assessment report: Dodecamethylcyclohexasiloxane. Bristol, Environment Agency.

Brooke, D., Crookes, M., Gray, D., Robertson, S. (2009c) Environmental risk assessment report: Octamethylcyclotetrasiloxane. Bristol, Environment Agency.

Buser, A.M., Kierkegaard, A., Bogdal, C., MacLeod, M., Scheringer, M., Hungerbühler, K. (2013) Concentrations in ambient air and emissions of cyclic volatile methylsiloxanes in Zürich, Switzerland. *Environ. Sci. Technol., 47,* 7045-7051

Cheng, Y., Shoeib, M., Ahrens, L., Harner, T., Ma, J. (2011) Wastewater treatment plants and landfills emit volatile methyl siloxanes (VMSs) to the atmosphere: Investigations using a new passive air sampler. *Environ. Pollut., 159*, 2380-2386

Companioni-Damas, E.Y., Santos, F.J., Galceran, M.T. (2014) Linear and cyclic methylsiloxanes in air by concurrent solvent recondensation–large volume injection–gas chromatography–mass spectrometry. *Talanta, 118*, 245-252

Cousins I.T., Jones K.C. (1998) Air-soil exchange of semi-volatile organic compounds (SOCs) in the UK. *Environ. Pollut., 102 (1),* 105-118.

Environment.no (2013) List of priority substances. Oslo, Norwegian Environment Agency. **URL:** http://www.environment.no/Tema/Kjemikalier/Kjemikalielister/Prioritetslisten/ [Accessed June 10, 2013].

EU (2004) Directive 2004/107/EC of the European Parliament and of the Council of 15 Dec. 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. *Off. J. Eur. Union.*, L 23, 3-16.

EU (2008) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. *Off. J. Eur. Com.*, L 141, 1-44.

Genualdi, S.G.S., Harner, T., Cheng, Y., MacLeod, M., Hansen, K.M., van Egmond, R., Shoeib, M., Lee, S.C. (2011) Global distribution of linear and cyclic volatile methyl siloxanes in air. *Environ. Sci. Technol., 45*, 3349-3354.

Green, N.W., Heldal, H.E., Måge, A., Aas, W., Gäfvert, T., Schrum, C., Boitsov, S., Breivik, K., Iosjpe, M. Yakushev, E., Skogen, M., Høgåsen, T., Eckhardt, S., Christiansen, A.B., Daae, K.L., Durand, D., Debloskaya, E. (2011) Tilførselsprogrammet 2010. Overvåking av tilførsler og miljøtilstand i Nordsjøen. Oslo, NIVA (Statlig program for forurensingsovervåking. Rapport 1097/2011. TA-2810/2011) (NIVA-rapport 6187 2011) (in Norwegian).

Halse, A.K., Schlabach, M., Eckhardt, S., Sweetman, A., Jones, K.C., Breivik, K. (2011) Spatial variability of POPs in European background air. *Atmos., Chem. Phys., 11*, 1549-1564, doi:10.5194/acp-11-1549-2011.

Halse, A.K., Schlabach, M., Sweetman, A.J., Jones, K.C., Breivik, K. (2012) Using passive air samplers to assess local sources versus long range atmospheric transport of POPs. *J. Environ. Monit., 14*, 2580-2590.

Hung, H., Kallenborn, K., Breivik, K., Su, Y., Brorstrom-Lunden, E., Olafsdottir, K., Thorlacius, J., Leppanen, S., Bossi, R., Skov, H., Mano, S., Patton, G., Stern, G., Sverko, E., Fellin, P. (2010) Atmospheric monitoring of organic pollutants in the Arctic under the Arctic Monitoring and Assessment Programme (AMAP): 1993-2006. *Sci. Total Environ., 408*, 2854-2873.

Kierkegaard, A., McLachlan, M.S. (2010) Determination of decamethylcyclopentasiloxane in air using commercial solid phase extraction cartridges. *J. Chromatogr. A., 1217,* 3557-3560.

Krogseth, I.S., Kierkegaard, A., McLachlan, M.S., Breivik, K., Hansen, K.M., Schlabach, M. (2013a) Occurrence and seasonality of cyclic volatile methyl siloxanes in Arctic air. *Environ. Sci. Technol., 47*, 502-509.

Krogseth, I.S., Zhang, X., Lei, Y.D., Wania, F., Breivik, K. (2013b) Calibration and application of a passive air sampler (XAD-PAS) for volatile methyl siloxanes. *Environ. Sci. Technol., 47*, 4463-4470.

McLachlan, M.S., Kierkegaard, A., Hansen, K.M., van Egmond, R., Christensen, J.H., Skjøth, C.A. (2010) Concentrations and fate of decamethylcyclopentasiloxane (D(5)) in the atmosphere. *Environ. Sci. Technol., 44*, 5365-5370

Pribylova, P., Kares, R., Boruvkova, J., Cupr, P., Prokes, R., Kohoutek, J., Holoubek, I., Klanova, J. (2012) Levels of persistent organic pollutants and polycyclic aromatic hydrocarbons in ambient air of Central and Eastern Europe. *Atmos. Pollut. Res., 3,* 494-505, doi:10.5094/APR.2012.057.

Stockholm Convention (2007) Stockholm Convention on Persistent Organic Pollutants. Châtelaine. **URL:** http://www.pops.int [accessed May 2014].

Stockholm Convention (2011) The new POPs under the Stockholm Convention. Châtelaine. **URL:** http://chm.pops.int/Implementation/NewPOPs/TheNewPOPs/tabid/672/Default.aspx [accessed May 2014].

Stockholm Convention (2012) Chemicals proposed for listing under the Convention. Châtelaine. **URL:** http://chm.pops.int/TheConvention/ThePOPs/ChemicalsProposedforListing/tabid/2510/Default.aspx [accessed May 2014].

Tomy, G.T., Stem, G.A., Muir, D.C.G., Fisk, A.T., Cymbalisty, C.D., Westmore, J.B. (1997) Quantifying C-10–C-13 polychloroalkanes in environmental samples by high-resolution gas chromatography/electron capture negative ion high resolution mass spectrometry. *Anal. Chem., 69,* 2762-2771.

Tørseth, K., Aas, W., Breivik, K., Fjæraa, A.M., Fiebig, M., Hjellbrekke, A.G., Myhre, C.L., Solberg, S., Yttri, K.E. (2012) Introduction to the European Monitoring and Evaluation Programme (EMEP) and observed atmospheric composition change during 1972–2009. *Atmos. Chem. Phys., 12*, 5447-5481.

Wang, D.-G., Norwood, W., Alaee, M., Byer, J.D., Brimble, S. (2013) Review of recent advances in research on the toxicity, detection, occurrence and fate of cyclic volatile methyl siloxanes in the environment. *Chemosphere, 93*, 711-725.

Whelan, M.J., Estrada, E., van Egmond, R. (2004) A modelling assessment of the atmospheric fate of volatile methyl siloxanes and their reaction products. *Chemosphere, 57*, 1427-1437.

UN/ECE (1998a) The 1998 Aarhus Protocol on Heavy Metal. Geneva. **URL:** http://www.unece.org/env/lrtap/hm_h1.html [accessed May 2014].

UN/ECE (1998b) The 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs). Geneva. **URL:** http://www.unece.org/env/lrtap/pops_h1.html [accessed May 2014].

UN/ECE (2010) The 1998 Aarhus Protocol on Persistent Organic Pollutants, including amendments adopted by the Parties on 18 Dec. 2009. Geneva (EC/EB.AIR/104). **URL:** http://www.unece.org/fileadmin/DAM/env/lrtap/full%20text/ece.eb.air.104.e.pdf [accessed May 2014].

UNEP (2010) Stockholm Convention on Persistent Organic Pollutants. Supporting document for the draft risk profile on short-chained chlorinated paraffins. Nairobi, United Nations Environment Programme (UNEP/POPS/POPRC.6/INF/15).

Varaprath, S., Stutts, D., Kozerski, G. (2006) A primer on the analytical aspects of silicones at trace levels – challenges and artifacts – a review. *Silicon Chem., 3*, 79-102.

Yucuis, R.A., Stanier, C.O., Hornbuckle, K.C. (2013) Cyclic siloxanes in air, including identification of high levels in Chicago and distinct diurnal variation. *Chemosphere, 92*, 905-910.

Annex 1

Monthly and annual averages of heavy metals in air and precipitation

Table A.1.1: Monthly and annual volume weighted mean concentrations of lead in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.96	1.18	0.69	0.82	0.89	0.37	1.18	0.49	0.40	0.53	1.14	0.49	0.60
Hurdal	0.62	0.25	0.19	0.42	0.58	0.56	0.80	0.24	0.61	0.23	0.36	0.31	0.41
Kårvatn	0.09	0.40	0.29	0.12	0.17	0.15	0.10	0.05	0.74	0.06	0.04	0.09	0.16
Svanvik	0.77	2.20	0.95	2.42	4.12	1.05	0.48	1.27	1.22	0.84	1.26	0.62	1.09

Table A.1.2: Monthly and annual volume weighted mean concentrations of cadmium in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.033	0.041	0.021	0.019	0.023	0.014	0.033	0.012	0.012	0.013	0.011	0.011	0.015
Hurdal	0.032	0.009	0.008	0.022	0.024	0.021	0.028	0.010	0.025	0.006	0.007	0.016	0.017
Kårvatn	0.002	0.021	0.013	0.005	0.008	0.004	0.004	0.003	0.008	0.003	0.002	0.002	0.006
Svanvik	0.026	0.129	0.038	0.169	0.296	0.071	0.018	0.046	0.049	0.048	0.087	0.033	0.059

Table A.1.3: Monthly and annual volume weighted mean concentrations of zinc in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	7.2	19.7	20.6	5.1	6.0	2.2	11.2	2.3	1.6	4.9	11.8	4.6	5.3
Hurdal	12.1	4.7	1.1	35.3	6.3	5.1	13.3	3.3	8.9	5.1	5.8	5.7	8.0
Kårvatn	1.3	21.9	40.3	1.0	2.6	0.7	1.2	1.5	6.5	4.8	3.3	2.4	6.5
Svanvik	6.0	4.6	5.9	14.3	12.2	5.6	3.0	2.9	2.9	1.5	2.9	1.4	3.9

Table A.1.4: Monthly and annual volume weighted mean concentrations of nickel in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.32	0.37	0.49	0.41	0.33	0.13	0.68	0.26	0.11	0.22	0.23	0.12	0.21
Svanvik	22.72	85.07	17.05	55.36	128.22	42.26	13.25	13.69	19.70	18.97	27.26	7.97	25.96

Table A.1.5: Monthly and annual volume weighted mean concentrations of arsenic in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.05	0.18	0.06	0.07	0.09	0.04	0.17	0.05	0.04	0.04	0.04	0.04	0.05
Svanvik	0.94	2.21	0.76	3.30	5.87	1.73	0.64	1.38	1.86	2.12	3.16	0.54	1.68

Table A.1.6: Monthly and annual volume weighted mean concentrations of copper in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.93	0.96	0.89	1.02	0.89	0.41	2.41	0.75	0.30	1.42	4.35	0.73	1.00
Svanvik	29.27	129.95	22.68	118.20	227.03	83.12	20.04	25.46	57.91	47.61	65.46	17.93	51.06

Table A.1.7: Monthly and annual volume weighted mean concentrations of cobalt in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.01	0.02	0.02	0.03	0.02	0.01	0.11	0.03	0.01	0.02	0.01	0.01	0.02
Svanvik	0.61	2.28	0.51	1.48	3.70	1.39	0.41	0.42	0.62	0.58	0.82	0.27	0.78

Table A.1.8: Monthly and annual volume weighted mean concentrations of chromium in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.10	0.18	0.05	0.09	0.06	0.05	0.29	0.05	0.05	0.05	0.07	0.05	0.06
Svanvik	0.15	0.42	0.21	0.58	0.90	0.47	0.15	0.16	0.20	0.15	0.21	0.06	0.23

Table A.1.9: Monthly and annual volume weighted mean concentrations of manganese in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.91	1.27	1.33	1.52	1.43	2.04	9.53	1.93	1.04	2.04	11.40	0.45	1.92
Svanvik	-	-	-	2.40	3.58	5.68	1.37	1.33	1.38	-	-	-	-

Table A.1.10: Monthly and annual volume weighted mean concentrations of vanadium in precipitation at Norwegian background stations 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	0.22	0.34	0.27	0.29	0.23	0.19	0.78	0.33	0.13	0.22	0.17	0.17	0.21
Svanvik	0.59	1.82	0.52	2.56	3.82	0.58	0.22	0.16	0.21	1.02	1.71	0.37	0.79

Table A.1.11: Monthly and annual volume weighted mean concentrations of aluminum in precipitation at Svanvik, 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Svanvik	12.87	36.04	20.91	44.00	65.33	69.23	21.82	18.88	15.20	7.61	12.75	6.29	22.54

Table A.1.12: Monthly and annual volume weighted mean concentrations of mercury in precipitation at Birkenes, 2013. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	3.7	4.4	5.4	10.3	8.0	7.2	16.0	14.4	4.7	3.8	0.7	1.6	5.5

Table A.1.13: Annual and monthly total precipitation measured using the bulk collector which is used for sampling of heavy metal. Unit mm.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	68	17	44	43	152	195	8	115	134	168	86	418	1447
Hurdal	40	19	3	78	159	152	19	139	57	138	48	203	1056
Kårvatn	7	83	87	91	61	189	158	92	47	105	192	64	1178
Svanvik	15	5	18	8	14	23	56	31	23	53	17	27	291

Table A.1.14: Monthly- and annual wet deposition of lead at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	65	20	31	35	135	73	10	56	53	89	98	205	872
Hurdal	25	5	1	33	93	85	15	33	35	32	17	63	435
Kårvatn	1	33	25	11	10	28	17	5	35	6	8	6	185
Svanvik	11	11	17	19	57	24	27	40	28	45	22	17	317

Table A.1.15: Monthly- and annual wet deposition of cadmium at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	2.2	0.7	0.9	0.8	3.6	2.7	0.3	1.3	1.6	2.2	1.0	4.5	21.9
Hurdal	1.3	0.2	0	1.8	3.9	3.2	0.5	1.4	1.4	0.9	0.3	3.3	18.2
Kårvatn	0	1.7	1.2	0.4	0.5	0.7	0.7	0.3	0.4	0.3	0.3	0.1	6.5
Svanvik	0.4	0.6	0.7	1.3	4.1	1.6	1	1.4	1.1	2.5	1.5	0.9	17.3

Table A.1.16: Monthly- and annual wet deposition of zinc at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	488	338	911	218	914	428	94	260	218	819	1021	1924	7634
Hurdal	479	89	4	2765	1011	772	259	463	505	701	276	1161	8485
Kårvatn	9	1822	3491	93	159	135	193	134	310	500	633	155	7633
Svanvik	89	23	106	114	168	129	167	91	67	80	51	38	1121

Table A.1.17: Monthly- and annual wet deposition of nickel at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	21	6	22	18	50	26	6	30	14	37	20	52	301
Svanvik	339	423	305	439	1764	980	747	429	449	1009	473	218	7555

Table A.1.18: Monthly- and annual wet deposition of arsenic at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	4	3	2	3	13	9	1	5	6	8	4	19	77
Svanvik	14	11	14	26	81	40	36	43	42	112	55	15	489

Table A.1.19: Monthly- and annual wet deposition of copper at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	63	16	39	43	135	80	20	86	40	240	375	307	1444
Svanvik	436	646	406	937	3123	1927	1130	798	1320	2531	1135	490	14859

Table A.1.20: Monthly- and annual wet deposition of cobalt at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	1	0	1	1	3	3	1	3	1	4	1	3	23
Svanvik	9	11	9	12	51	32	23	13	14	31	14	7	226

Table A.1.21: Monthly- and annual wet deposition of chromium at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	7	3	2	4	9	9	2	6	6	9	7	21	85
Svanvik	2	2	4	5	12	11	9	5	5	8	4	2	67

Table A.1.22: Monthly- and annual wet deposition of manganese at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	62	22	59	65	218	398	80	221	139	344	983	190	2780
Svanvik	-	-	-	19	49	132	77	42	31	-	-	-	697

Table A.1.23: Monthly- and annual wet deposition of vanadium at Norwegian background stations 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Birkenes	15	6	12	12	35	37	7	38	17	38	15	70	301
Svanvik	9	9	9	20	53	14	12	5	5	54	30	10	229

Table A.1.24: Monthly- and annual wet deposition of aluminum at Svanvik, 2013. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2013
Svanvik	192	179	374	349	899	1605	1230	592	346	405	221	172	6558

Table A.1.25a: Annual average volume weighed mean concentration of heavy metals in precipitation at Norwegian background sites, 1976, Aug. 1978-june 1979; 1980 (Feb.-Dec.), 1981-2013.

Site	Year	Pb µg/l	Cd µg/l	Zn µg/l	Ni µg/l	As µg/l	Cu µg/l	Co µg/l	Cr µg/l	V µg/l	Al µg/l	Hg ng/l
Birkenes	1976	12.7	0.27	28.9								
	1978	10.8	0.27	17.9								
	1980	7.9	0.34	15.7								
	1981	7.4	0.24	6.2								
	1982	8.8	0.69	7								
	1983	5.4	0.25	6.6								
	1984	6.2	0.29	12.1								
	1985	4.1	0.09	9.4								
	1986	4.8	0.12	9								
	1987	3.5	0.12	9.2								
	1988	7.4	0.12	14.1								
	1989	5.4	0.11	11.4								
	1990	3.8	0.12	9.5								
	1991	3.6	0.06	7								
	1992	2.9	0.04	5.2								
	1993	3.1	0.06	6.5								
	1994	2.6	0.05	5								
	1995	2.2	0.05	6								
	1996	2.8	0.06	4.9								
	1997	1.7	0.03	4.2								
	1998	1.59	0.043	4.9								
	1999	1.5	0.040	4.4								
	2000	1.39	0.030	3.2								
	2001	1.25	0.032	4.7								
	2002	0.99	0.034	3.6								
	2003	1.57	0.043	3.9								
	2004	1.3	0.040	4.1	0.21	0.12	0.35	0.01	0.11	0.61		9.8
	2005	1.17	0.035	5.3	0.47	0.26	0.76	0.01	0.30	1.11		8.9
	2006	0.88	0.029	3.4	0.2	0.20	0.51	0.01	0.15	0.76		8.0
	2007	0.67	0.024	2.8	0.23	0.10	0.37	0.02		0.64		6.3
	2008	0.78	0.025	2.9	0.13	0.16	0.39	0.01	0.12	0.78		6.4
	2009	0.92	0.04	3.9	0.19	0.18	0.46	0.01	0.12	0.75		9.4
	2010	0.91	0.039	4.3	0.2	0.18	0.54	0.02	0.13	0.51		9.1
	2011	0.63	0.027	3.5	0.15	0.12	0.58	0.01	0.10	0.52		5.3
	2012	0.58	0.02	4.4	0.25	0.08	0.52	0.01	0.06	0.21		4.7
	2013	0.60	0.015	5.3	0.21	0.05	1.00	0.02	0.06	0.21		5.5
Nordmoen	1987	4.6	0.10	8.4								
	1988	5.6	0.10	11								
	1989	4.6	0.08	7.3								
	1990	3.8	0.14	5.6								
	1991	2.6	0.06	4.3								
	1992	2.3	0.04	4.4								
	1993	1.8	0.04	3.5								
	1994	1.7	0.05	4								
	1995	2	0.04	5.2								
	1996	1.9	0.04	4.3								
Hurdal	1997	1.26	0.056	4.4								
	1998	1.55	0.063	4.9								
	1999	1.18	0.032	6.3								
	2000	1.13	0.042	4.2								
	2001	0.93	0.042	4.8								
	2002	0.7	0.026	4.1								

Table A.1.25a, cont.

Site	Year	Pb µg/l	Cd µg/l	Zn µg/l	Ni µg/l	As µg/l	Cu µg/l	Co µg/l	Cr µg/l	V µg/l	Al µg/l	Hg ng/l
Hurdal, cont.	2003	0.97	0.032	3.7								
	2004	0.89	0.041	10								
	2005	1.23	0.070	10.3								
	2006	0.96	0.061	8.4								
	2007	0.91	0.065	10.3								
	2008	0.74	0.044	7								
	2009	0.79	0.043	7.4								
	2010	1.33	0.030	8.9								
	2011	0.92	0.028	6.4								
	2012	0.49	0.017	6.8								
	2013	0.41	0.017	8								
Kårvatn	1979	1.5	0.04	3								
	1980	1.4	0.06	4.2								
	1981	1.4	0.09	3								
	1982	1.5	0.10	3.1								
	1983	0.7	0.12	2.9								
	1984	1.3	0.07	3.6								
	1985	1.1	0.06	4								
	1986	1.4	0.01	3.2								
	1987	1.1	0.03	2.5								
	1988	0.9	0.06	4.2								
	1989	0.3	0.05	1.8								
	1990	0.2	0.06	1								
	1991	0.3	0.01	1								
	1992	0.2	<0.01	0.8								
	1993	0.2	0.01	0.6								
	1994	0.4	0.02	1.2								
	1995	0.2	0.01	1.2								
	1996	0.5	0.01	1.4								
	1997	0.7	0.01	1.6								
	1998	0.2	0.01	1.3	0.1	0.1	0.1	0.01	0.3		0.3	
	1999	0.2	0.02	2.1								
	2000	0.18	0.01	1								
	2001	0.13	0.01	1.4								
	2002	0.32	0.018	1.2								
	2003	0.25	0.009	1								
	2004	0.13	0.005	1.2								
	2005	0.12	0.005	0.9								
	2006	0.17	0.010	1.9								
	2007	0.09	0.007	0.9								
	2008	0.1	0.005	1.2								
	2009	0.09	0.010	1.3								
	2010	0.14	0.009	3.7								
	2011	0.11	0.013	1.4								
	2012	0.11	0.005	1.5								
	2013	0.16	0.006	6.5								
Svanvik	1987	2	0.14	6	19.9*	2.4*	21.8*					
	1988	3.7	0.1	7.4	12.8	1.6	14.6					
	1989	1.4	0.14	4.6	15.5	1.3	14.4					
	1990	1.6	0.14	6.2	11.4	1.8	13.6	0.4	0.5			
	1991	1.3	0.07	3.4	9.3	1.1	10.4	0.3	0.4			
	1992	1.1	0.11	2.8	8.0	1.1	11.9	0.3	0.5			
	1993	1.1	0.12	3	10.9	1.2	13.4	0.4	0.6			
	1994	1.4	0.08	5	13.4	1.4	12.5	0.4	0.4			

Table A.1.25a, cont.

Site	Year	Pb µg/l	Cd µg/l	Zn µg/l	Ni µg/l	As µg/l	Cu µg/l	Co µg/l	Cr µg/l	V µg/l	Al µg/l	Hg ng/l
Svanvik, cont.	1995	1.7	0.11	5.4	17.4	1.8	17.4	0.6	0.4			
	1996	0.9	0.06	3.3	17.5	1.1	18.7	0.6	0.4			
	1997	1.9	0.11	3.8	17.3	1.8	21.4	0.6	0.3			
	1998	1.08	0.11	4.1	23.7	2.34	28.1	0.72	0.39			
	1999	0.83	0.08	8.4	11.1	1.41	14.0	0.37	0.32			
	2000	1.99	0.12	5.4	17.8	1.85	20.3	0.53	0.25			
	2001	2.56	0.16	8.5	20.7	2.31	20.2	0.65	0.39			
	2002	2.64	0.054	7	11.1	1.26	12.0	0.32	0.21			
	2003	2.32	0.08	6.2	10.6	0.85	12.0	0.34	0.22			
	2004	1.32	0.084	6.5	36.9	0.91	31.0	0.95	0.39			
	2005	1.84	0.143	5.2	55.3	1.72	58.0	1.59	0.41			
	2006	1.15	0.134	8.5	33.4	1.31	44.5	1.14	0.31			
	2007	1.25	0.231	4.5	45.2	1.83	41.6	1.14	0.61			
	2008	0.84	0.181	4.7	29.8	1.3	25.4	0.90	0.48			
	2009	1.63	0.146	3.8	42.0	2.21	32.6	1.13	0.85	0.56	15	
	2010	0.78	0.082	4.2	22.6	0.64	11.9	0.50	3.12	0.66	31	
	2011	0.85	0.186	3.9	17.5	1.06	30.1	0.58	0.34	0.46	22	
	2012	0.59	0.041	2.9	15.7	0.81	24.5	0.47	0.18	0.33	22	
	2013	1.09	0.059	3.9	26.0	1.7	51.1	0.78	0.23	0.79	23	

Table A.1.25b: Annual average volume weighed mean concentration of heavy metals in precipitation at Norwegian background sites, which has been closed down.

Site	Year	Pb µg/l	Cd µg/l	Zn µg/l	Ni µg/l	As µg/l	Cu µg/l	Co µg/l	Cr µg/l	Hg ng/l
Lista	1990									13.8
	1991									11.8
	1992									10.9
	1993									11.3
	1994	2.7	0.05	7.8	0.3	0.2	1		0.2	8.1
	1995	2.3	0.06	8.6	0.4	0.4	1.1		0.8	13.9
	1996	3	0.07	8.6	0.4	0.4			0.3	19.7
	1997	2.8	0.05	6.6	0.4	0.5	1	0.04	0.2	10.6
	1998	2.08	0.047	8.8	0.59	0.2	1.13	0.03	0.58	9
	1999	1.5	0.03	7.4	0.4	0.2	1.7	0.03	0.2	9.7
	2000	1.57	0.037	6.6	0.34	0.28	1.13	0.03	<0.2	7.3
	2001	1.52	0.056	7.4	0.37	0.18	1.28	0.02	0.31	7.3
	2002	2.15	0.033	6.8	0.3	0.29	1.3	0.02	0.16	12.8
	2003	1.92	0.063	7.5	0.5	1.01	1.3	0.04	0.31	8.3
Ualand	1994	2	0.04	4	0.2	0.1	0.5	0.02	0.1	
	1995	1.7	0.03	3.3	0.2	0.1	0.3	0.01	0.1	
	1996	1.3	0.03	2.5	0.2	0.1	0.9	0.01	0.2	
	1997	2.77	0.02	2.6	0.2	0.1	0.4	0.01	0.1	
	1998	1.24	0.024	2.7	0.19	0.1	0.3	0.02	0.17	
	1999	0.88	0.023	2.3	<0.2	<0.1	0.23	0.01	<0.2	
	2000	0.71	0.021	1.5	<0.2	<0.1	0.23	0.01	<0.2	
Solhomfjell	1994	2.4	0.06	6	0.2	0.1	0.7	0.02	0.1	
	1995	1.9	0.07	6	0.6	0.2	1.1	0.03	0.2	
	1996	2.3	0.05	5.7	0.3	0.2	0.9	0.02	<0.2	
Møsvatn	1994	1	0.04	2.9	0.6	0.1	0.5	0.03	<0.1	
	1995	0.9	0.03	2.8	0.3	0.1	0.9	0.01	0.1	
	1996	1	0.02	4.5	0.4	0.1	1	0.02	0.1	
	1997	1	0.02	4.5						
	1998	0.88	0.044			0.07		0.03	0.13	
	1999	1.05	0.042	5.7	0.29	<0.1	1.65	0.02	<0.2	
	2000	1.02	0.042	6.2	0.29	<0.1	1.72	0.01	<0.2	
Osen	1988	4.7	0.31	12.7						
	1989	2.7	0.08	5.4						
	1990	2.7	0.09	5.6						
	1991	2	0.03	4.2						
	1992	1.6	0.05	5.5						
	1993	1.2	0.06	3.5						
	1994	1.4	0.05	5.9						
	1995	2.1	0.07	8.8						
	1996	1.5	0.03	4.4						
	1997	0.9	0.02	4						
	1998	0.87	0.033	4.7						
	1999	1.05	0.042	7.1						
	2000	1.37	0.047	5.5						
	2001	0.59	0.019	3.3						
	2002	0.87	0.029	4.3						
	2003	0.61	0.031	5.1						
Valdalen	1994	1	0.03	4.2	0.1	0.1	0.6	0.01	0.1	
	1995	1.4	0.03	4.6	0.4	0.1	0.8	0.02	0.2	
	1996	1.1	0.03	4.1	0.3	0.1	1	0.03	0.2	
	1997	1.1	0.05	6.2	0.4	0.1	0.1	0.02	0.2	
	1998	0.76	0.03	4.8	0.17	0.09	0.57	0.02	0.16	
	1999	0.69	0.1	9.6	0.47	<0.1	1.13	0.02	0.37	
	2000	1.01	0.026	4.2	<0.2	<0.1	0.47	0.02	<0.2	

Table A.1.25b, cont.

Site	Year	Pb µg/l	Cd µg/l	Zn µg/l	Ni µg/l	As µg/l	Cu µg/l	Co µg/l	Cr µg/l	Hg ng/l
Namsvatn	1994	0.5	0.03	2.3	0.2	0.1	0.4	0.02	0.1	
	1995	0.5	0.01	2.3	0.3	0.1	0.2	0.01	0.1	
	1996	0.5	0.02	3	0.1	0.1	0.5	0.01	<0.2	
Øverbygd	1995	0.4	0.01	2.3	0.4	0.1	0.5	0.02	0.1	
	1996	0.5	0.03	3.5	0.4	0.1	1.3	0.02	0.3	
	1997	0.5	0.01	2.7	0.1	0.1	0.3	0.01	0.1	
	1998	0.4	0.01	3.8	0.2	0.1	0.6	0.02	0.1	
	1999	0.54	0.01	5	<0.2	<0.1	0.33	0.01	<0.2	
	2000	0.37	0.02	1.9	0.21	<0.1	0.38	0.01	<0.2	
Jergul	1979	3.5	0.22	7.8						
	1980	2.6	0.08	4.5						
	1981	1.8	0.05	3.5						
	1982	2.3	0.11	3.1						
	1983	1.5	0.07	3.6						
	1984	2.2	0.09	9.8						
	1985	2	0.08	5						
	1986	2	0.03	5.2						
	1987	1.3	0.07	4.6						
	1988	1.3	0.07	5.1						
	1989	1.3	0.05	3.3						
	1990	0.7	0.16	2.7						
	1991	0.7	0.02	2.2						
	1992	0.5	0.05	1.6						
	1993	0.5	0.05	2.4						
	1994	0.5	0.03	4.1						
	1995	0.8	0.04	3.5						
	1996	0.5	0.02	3.3						
Karasjok	1997	0.6	0.02	3.1						
	1998	0.8	0.04	3.5						
	1999	0.44	0.03	5.8						
	2000	0.57	0.02	11.6						
	2001	0.67	0.03	4.8						
	2002	0.58	0.033	6.4						
	2003	0.59	0.013	3.4						
	2004	0.74	0.014	4						
	2005	0.5	0.019	4.3						
	2006	0.37	0.02	2.8						
	2007	0.47	0.029	4.7						
	2008	0.38	0.017	7.6						
	2009	0.28	0.024	4.7						

Table A.1.26: Monthly- and annual average mean concentrations of heavy metals in PM_{10} and mercury in gas phase at Birkenes in 2013.Unit ng/m³.

	As	Cd	Cr	Co	Cu	Pb	Ni	V	Zn	Hg(g)
JAN	0.11	0.029	0.24	0.009	0.19	0.64	0.14	0.15	2.8	1.69
FEB	0.17	0.041	0.19	0.019	0.56	0.97	0.37	0.38	4.8	1.70
MAR	0.23	0.041	0.24	0.066	0.62	1.11	0.33	0.46	5.1	1.57
APR	0.16	0.032	0.28	0.026	0.44	0.84	0.39	0.52	4.3	1.53
MAY	0.27	0.048	0.39	0.045	0.93	1.28	0.76	0.85	5.1	1.51
JUN	0.12	0.026	0.27	0.026	0.40	0.59	0.47	0.48	2.4	1.55
JUL	0.08	0.011	0.44	0.028	0.45	0.35	0.50	0.35	2.3	1.48
AUG	0.12	0.016	0.27	0.028	0.56	0.49	0.47	0.55	2.0	1.50
SEP	0.20	0.032	0.29	0.027	0.84	0.87	0.47	0.42	7.4	1.42
OCT	0.21	0.030	0.28	0.017	0.57	0.80	0.33	0.24	5.4	1.57
NOV	0.09	0.014	0.28	0.009	0.22	0.39	0.12	0.08	1.9	1.47
DEC	0.05	0.012	0.74	0.011	0.42	0.52	0.23	0.18	2.9	1.59
2013	0.15	0.027	0.33	0.026	0.52	0.73	0.38	0.39	3.9	1.56

Table A.1.27: Monthly- and annual average mean concentrations of heavy metals in aerosols and mercury in gas phase at Andøya in 2013. Unit: ng/m³.

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
JAN	0.04	0.010	0.10	0.005	0.28	0.31	0.34	0.06	0.08	1.6	1.66
FEB	0.02	0.006	0.07	0.004	0.17	0.20	0.22	0.07	0.10	0.9	1.68
MAR	0.10	0.016	0.11	0.014	0.32	0.58	0.60	0.14	0.15	1.9	1.58
APR	0.06	0.010	0.08	0.032	0.25	0.33	0.67	0.13	0.15	1.1	1.46
MAY	0.05	0.009	0.26	0.020	0.39	0.30	0.90	0.20	0.20	1.8	1.41
JUN	0.02	0.002	0.05	0.006	0.10	0.08	0.19	0.12	0.15	1.5	1.40
JUL	0.04	0.006	0.10	0.014	0.21	0.20	0.58	0.17	0.26	2.0	1.44
AUG	0.02	0.004	0.05	0.004	0.11	0.09	0.15	0.10	0.10	1.3	1.42
SEP	0.08	0.019	0.18	0.017	0.32	0.61	0.46	0.33	0.14	2.5	1.50
OCT	0.02	0.003	0.05	0.004	0.11	0.09	0.14	0.07	0.05	0.8	1.56
NOV	0.02	0.002	0.05	0.003	0.11	0.07	0.21	0.08	0.04	0.6	1.60
DEC	0.01	0.002	0.19	0.005	0.68	0.06	0.63	0.10	0.04	1.1	1.69
2013	0.04	0.008	0.11	0.011	0.24	0.24	0.41	0.14	0.12	1.4	1.54

Table A.1.28: Monthly- and annual average mean concentrations of heavy metals in aerosols and mercury in gas phase at Zeppelin Mountain in 2013. Unit: ng/m³.

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
JAN	0.28	0.035	0.40	0.020	0.27	1.18	1.15	0.23	0.12	3.9	1.52
FEB	0.05	0.009	0.13	0.009	0.11	0.31	0.57	0.07	0.06	1.7	1.65
MAR	0.26	0.026	0.13	0.014	0.34	0.95	0.69	0.12	0.10	2.0	1.39
APR	0.11	0.023	0.04	0.018	0.47	0.77	0.44	0.18	0.09	1.2	1.22
MAY	0.03	0.005	0.03	0.003	0.06	0.13	0.14	0.02	0.03	0.6	1.40
JUN	0.03	0.004	0.40	0.019	0.27	0.14	1.22	0.17	0.11	2.9	1.45
JUL	0.02	0.004	0.17	0.010	0.29	0.07	0.71	0.09	0.07	3.8	1.52
AUG	0.01	0.001	0.03	0.001	0.12	0.04	0.04	0.01	0.02	0.8	1.63
SEP	0.04	0.007	0.06	0.006	0.33	0.41	0.24	0.17	0.04	1.9	1.51
OCT	0.03	0.003	0.29	0.026	0.31	0.51	1.25	0.20	0.14	3.9	1.48
NOV	0.03	0.004	0.18	0.013	0.16	0.20	0.85	0.08	0.07	1.8	1.40
DEC	0.17	0.019	0.12	0.012	0.24	0.61	0.45	0.12	0.06	2.1	1.52
2013	0.10	0.012	0.16	0.012	0.25	0.46	0.62	0.12	0.07	2.3	1.47

Table A.1.29: Annual mean concentration of heavy metals in air and aerosols at Norwegian background sites. Unit: ng/m³.

Site	Year	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg (g)	Hg (part)	RGM Apr.-May
Lista	1991	0.77	0.063	1.86		0.80	2.69		0.59		4.4			
	1992	0.19	0.046	1.79		0.47	2.35		1.33		3.9	2.06		
	1993	0.41	0.066	3.67		0.85	3.67		0.81		7.0	1.84		
	1994	0.36	0.067	2.80		0.90	3.67		0.88		4.5	1.84		
finfraksjon	1995	0.34	0.06	0.28		0.41	2.74		0.56	1.10	4.2	1.63		
$PM_{(2.5)}$	1996	0.35	0.068	0.32		0.42	2.95		0.58	1.51	4.3	1.62		
	1997	0.24	0.063	0.57	0.02	0.50	2.55		0.68	1.29	5.0	1.40		
	1998	0.21	0.045	0.61	0.01	0.39	1.94		0.21	0.98	3.9	1.40		
	1999	0.19	0.05	0.18	0.02	0.27	1.82		0.30	0.66	3.9	1.86		
	2000	0.22	0.052	0.82	0.02	0.29	1.92		0.65	1.04	4.3	1.67		
	2001	0.49	0.055	0.37	0.02	0.32	1.98		0.62	6.40	5.4	1.65		
	2002	0.24	0.053	0.30	0.02	0.49	2.43		0.53	1.15	4.2	1.64		
	2003	0.40	0.073	0.28	0.02	0.48	2.47		0.94	1.98	7.5	1.77		
grovfraksjon	1995	0.13	0.018	1.54		0.64	1.02		0.25	0.38	1.9			
(PM_{10}-$PM_{2.5}$)	1996	0.10	0.015	0.77		0.46	0.79		0.26	0.33	1.5			
	1997	0.08	0.016	0.50	0.03	0.73	0.72		0.23	0.36	2.2			
	1998	0.06	0.148	0.93	0.02	0.40	0.62		0.41	0.25	3.1			
	1999	0.08	0.012	1.36	0.04	0.47	0.52		0.27	0.38				
	2000	0.07	0.014	0.69	0.01	0.37	0.52		0.10	0.35	1.8			
	2001	0.17	0.011	0.64	0.01	0.32	0.44		0.13	1.69	1.6			
	2002	0.06	0.009	0.74	0.01	0.44	0.56		0.11	0.33	1.6			
	2003	0.10	0.009	0.47	0.02	0.37	0.47		0.18	0.58	1.9			
Birkenes	2004	0.20	0.044	<DL		0.83	1.61		0.57	0.70	3.9	1.70		
	2005	0.52	0.088	1.07	0.08	3.45	1.99		2.18	1.44	15.1	1.90		
	2006	0.31	0.063	1.16	0.05	1.56	2.01		0.75	1.20	5.8	1.76		
	2007	0.21	0.047	0.52	0.029	0.82	1.29		0.61	0.81	4.3	1.83		
	2008	0.20	0.035	-	0.030	0.83	1.04		0.55	0.66	3.6	1.73		
	2009	0.21	0.037	1.45	0.028	0.71	1.07		0.66	0.82	5.4	1.69		
Birkenes II	2010	0.18	0.040	0.39	0.033	0.82	1.88		0.50	0.61	4.1	*(1.66)*		
	2011	0.33	0.050	0.71	0.039	0.93	1.70		0.61	0.61	6.1	1.65		
	2012	0.15	0.028	0.55	0.019	0.52	0.80		0.29	0.35	3.1	1.62		
	2013	0.15	0.027	0.33	0.026	0.52	0.73		0.38	0.39	3.9	1.56		
Andøya	2010	0.07	0.017	0.44	0.011	0.53	0.58	0.38	0.32	0.25	1.3	1.67		
	2011	0.06	0.010	0.17	0.008	0.27	0.30	0.37	0.12	0.19	0.9	1.61		
	2012	0.06	0.011	0.24	0.013	0.49	0.34	0.58	0.17	0.15	1.5	1.61		
	2013	0.04	0.008	0.11	0.011	0.24	0.24	0.41	0.14	0.12	1.4	1.54		
Zeppelin	1994	0.23	0.034	0.20	0.01	0.32	0.83	0.37	0.19	0.17	1.9	1.79		
	1995	0.14	0.019	0.22	0.01	0.31	0.64	0.42	0.15	0.19	1.5	1.62		
	1996	0.05	0.01	0.23	0.02	0.28	0.48	0.57	0.14	0.12	1.5	1.59		
	1997	0.13	0.024		0.02	0.40	0.69	0.34	0.13	0.20	1.5	1.18		
	1998	0.12	0.027	0.16	0.14	0.35	0.71	0.34	0.12	0.11	1.4	1.55		
	1999	0.10	0.022	0.14	0.06	0.33	0.49	0.47	0.14	0.17	1.6	1.76		
	2000	0.30	0.018	0.06	0.01	0.41	0.62	0.34	0.09	0.07	1.5	1.50		
	2001	0.40	0.016	0.04	0.01	0.31	0.50	0.24	0.08	0.12	1.3	1.56	1.62	
	2002	0.39	0.027	0.04	0.01	0.25	0.66	0.26	0.07	0.08	1.2	1.60	5.31	5.99
	2003	0.12	0.021	0.09	0.01	0.23	0.69	0.34	0.10	0.14	1.3	1.61	2.20	14.47
	2004	0.07	0.018	0.11	0.04	0.31	0.63	0.40	0.10	0.08	4.1	1.50		42.39
	2005	0.11	0.118	0.13	0.03	0.92	1.04	0.40	0.13	0.13	3.2	1.58		
	2006	0.05	0.016	0.08	0.01	0.30	0.44	0.34	0.05	0.10	1.6	1.60		
	2007	0.05	0.023	0.08	0.01	0.61	0.60	0.20	0.09	0.06	1.4	1.68		
	2008	0.05	0.012	0.07	0.007	0.37	0.37	0.23	0.08	0.08	1.6	1.58		
	2009	0.06	0.017	0.14	0.013	0.30	0.43	0.43	0.13	0.13	1.5	1.55		
	2010	0.05	0.014	0.10	0.013	0.17	0.38	0.45	0.14	0.10	1.0	1.56		
	2011	0.07	0.015	0.11	0.010	0.16	0.38	0.45	0.09	0.08	1.0	1.52		
	2012	0.04	0.008	0.09	0.008	0.13	0.22	0.35	0.07	0.05	1.2	1.51		
	2013	0.10	0.012	0.16	0.012	0.25	0.46	0.62	0.12	0.07	2.3	1.47		

Annex 2

Monthly and annual concentrations of persistent organic pollutants in air and precipitation

Table A.2.1: Monthly mean concentrations (pg/m³) for organochlorine pesticides (OCPs) in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HCB	76.75	62.03	72.85	55.45	39.48	39.63	29.40	28.68	41.13	60.02	55.26	63.22
α-HCH	3.04	2.83	3.37	4.38	7.98	<LOD	8.82	6.18	6.27	5.65	4.09	3.14
γ-HCH	0.91	0.97	0.80	1.40	4.65	<LOD	4.89	6.17	3.61	3.39	1.74	1.66
cis-CD	0.32	0.23	0.27	0.39	0.58	0.37	0.68	0.64	0.44	0.45	0.45	0.41
cis-NO	0.02	0.01	0.01	0.03	0.05	0.00	0.08	0.07	0.05	0.04	0.03	0.03
trans-CD	0.18	0.15	0.15	0.19	0.25	0.15	0.23	0.19	0.14	0.18	0.26	0.26
trans-NO	0.27	0.21	0.24	0.37	0.57	0.52	0.55	0.53	0.38	0.43	0.40	0.41
pp-DDT	0.10	0.12	0.06	0.12	0.39	<LOD	0.62	0.44	1.00	0.43	0.12	0.11
op-DDT	0.10	0.13	0.08	0.21	0.46	0.15	0.35	0.34	1.26	0.38	0.17	0.18
pp-DDE	0.66	0.73	0.37	0.72	1.21	<LOD	0.70	1.14	3.13	2.30	0.58	1.05
op-DDE	0.07	0.08	0.06	0.08	0.10	<LOD	0.12	0.06	0.13	0.11	0.05	0.09
pp-DDD	0.01	0.02	0.03	0.11	0.11	0.06	0.16	0.05	0.03	0.08	0.03	0.02
op-DDD	0.02	0.02	0.02	0.01	0.04	<LOD	0.21	0.04	0.05	0.06	0.02	0.03

Table A.2.2: Monthly mean concentrations (pg/m³) for PCBs in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PCB-18	0.67	1.05	1.02	1.11	1.95	1.12	0.58	0.94	0.91	0.90	0.71	0.69
PCB-28	0.66	0.78	0.59	0.91	1.82	0.87	0.59	0.84	0.88	0.75	0.54	0.50
PCB-31	0.60	0.71	0.56	0.82	1.56	0.80	0.54	0.78	0.76	0.66	0.49	0.45
PCB-33	0.38	0.46	0.35	0.52	0.93	0.44	0.29	0.46	0.49	0.40	0.31	0.26
PCB-37	0.07	0.08	0.05	0.08	0.16	0.07	0.06	0.09	0.07	0.07	0.05	0.04
PCB-47	0.67	0.34	0.44	0.82	1.94	1.80	2.82	2.08	1.21	2.98	3.70	0.61
PCB-52	0.68	0.46	0.54	0.79	1.55	1.02	0.86	1.12	0.91	0.68	0.48	0.54
PCB-66	0.21	0.09	0.12	0.23	0.51	0.24	0.21	0.29	0.26	0.17	0.12	0.13
PCB-74	0.13	0.06	0.08	0.15	0.32	0.15	0.13	0.17	0.16	0.11	0.07	0.08
PCB-99	0.11	0.10	0.11	0.18	0.33	0.19	0.18	0.23	0.18	0.14	0.09	0.12
PCB-101	0.28	0.26	0.26	0.41	0.87	0.63	0.59	0.80	0.56	0.42	0.27	0.29
PCB-105	0.02	0.02	0.02	0.03	0.07	0.03	0.04	0.05	0.03	0.02	0.01	0.02
PCB-114	0.003	0.003	0.002	0.004	0.007	0.005	0.006	0.004	0.006	0.003	0.003	0.003
PCB-118	0.07	0.07	0.06	0.11	0.25	0.14	0.15	0.19	0.13	0.09	0.06	0.07
PCB-122	0.003	0.002	0.002	0.002	0.003	0.002	0.003	0.002	0.003	0.002	0.003	0.002
PCB-123	0.003	0.003	0.003	0.003	0.004	0.003	0.005	0.003	0.003	0.003	0.003	0.003
PCB-128	0.012	0.012	0.011	0.015	0.037	0.025	0.031	0.038	0.028	0.018	0.007	0.011
PCB-138	0.08	0.07	0.08	0.12	0.29	0.20	0.23	0.30	0.21	0.14	0.07	0.09
PCB-141	0.02	0.02	0.02	0.03	0.08	0.06	0.07	0.09	0.06	0.04	0.02	0.02
PCB-149	0.15	0.14	0.14	0.22	0.54	0.46	0.45	0.59	0.35	0.25	0.16	0.16
PCB-153	0.15	0.13	0.13	0.20	0.47	0.35	0.37	0.49	0.31	0.23	0.13	0.15
PCB-156	0.006	0.005	0.005	0.006	0.013	0.008	0.012	0.014	0.008	0.007	0.003	0.004
PCB-157	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.001
PCB-167	0.003	0.003	0.003	0.004	0.008	0.006	0.007	0.009	0.005	0.004	0.002	0.003
PCB-170	0.015	0.009	0.012	0.009	0.026	0.022	0.028	0.033	0.023	0.019	0.006	0.008
PCB-180	0.04	0.03	0.03	0.04	0.09	0.07	0.08	0.10	0.08	0.06	0.02	0.03
PCB-183	0.012	0.010	0.010	0.013	0.035	0.027	0.032	0.042	0.028	0.017	0.008	0.009
PCB-187	0.03	0.03	0.03	0.04	0.10	0.09	0.09	0.12	0.09	0.06	0.03	0.04
PCB-189	0.002	0.002	0.001	0.001	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.001
PCB-194	0.005	0.006	0.004	0.003	0.004	0.004	0.006	0.007	0.004	0.006	0.003	0.003
PCB-206	0.002	0.005	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.004	0.002	0.002
PCB-209	0.009	0.006	0.006	0.006	0.007	0.006	0.007	0.007	0.006	0.006	0.006	0.006
sum Trichlor	3.31	4.31	3.56	4.97	9.32	4.62	2.84	4.34	4.29	4.03	3.01	2.79
sum-tetrachlor	2.14	1.18	1.41	2.27	4.90	3.96	4.67	4.44	3.21	4.86	5.18	1.81
sum-pentachlor	0.48	0.45	0.45	0.75	1.53	1.01	0.97	1.27	0.92	0.68	0.43	0.49
sum-hexachlor	0.43	0.38	0.40	0.59	1.43	1.11	1.17	1.54	0.98	0.69	0.39	0.44
sum-heptachlor	0.10	0.08	0.09	0.10	0.25	0.20	0.23	0.30	0.22	0.15	0.07	0.08
Sum PCB7	1.95	1.79	1.69	2.58	5.34	3.27	2.87	3.85	3.10	2.37	1.57	1.65
sum PCB	6.86	5.11	5.91	8.68	17.46	10.91	9.90	11.92	9.63	10.41	9.08	5.62

Table A.2.3: Monthly mean concentrations (pg/m³) for PBDE and TBA in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BDE-28	0.010	0.006	0.007	0.009	0.014	0.010	0.008	0.017	0.006	0.006	0.006	0.024
BDE-47	0.06	0.05	0.05	0.06	0.09	0.09	0.07	0.50	0.05	0.05	0.05	0.17
BDE-49	0.005	0.005	0.007	0.007	0.012	0.034	0.008	0.013	0.005	0.006	0.006	0.016
BDE-66	0.005	0.005	0.005	0.006	0.007	0.080	0.006	0.008	0.026	0.005	0.005	0.012
BDE-71	0.003	0.003	0.003	0.004	0.004	0.056	0.003	0.003	0.024	0.003	0.003	0.004
BDE-77	0.002	0.001	0.002	0.003	0.003	0.052	0.001	0.001	0.001	0.001	0.001	0.002
BDE-85	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.006
BDE-99	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.09	0.04	0.04	0.04	0.07
BDE-100	0.008	0.008	0.008	0.008	0.011	0.008	0.009	0.025	0.007	0.007	0.007	0.012
BDE-119	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003
BDE-138	0.010	0.010	0.008	0.016	0.013	0.008	0.006	0.006	0.006	0.006	0.006	0.012
BDE-153	0.011	0.011	0.010	0.011	0.013	0.011	0.011	0.011	0.011	0.012	0.012	0.027
BDE-154	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.023
BDE-183	0.016	0.013	0.015	0.016	0.020	0.015	0.015	0.013	0.013	0.024	0.028	0.093
BDE-196	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.15
BDE-206	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.09	0.23
BDE-209	*0.59*	*0.59*	*0.59*	*0.60*	*0.61*	*0.61*	*0.61*	*0.71*	*0.61*	*0.60*	*0.60*	*1.48*
Sum PBDE	0.92	0.90	0.91	0.94	1.01	1.18	0.96	1.57	0.96	0.93	0.94	2.33
TBA	4.76	5.06	3.52	3.92	3.70	4.71	3.07	3.89	5.39	8.21	6.73	6.60

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.4: Monthly mean concentrations (pg/m³) for HBCD in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
α-HBCD	*0.04*	*0.05*	*0.02*	*0.04*	*0.08*	*0.03*	*0.03*	*0.02*	*0.03*	*0.06*	*0.02*	*0.84*
ß-HBCD	*0.06*	*0.08*	*0.09*	*0.09*	*0.12*	*0.06*	*0.09*	*0.05*	*0.03*	*0.09*	*0.09*	*0.09*
γ-HBCD	*0.03*	*0.02*	*0.02*	*0.04*	*0.07*	*0.03*	*0.01*	*0.01*	*0.01*	*0.07*	*0.02*	*0.36*
sum_HBCD	*0.13*	*0.15*	*0.12*	*0.17*	*0.26*	*0.12*	*0.13*	*0.07*	*0.07*	*0.22*	*0.12*	*1.29*

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.5: Monthly mean concentrations (ng/m^3) for PAH in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Naphthalene	0.75	0.62	0.29	0.12	0.11	0.12	0.11	0.11	0.11	0.11	0.12	0.29
2-Methylnaphthalene	0.32	0.21	0.17	0.11	0.08	0.14	0.08	0.08	0.08	0.09	0.09	0.19
1-Methylnaphthalene	0.22	0.14	0.10	0.07	0.05	0.09	0.05	0.05	0.05	0.06	0.06	0.13
Biphenyl	1.10	1.01	0.55	0.20	0.10	0.09	0.05	0.04	0.07	0.12	0.14	0.28
Acenaphthylene	0.08	0.09	0.05	0.02	0.05	0.01	0.01	0.01	0.06	0.02	0.01	0.05
Acenaphthene	0.14	0.10	0.10	0.11	0.09	0.60	0.06	0.05	0.06	0.08	0.06	0.46
Dibenzofuran	3.23	2.87	1.59	0.67	0.76	0.50	0.25	0.22	0.32	0.51	0.43	0.96
Fluorene	1.94	1.20	0.69	0.33	0.50	0.52	0.22	0.21	0.28	0.45	0.29	0.84
Dibenzothiophene	0.05	0.01	0.03	0.04	0.09	0.07	0.04	0.02	0.04	0.04	0.02	0.04
Phenanthrene	1.58	1.32	0.79	0.57	1.22	0.71	0.44	0.64	0.75	1.06	0.58	1.29
Anthracene	0.022	0.034	<0.01	<0.01	0.060	<0.01	<0.01	0.010	0.016	<0.01	0.011	0.015
3-Methylphenanthrene	0.11	0.06	0.04	0.04	0.08	0.04	0.03	0.03	0.05	0.07	0.04	0.08
2-Methylphenanthrene	0.15	0.08	0.05	0.05	0.11	0.05	0.03	0.04	0.06	0.08	0.05	0.10
2-Methylanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9-Methylphenanthrene	0.05	0.03	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0.03	0.02	0.03
1-Methylphenanthrene	0.08	0.07	0.04	0.03	0.09	0.02	0.02	0.03	0.03	0.05	0.04	0.06
Fluoranthene	0.51	0.29	0.25	0.12	0.22	0.08	0.06	0.08	0.09	0.16	0.09	0.25
Pyrene	0.29	0.15	0.14	0.06	0.14	0.04	0.03	0.03	0.05	0.08	0.05	0.13
Benzo(a)fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Retene	0.12	0.06	0.07	0.04	0.17	0.01	0.02	0.02	0.02	0.04	0.04	0.04
Benzo(b)fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Benzo(ghi)fluoranthene	0.10	0.05	0.05	0.01	0.03	0.02	<0.01	0.01	0.01	0.02	0.01	0.07
Cyclopenta(cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benz(a)anthracene	0.08	0.03	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.03	0.02	0.04	0.04	0.02	0.15
Triphenylene	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	0.01	0.01	<0.01	0.04
Chrysene/Triphenylene	0.26	0.07	0.08	0.04	0.12	0.08	0.02	0.03	0.05	0.05	0.02	0.19
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.03	0.02	0.02	0.03	0.01	0.14
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	0.04
Benzo(b/j/k)fluoranthenes	0.29	0.05	0.12	0.03	0.08	0.07	0.02	0.03	0.04	0.05	0.02	0.22
Benzo(a)fluoranthene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(e)pyrene	0.14	0.02	0.05	0.02	0.06	0.04	0.01	0.01	0.02	0.02	<0.01	0.09
Benzo(a)pyrene	0.05	0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
Perylene	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Inden(123-cd)pyrene	0.11	0.06	0.06	0.01	0.02	0.02	<0.01	<0.01	0.01	0.02	<0.01	0.06
Dibenzo(ac/ah)anthracenes	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Benzo(ghi)perylene	0.06	0.04	0.04	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Anthanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Coronene	0.04	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Dibenzo(ae)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Dibenzo(ai)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Sum PAH16	5.60	3.92	2.45	1.37	2.44	2.32	1.01	1.20	1.50	2.08	1.27	3.78
Sum PAH	11.91	8.70	5.46	2.76	4.32	3.39	1.60	1.81	2.33	3.27	2.26	6.00

Table A.2.6: Monthly mean concentrations (pg/m³) for PFAS in air at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FTS_6-2	*0.22*	*0.20*	*0.28*	*0.32*	*0.36*	*0.26*	*0.33*	*0.50*	*0.32*	*0.53*	*0.29*	*0.25*
PFBS	*missing*	*0.03*	*0.11*	*0.06*	*0.09*	*0.08*	*0.08*	*0.12*	*0.08*	*0.07*	*0.06*	*0.06*
PFDcA	*0.40*	*0.09*	*0.19*	*0.43*	*1.09*	*0.06*	*0.12*	*0.15*	*0.08*	*0.17*	*0.06*	*0.06*
PFDcS	*0.11*	*0.06*	*0.16*	*0.04*	*0.04*	*0.04*	*0.05*	*0.07*	*0.04*	*0.05*	*0.04*	*0.03*
PFHpA	missing	0.06	0.26	0.69	6.38	0.22	0.22	0.20	0.16	0.46	0.09	0.07
PFHxA	missing	0.07	0.22	0.31	2.47	0.24	0.26	0.25	0.18	0.31	0.09	0.07
PFHxS	*missing*	*0.02*	*0.11*	*0.25*	*0.05*	*0.04*	*0.12*	*0.07*	*0.04*	*0.31*	*0.04*	*0.04*
PFNA	0.14	0.09	0.19	0.43	3.79	0.14	0.23	0.21	0.17	0.72	0.06	0.11
PFOA	missing	0.12	0.17	1.51	16.39	0.48	0.51	0.55	0.58	2.72	0.24	0.33
PFOS	0.13	0.06	0.22	0.23	0.17	0.12	0.22	0.19	0.15	2.51	0.07	0.14
PFOSA	0.11	0.06	0.15	0.24	0.51	0.27	0.45	0.38	0.25	0.25	0.15	0.18
PFUnA	*0.13*	*0.07*	*0.21*	*0.49*	*2.20*	*0.09*	*0.09*	*0.27*	*0.08*	*0.14*	*0.05*	*0.04*

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.7: Monthly mean concentrations (ng/l) for HCB, α-HCH, γ-HCH and PCBs in precipitation at Birkenes, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HCB	0.14	0.15	0.11	0.10	0.10	0.13	0.16	0.06	0.03	0.04	0.07	0.04
α-HCH	0.05	0.06	0.04	0.13	0.18	0.14	0.13	0.06	0.13	0.12	0.12	0.10
γ-HCH	0.08	0.08	0.06	0.55	0.45	0.48	0.32	0.17	0.20	0.30	0.15	0.20
PCB-28	0.007	0.010	0.011	0.008	0.007	0.008	0.010	0.005	0.004	0.004	0.005	0.003
PCB-52	0.007	0.009	0.010	0.006	0.007	0.010	0.016	0.007	0.013	0.008	0.021	0.004
PCB-99	0.003	0.004	0.003	0.004	0.003	0.009	0.016	0.009	0.009	0.005	0.002	0.002
PCB-101	0.008	0.013	0.008	0.007	0.010	0.056	0.103	0.059	0.100	0.092	0.010	0.005
PCB-118	0.009	0.015	0.005	0.009	0.008	0.051	0.096	0.055	0.094	0.046	0.004	0.003
PCB-138	0.010	0.018	0.003	0.010	0.006	0.112	0.215	0.114	0.217	0.112	0.009	0.007
PCB-153	0.011	0.018	0.004	0.011	0.009	0.111	0.221	0.126	0.196	0.096	0.020	0.008
PCB-180	0.005	0.012	0.003	0.009	0.003	0.036	0.065	0.036	0.066	0.034	0.009	0.005
sum PCB-7	0.060	0.099	0.047	0.064	0.053	0.393	0.742	0.411	0.699	0.397	0.080	0.037

Table A.2.8: Monthly mean concentrations (pg/m³) for organochlorine pesticides (OCPs) in air at Andøya, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HCB	25.93	31.70	37.83	33.00	20.07	14.10	19.06	13.70	19.98	36.95	42.27	42.36
α-HCH	3.04	3.21	3.61	4.02	3.41	3.79	4.03	3.82	6.07	5.83	4.31	3.31
γ-HCH	0.42	0.91	0.54	0.76	0.92	1.31	1.14	2.09	1.39	1.07	0.59	0.42
pp-DDT	0.05	0.12	0.03	0.04	0.06	0.07	0.03	0.07	0.11	0.09	0.08	0.06
op-DDT	0.12	0.20	0.11	0.12	0.11	0.14	0.07	0.14	0.24	0.16	0.15	0.14
pp-DDE	0.60	1.15	0.35	0.31	0.20	0.17	0.12	0.15	0.45	0.37	0.41	0.48
op-DDE	0.10	0.14	0.08	0.06	0.04	0.03	0.02	0.02	0.05	0.04	0.05	0.07
pp-DDD	0.01	0.01	0.01	0.05	0.06	0.06	0.01	0.01	0.02	0.06	0.01	0.01
op-DDD	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02

Table A.2.9: Monthly mean concentrations (pg/m³) for PCBs in air at Andøya, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PCB-18	0.78	1.15	0.75	0.87	0.60	0.41	0.27	0.30	0.80	0.68	0.64	0.90
PCB-28	0.56	0.95	0.59	0.63	0.53	0.35	0.23	0.28	0.58	0.39	0.36	0.52
PCB-31	0.52	0.89	0.57	0.58	0.49	0.33	0.22	0.27	0.51	0.35	0.33	0.47
PCB-33	0.30	0.55	0.35	0.34	0.27	0.17	0.12	0.15	0.31	0.21	0.20	0.30
PCB-37	0.05	0.10	0.05	0.04	0.04	0.03	0.02	0.02	0.04	0.02	0.03	0.04
PCB-47	0.50	0.60	0.69	0.54	1.61	0.91	1.11	1.03	0.68	0.41	0.41	0.47
PCB-52	0.55	0.80	0.53	0.59	0.56	0.41	0.31	0.40	0.51	0.40	0.36	0.46
PCB-66	0.14	0.23	0.13	0.16	0.15	0.09	0.07	0.09	0.14	0.09	0.08	0.12
PCB-74	0.10	0.16	0.09	0.11	0.10	0.06	0.04	0.06	0.09	0.06	0.05	0.08
PCB-99	0.12	0.21	0.12	0.13	0.12	0.08	0.06	0.08	0.12	0.09	0.07	0.10
PCB-101	0.26	0.40	0.24	0.29	0.30	0.24	0.17	0.26	0.27	0.21	0.17	0.21
PCB-105	0.02	0.03	0.02	0.03	0.02	0.01	0.01	0.02	0.03	0.02	0.01	0.02
PCB-114	0.002	0.004	0.002	0.003	0.003	0.001	0.002	0.002	0.003	0.002	0.002	0.002
PCB-118	0.08	0.12	0.07	0.09	0.08	0.06	0.04	0.06	0.09	0.06	0.05	0.06
PCB-122	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.002	0.002	0.002
PCB-123	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.005	0.004	0.002	0.002
PCB-128	0.011	0.017	0.009	0.013	0.012	0.010	0.007	0.009	0.012	0.006	0.006	0.005
PCB-138	0.08	0.12	0.07	0.09	0.09	0.07	0.06	0.09	0.09	0.07	0.05	0.06
PCB-141	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01
PCB-149	0.14	0.21	0.12	0.15	0.17	0.15	0.12	0.21	0.15	0.12	0.09	0.10
PCB-153	0.13	0.19	0.11	0.14	0.14	0.12	0.09	0.16	0.13	0.10	0.08	0.09
PCB-156	0.004	0.005	0.003	0.004	0.004	0.004	0.003	0.004	0.003	0.001	0.001	0.001
PCB-157	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
PCB-167	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.001
PCB-170	0.006	0.008	0.006	0.007	0.007	0.006	0.008	0.009	0.004	0.004	0.012	0.003
PCB-180	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02
PCB-183	0.008	0.012	0.007	0.009	0.010	0.009	0.008	0.014	0.006	0.006	0.009	0.004
PCB-187	0.03	0.05	0.02	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.02
PCB-189	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
PCB-194	0.002	0.002	0.003	0.005	0.003	0.001	0.002	0.002	0.002	0.001	0.001	0.001
PCB-206	0.002	0.002	0.002	0.003	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002
PCB-209	0.004	0.003	0.007	0.005	0.004	0.002	0.003	0.003	0.002	0.002	0.002	0.002
sum-trichlor	3.17	5.22	3.30	3.52	2.77	1.78	1.13	1.33	2.91	2.15	2.03	2.92
sum-tetrachlor	1.47	2.04	1.62	1.60	2.68	1.76	1.72	1.72	1.42	0.96	0.90	1.12
sum-pentachlor	0.49	0.76	0.45	0.54	0.52	0.40	0.28	0.42	0.51	0.37	0.30	0.39
sum-hexachlor	0.37	0.57	0.33	0.41	0.43	0.38	0.32	0.50	0.40	0.31	0.25	0.26
sum-heptachlor	0.06	0.10	0.06	0.07	0.07	0.06	0.06	0.10	0.05	0.05	0.07	0.04
Sum PCB7	1.67	2.61	1.62	1.84	1.72	1.28	0.91	1.27	1.68	1.23	1.09	1.41
Sum PCB	5.56	8.69	5.76	6.15	6.49	4.38	3.68	4.06	5.29	3.84	3.55	4.73

Table A.2.10: Monthly mean concentrations (pg/m^3) for BDE and TBA in air at Andøya, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BDE-28	0.008	0.008	0.007	0.006	0.010	0.011	0.006	0.005	0.008	0.004	0.006	0.006
BDE-47	0.05	0.04	0.03	0.04	0.14	0.20	0.07	0.05	0.25	0.06	0.04	0.03
BDE-49	0.006	0.005	0.004	0.004	0.006	0.011	0.004	0.004	0.008	0.003	0.003	0.003
BDE-66	0.004	0.005	0.003	0.003	0.005	0.007	0.004	0.003	<LOD	0.004	<LOD	0.003
BDE-71	0.003	0.003	0.002	0.011	0.003	0.004	0.003	0.002	0.002	0.003	0.002	0.003
BDE-77	0.001	0.002	0.001	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001
BDE-85	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.004	0.004	0.004
BDE-99	0.03	0.03	0.02	0.03	0.09	0.12	0.03	0.03	0.05	0.03	0.03	0.03
BDE-100	0.006	0.005	0.005	0.005	0.013	0.018	0.007	0.006	0.011	0.007	0.005	0.005
BDE-119	0.001	0.002	0.001	0.001	0.003	0.003	0.001	0.001	0.001	0.002	0.001	0.002
BDE-138	0.009	0.011	0.006	0.004	0.011	0.007	0.005	0.004	0.004	0.005	0.004	0.007
BDE-153	0.008	0.008	0.007	0.008	0.008	0.011	0.009	0.008	0.008	0.008	0.008	0.008
BDE-154	0.007	0.007	0.007	0.007	0.007	0.009	0.008	0.007	0.007	0.007	0.007	0.007
BDE-183	0.009	0.012	0.009	0.009	0.010	0.010	0.011	0.009	0.009	0.009	0.009	0.009
BDE-196	0.04	0.04	0.04	0.04	0.04	0.07	0.05	0.04	0.04	0.04	0.04	0.05
BDE-206	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.15	0.07	0.07	0.07
BDE-209	*0.42*	*0.42*	*0.77*	*0.43*	*0.46*	*0.49*	*0.50*	*0.43*	*0.43*	*0.43*	*0.72*	*0.49*
sum PBDE	0.67	0.67	1.00	0.66	0.88	1.04	0.79	0.67	0.99	0.68	0.95	0.72
TBA	3.78	4.67	3.21	3.10	4.70	4.49	19.37	4.42	4.92	6.45	5.90	4.13

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.11: Monthly mean concentrations (pg/m^3) for PFAS in air at Andøya, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FTS_6-2	*0.07*	*0.05*	*0.11*	*0.21*	*0.14*	*0.13*	*0.16*	*0.09*	*0.10*	*0.12*	*0.17*	*0.17*
PFBS	*0.02*	*0.02*	*missing*	*0.05*	*0.07*	*0.04*	*0.04*	*0.02*	*0.02*	*0.03*	*0.05*	*0.05*
PFDcA	0.10	0.06	0.13	0.18	0.16	0.14	0.20	0.05	0.10	0.15	3.03	0.22
PFDcS	0.03	0.03	0.05	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03
PFHpA	*missing*	*0.04*	*missing*	*0.17*	*0.14*	*0.09*	*0.14*	*0.09*	*0.05*	*0.13*	*0.15*	*0.10*
PFHxA	0.05	0.03	0.05	0.14	0.22	0.14	0.30	0.09	0.09	0.05	0.07	0.07
PFHxS	*0.02*	*0.02*	*missing*	*0.04*	*0.03*	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*	*0.04*	*0.03*
PFNA	0.06	0.07	0.07	0.19	0.29	0.27	0.33	0.12	0.10	0.11	0.08	0.16
PFOA	0.12	0.11	0.15	0.33	0.61	0.23	0.69	0.14	0.07	0.21	0.12	0.14
PFOS	0.09	0.06	0.12	0.06	0.08	0.09	0.09	0.03	0.06	0.11	0.07	0.08
PFOSA	*0.04*	*0.03*	*0.04*	*0.19*	*0.08*	*0.04*	*0.06*	*0.03*	*0.04*	*0.04*	*0.06*	*0.05*
PFUnA	*0.05*	*0.03*	*0.07*	*0.23*	*0.07*	*0.03*	*0.19*	*0.02*	*0.03*	*0.04*	*0.05*	*0.04*

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.12: Monthly mean concentrations (pg/m^3) for organochlorine pesticides (OCPs) in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HCB	74.75	74.77	78.30	84.30	81.35	87.90	86.65	80.98	75.17	72.30	81.24	81.24
α-HCH	4.09	3.72	4.80	5.12	4.26	4.66	6.65	6.65	6.32	6.92	5.90	4.56
γ-HCH	0.74	0.68	0.67	0.70	0.60	0.61	1.04	1.21	0.81	0.77	0.82	0.68
cis-CD	0.40	0.37	0.32	0.34	0.41	0.36	0.41	0.44	0.38	0.46	0.38	0.47
cis-NO	0.02	0.02	0.01	0.02	0.05	0.05	0.06	0.07	0.05	0.04	0.02	0.02
trans-CD	0.22	0.22	0.17	0.15	0.12	0.09	0.08	0.08	0.07	0.11	0.15	0.24
trans-NO	0.34	0.38	0.26	0.31	0.39	0.30	0.32	0.36	0.30	0.36	0.28	0.39
pp-DDT	0.08	0.09	0.04	0.04	0.02	0.02	0.02	0.05	0.04	0.05	0.05	0.09
op-DDT	0.16	0.17	0.10	0.11	0.04	0.02	0.08	0.06	0.14	0.09	0.11	0.18
pp-DDE	0.78	0.72	0.25	0.12	0.07	0.07	0.07	0.12	0.15	0.17	0.38	0.73
op-DDE	0.11	0.10	0.07	0.04	0.01	0.02	0.02	0.02	0.02	0.03	0.04	0.10
pp-DDD	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
op-DDD	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02

Table A.2.13: Monthly mean concentrations (pg/m^3) for PCBs in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PCB-18	1.05	2.12	1.64	1.21	1.40	1.43	1.75	2.90	2.39	1.22	1.76	1.91
PCB-28	1.14	1.61	1.51	0.95	1.14	1.09	1.38	2.14	1.66	1.14	1.30	1.32
PCB-31	1.05	1.51	1.35	0.92	1.04	1.02	1.28	2.01	1.59	0.98	1.17	1.19
PCB-33	0.80	1.11	1.28	0.67	0.88	0.76	1.00	1.54	1.27	0.92	0.98	0.92
PCB-37	0.14	0.16	0.30	0.10	0.17	0.11	0.16	0.21	0.15	0.18	0.18	0.15
PCB-47	0.32	0.40	0.56	0.29	0.31	0.20	0.25	0.36	0.29	0.36	0.39	0.36
PCB-52	0.71	0.88	0.80	0.60	0.58	0.51	0.59	0.82	0.68	0.61	0.70	0.75
PCB-66	0.27	0.25	0.28	0.15	0.16	0.11	0.15	0.18	0.15	0.16	0.20	0.21
PCB-74	0.16	0.16	0.17	0.11	0.10	0.07	0.09	0.11	0.10	0.11	0.12	0.14
PCB-99	0.15	0.16	0.13	0.12	0.07	0.06	0.07	0.10	0.10	0.10	0.11	0.15
PCB-101	0.32	0.36	0.31	0.26	0.23	0.20	0.24	0.31	0.24	0.24	0.25	0.32
PCB-105	0.03	0.04	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.04
PCB-114	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.003	0.003	0.003	0.004	0.003
PCB-118	0.11	0.12	0.08	0.07	0.05	0.05	0.06	0.07	0.08	0.07	0.07	0.12
PCB-122	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.003	0.004	0.004	0.003
PCB-123	0.003	0.004	0.005	0.001	0.002	0.001	0.002	0.002	0.003	0.004	0.004	0.006
PCB-128	0.014	0.018	0.009	0.009	0.006	0.006	0.009	0.011	0.010	0.009	0.003	0.009
PCB-138	0.08	0.10	0.06	0.06	0.05	0.05	0.06	0.07	0.06	0.06	0.05	0.09
PCB-141	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.00	0.01	0.02
PCB-149	0.13	0.17	0.12	0.12	0.12	0.10	0.14	0.16	0.12	0.10	0.10	0.15
PCB-153	0.13	0.16	0.10	0.10	0.09	0.07	0.09	0.12	0.09	0.09	0.08	0.13
PCB-156	0.005	0.006	0.003	0.003	0.002	0.002	0.003	0.003	0.003	0.001	0.002	0.004
PCB-157	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002
PCB-167	0.003	0.004	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.003	0.002	0.002
PCB-170	0.007	0.008	0.003	0.004	0.004	0.004	0.005	0.006	0.003	0.002	0.003	0.006
PCB-180	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02
PCB-183	0.007	0.011	0.007	0.006	0.005	0.005	0.007	0.010	0.005	0.002	0.002	0.005
PCB-187	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.02	0.01	0.03
PCB-189	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.002
PCB-194	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.003
PCB-206	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.002
PCB-209	0.007	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.003
sum-trichlor	5.93	9.11	8.10	5.38	6.35	6.18	7.81	12.15	9.21	5.56	6.89	7.07
sum-tetrachlor	1.92	2.14	2.15	1.47	1.43	1.20	1.45	1.90	1.23	1.24	1.41	1.45
sum-pentachlor	0.62	0.69	0.56	0.47	0.37	0.31	0.40	0.50	0.44	0.44	0.45	0.63
sum-hexachlor	0.38	0.47	0.31	0.30	0.28	0.24	0.32	0.38	0.30	0.26	0.24	0.40
sum-heptachlor	0.06	0.08	0.04	0.04	0.04	0.04	0.05	0.07	0.03	0.03	0.03	0.05
Sum PCB7	2.50	3.25	2.88	2.04	2.16	1.97	2.44	3.55	2.84	2.22	2.47	2.75
Sum PCB	8.91	12.50	11.17	7.67	8.47	7.98	10.04	15.01	11.21	7.54	9.02	9.61

Table A.2.14: Monthly mean concentrations (pg/m^3) for BDE and TBA in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BDE-28	0.008	0.021	0.004	0.006	0.233	0.012	0.007	0.013	0.017	0.057	0.010	0.011
BDE-47	0.09	0.10	0.05	0.07	0.94	0.51	0.22	0.52	0.69	0.57	0.13	0.47
BDE-49	0.005	0.032	0.004	0.005	0.068	0.018	0.006	0.012	0.032	0.084	0.006	0.016
BDE-66	0.005	0.016	0.006	0.005	0.233	0.011	0.095	0.006	0.018	0.038	0.004	0.009
BDE-71	0.004	0.004	0.004	0.003	0.066	0.003	0.089	0.003	0.004	0.009	0.003	0.003
BDE-77	0.003	0.002	0.004	0.002	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001
BDE-85	0.006	0.005	0.013	0.006	0.008	0.005	0.005	0.005	0.005	0.005	0.004	0.005
BDE-99	0.04	0.06	0.04	0.04	0.41	0.04	0.04	0.08	0.10	0.19	0.05	0.04
BDE-100	0.008	0.025	0.008	0.008	0.257	0.018	0.011	0.019	0.029	0.067	0.009	0.010
BDE-119	0.004	0.002	0.008	0.003	0.004	0.001	0.006	0.001	0.002	0.001	0.002	0.001
BDE-138	0.015	0.010	0.025	0.011	0.006	0.006	0.006	0.006	0.006	0.006	0.004	0.006
BDE-153	0.012	0.010	0.017	0.011	0.010	0.010	0.010	0.010	0.011	0.010	0.008	0.010
BDE-154	0.010	0.009	0.010	0.009	0.013	0.009	0.009	0.009	0.009	0.009	0.010	0.009
BDE-183	0.013	0.012	0.016	0.014	0.012	0.012	0.012	0.012	0.013	0.012	0.020	0.012
BDE-196	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05
BDE-206	0.10	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.23	0.09
BDE-209	*0.62*	*0.73*	*0.60*	*0.60*	*1.11*	*0.56*	*0.57*	*0.56*	*0.60*	*0.88*	*0.60*	*0.68*
sum PBDE	1.00	1.19	0.96	0.94	3.52	1.35	1.23	1.40	1.69	2.08	1.13	1.42
TBA	8.35	5.12	3.74	2.01	3.13	2.97	6.26	9.02	6.94	10.65	10.89	6.55

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.15: Monthly mean concentrations (pg/m^3) for HBCD in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
α-HBCD	*0.03*	*0.08*	*0.03*	*0.03*	*0.04*	*0.04*	*0.03*	*0.02*	*0.03*	*0.03*	*0.14*	*0.04*
ß-HBCD	*0.08*	*0.18*	*0.07*	*0.13*	*0.15*	*0.15*	*0.10*	*0.09*	*0.08*	*0.10*	*0.06*	*0.09*
γ-HBCD	*0.01*	*0.05*	*0.01*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.01*	*0.02*	*0.16*	*0.01*
sum_HBCD	*0.13*	*0.31*	*0.10*	*0.17*	*0.20*	*0.21*	*0.15*	*0.13*	*0.12*	*0.15*	*0.36*	*0.14*

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.16: Monthly mean concentrations (ng/m^3) for PAH in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Naphthalene	1.67	1.05	0.40	0.10	0.31	0.25	0.24	0.12	0.17	0.26	1.31	1.90
2-Methylnaphthalene	0.41	0.32	0.08	0.05	0.12	0.05	0.07	0.05	0.06	0.08	0.24	0.35
1-Methylnaphthalene	0.31	0.24	0.06	0.03	0.06	0.03	0.04	0.03	0.03	0.05	0.21	0.29
Biphenyl	1.68	1.33	0.63	0.16	0.04	0.03	0.03	0.03	0.05	0.13	0.73	1.10
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Acenaphthene	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzofuran	1.86	1.66	0.89	0.33	0.08	0.04	0.04	0.06	0.13	0.18	0.69	1.16
Fluorene	0.77	0.67	0.14	0.03	0.02	0.02	0.03	0.03	0.04	0.06	0.29	0.57
Dibenzothiophene	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Phenanthrene	0.20	0.09	0.05	0.02	0.03	0.02	0.04	0.03	0.03	0.02	0.04	0.09
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
3-Methylphenanthrene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
2-Methylphenanthrene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
2-Methylanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9-Methylphenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1-Methylphenanthrene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	0.12	0.03	0.03	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.06
Pyrene	0.07	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
Benzo(a)fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Retene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(b)fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(ghi)fluoranthene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cyclopenta(cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benz(a)anthracene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
Triphenylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene/Triphenylene	0.04	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.03
Benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Benzo(b/j/k)fluoranthenes	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.05
Benzo(a)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(e)pyrene	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Benzo(a)pyrene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Inden(123-cd)pyrene	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Dibenzo(ac/ah)anthracenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(ghi)perylene	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Anthanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Coronene	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ae)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ai)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sum PAH16	2.91	1.90	0.67	0.19	0.40	0.34	0.37	0.22	0.30	0.39	1.71	2.78
Sum PAH	7.37	5.51	2.39	0.79	0.77	0.56	0.65	0.45	0.62	0.87	3.64	5.70

Table A.2.17: Monthly mean concentrations (pg/m^3) for PFAS in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FTS_6-2	*0.08*	*0.07*	*0.06*	*0.14*	*0.16*	*0.16*	*0.13*	*0.38*	*0.14*	*0.10*	*0.12*	*0.12*
PFBS	*0.02*	*missing*	*0.02*	*0.05*	*0.04*	*0.04*	*0.04*	*0.04*	*0.05*	*0.04*	*0.03*	*0.03*
PFDcA	0.09	0.19	0.09	0.13	0.11	0.07	0.10	0.04	0.08	0.03	0.06	0.08
PFDcS	*0.04*	*0.04*	*0.03*	*0.01*	*0.02*	*0.02*	*0.02*	*0.04*	*0.02*	*0.01*	*0.01*	*0.01*
PFHpA	0.04	missing	0.17	0.33	0.24	0.11	0.20	0.11	0.09	0.04	0.05	0.05
PFHxA	0.03	missing	0.05	0.11	0.18	0.12	0.19	0.10	0.11	0.04	0.06	0.05
PFHxS	*0.03*	*missing*	*0.02*	*0.02*	*0.02*	*0.03*	*0.03*	*0.04*	*0.02*	*0.02*	*0.02*	*0.02*
PFNA	0.07	0.06	0.04	0.18	0.15	0.09	0.16	0.09	0.08	0.05	0.06	0.08
PFOA	0.20	0.35	0.27	0.66	0.35	0.25	0.36	0.27	0.29	0.13	0.19	0.25
PFOS	0.03	0.03	0.03	0.08	0.05	0.05	0.06	0.27	0.05	0.03	0.05	0.13
PFOSA	0.04	0.07	0.04	0.17	0.34	0.45	0.46	0.34	0.32	0.08	0.05	0.12
PFUnA	*0.04*	*0.06*	*0.03*	*0.04*	*0.04*	*0.04*	*0.05*	*0.04*	*0.04*	*0.03*	*0.03*	*0.04*

Italic data means that more than 60% of the data is below the detection limit and should be considered as the upper concentrations.

Table A.2.18: Monthly mean concentrations (pg/m^3) for SCCP and MCCP in air at Zeppelin, 2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SCCP	185.8	282.8	596.5	219.0	401.3	221.5	235.2	195.5	475.8	392.8	520.3	518.6
MCCP	2.8	2.8	12.8	8.8	26.0	40.0	41.6	5.3	34.3	42.0	18.2	28.5

Annex 3

Description of methods for sampling, chemical analysis and quality control

Heavy metals

For heavy metals, there are specific requirements for cleanliness for preparation and treatment of the equipment to avoid contamination, i.e. acid-washed equipment is used for sampling and preparations.

Except for mercury, all the trace elements are analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The ion optic is optimized for 115 In. The samples are preserved with 1% HNO_3 and an internal standard is used (indium).

For precipitation, a bulk sampler (funnel+collector), from NILU Innovation is used. Precipitation amount is determined by weighing. The entire sample is sent to NILUs laboratory at Kjeller.

Table A.3.1: Quantification limits for heavy metals in precipitation.

Parameter	Lower quantification limit	
As	0.3	(µg As/l)
Zn	0.4	(µg Zn/l)
Pb	0.2	(µg Pb/l)
Ni	0.07	(µg Ni/l)
Cd	0.03	(µg Cd/l)
Cu	0.3	(µg Cu/l)
Cr	0.3	(µg Cr/l)
Co	0.01	(µg Co/l)
V	0.02	(µg V/l)

Sampling of air for the analysis of heavy metals in the particles at Birkenes occurs by means of a Kleinfiltergerät with a PM_{10}-impactor. Weekly samples on Whatman quartz 47 mm filter are collected. This is the same sampler and filter as is used to collect EC/OC. The airflow is 2.3 m^3/hour. At Andøya and the Zeppelin Observatory, sampling of heavy metals in particles are done using a Digitel high volume sampler without any defined size cut off. The airflow rate is 20 m^3/hour, and Whatman 41 filters are used. The filters are digested with nitric acid by Ultraclave, a microwave based decomposition technique.

Table A.3.2: Quantification limit for heavy metals in aerosols.

	Lower quantification limit (ng/m^3)		
	Birkenes	Andøya	Zeppelin
Pb	0.16	0.01	0.004
Cd	0.003	0.004	0.002
Zn	0.58	0.74	1.81
Cu	0.13	0.04	0.08
Ni	0.18	0.08	0.08
Cr	1.88	0.5	0.23
Co	0.001	0.002	0.001
As	0.01	0.002	0.0007
Mn		0.02	0.12
V	0.01	0.0007	0.004

Mercury

For precipitation sampling of mercury, the IVLs (Swedish Environmental Research Institute AB, Sweden) sampler designed for this element is used. The collector is produced by quartz. The sampler is protected against sunlight, and it is located 2 meters above the ground.

Mercury in precipitation is preserved with HCl. A day before analysis, BrCl is added to oxidise all the mercury in precipitation to Hg^{2+}. During the analysis, all the mercury is reduced to Hg^0 and absorbed on gold trap. Hg is desorbed form the gold traps using heat and detected using atomfluorescens spectrophotometry. The detection limit for the method is 0.2 ng Hg absolute amount.

Total gaseous mercury (TGM) is measured with a Tekran Hg monitor where the mercury collected on gold traps in time intervals of 5 minutes at a sampling rate of 1.5 l / min. Mercury is desorbed from the gold traps using heat and detected using atomfluorescens-spectrophotometry. The detection limit for the method is 0.2 ng Hg absolute amount.

POPs and emerging pollutants

Sampling of OCPs, PCBs, PBDEs, HBCDs, TBA, PAHs, PFAs and S/MCCPs

Air samples were 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 air flow rate of 25 m^3/hour; a glass fiber filter (GFF) that collects the particle-associated compounds; and two pre-cleaned PUF plugs that collect the gas phase compounds. For PFAS, only a GFF was used. Specification on each sampler type is given in Table A.3.3. Flow-rate 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 A.3.3: Specification on air samplers.

	DIGITEL	NILU sampler
Flow rate	~25 m^3/hour	~25 m^3/hour
Filter	GFF: Whatman Type GF/C	GFF: Gelman Type AE
PUF plugs	Diameter 75 mm, length 40 mm, density 25 kg/m^3	Diameter 110 mm, length 50 mm, density 25 kg/m^3
Usage	PBDEs, HBCDs, TBA (Zeppelin) OCPs, PCBs, PBDEs, HBCDs, TBA, PAHs, PFAS (Andøya) OCPs, PCBs, PBDEs, HBCDs, TBA, PAHs (Birkenes)	OCPs, PCBs, PAHs, PFAS, S/MCCPs (Zeppelin) PFAS (Birkenes)

Sampling was done on a weekly basis for each POP class at each observatory. The sampling duration for each sampling station and POP class varied according to Table A.3.4. The variable sampling lengths resulted in actual total air volumes of 600-1950 m^3 (as reported on sampling protocols).

Table A.3.4: Sampling durations for individual POP classes at each sampling station.

	Birkenes	Andøya	Zeppelin
OCPs	24 h	72 h	48 h
PCBs	24 h	72 h	48 h
PAHs	24 h	-	48 h
PBDEs	48 h	72 h	72 h
HBCDs	48h	-	72 h
PFAS	24 h	48 h	48 h
S/MCCPs	24 h	-	-

After sampling, the exposed filters (GFF and PUFs) were 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 followed the yearly sample batch in order to control potential contamination risks (as a part of the extensive quality control procedure of the NILU monitoring program). All exposed filters were registered and stored frozen (–20°C) prior to analysis and quantification. The GFF and PUFs were extracted in the same solvent to obatin the bulk concentration (gas+particle phase) of the individual target compounds (below). Exceptions were PFAS for which only GFFs were used during sampling and the obtained concentrations represent the particle phase concentrations.

Sampling of Cyclic volatile methyl siloxanes (cVMS)

Sampling of cVMS differed from the rest of the compounds. Sampling was done with a solid-phase extraction active air sampling (SPE-AAS) method with an ENV+ sorbent (hydroxylated polystyrene divinylbenzene copolymer) (Kierkegaard and McLachlan, 2010, Krogseth et al., 2013a) with a flow rate of 1.0 m^3 per hour. Sampling was done during two sampling campaigns; one in summer (18th July -8th Aug) and one in early winter (8th -29th Nov) 2013. Each campaign contained six individual sampling events. The average sampling time was 82.3 ± 15.8 h, and the average volume of air sampled was 87.3 ± 17 m^3.

Analysis and quantification of OCPs, PCBs and S/MCCPs

Samples were spiked with 20 µL of internal standards (IS) containing 13C-labelled PCB congeners (~230 pg/µL), 20 µL IS containing 13C-labelled OCP congeners (~100-2500 pg/µL), 50 µL IS containing ^{13}C-labelled hexachlorodecane (~1000 pg/µL) for SCCP and 20 µL IS containing ^{13}C-labelled trans-CD (~500 pg/µL) for MCCP, and then Soxhlet extracted for 8 h in in diethylether/*n*-hexan (10:90, v:v). The filters and the corresponding PUF plugs were extracted separately but in the same solvent in order to unify the sample. The extract was concentrated and cleaned by acid treatment and silica fractionation. Before quantitative

analysis, 20 µL of unlabelled tetrachloronaphthalene (TCN, 100 pg/µL) was added as recovery standard (RS).

Identification and quantification of the PCBs and OCPs was carried out using a high-resolution gas chromatography coupled to a high-resolution mass spectrometer as detector (HRGC/HRMS). The analyses were performed in Electron Impact ionization mode (EI: PCBs, HCB, HCHs, DDTs) and Negative Ion Chemical Ionization mode (NICI: Chlordanes) using selected ion monitoring (SIM) for the respective compounds groups. In total, 32 PCB congeners and 13 organochlorine pesticides (OCPs) were quantified.

SCCPs and MCCPs were identified and quantified using a GC coupled to a VG AutoSpec, HRMS operating in ECNI mode (GC/HRMS-ECNI).

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 8 h in in cyclohexane. The filters 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 silica fractionation. 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. In total, 28 PAH and 7 methyl-PAH were quantified.

Analysis and quantification PBDEs, TBA, HBCDs

Samples were spiked with 20 µL of internal standards (IS) containing 13C-labelled PBDE congeners (~270-2500 pg/µL) and 20 µL IS containing 13C-labelled HBCD congeners (100 pg/µL), and then Soxhlet extracted for 8 h in in diethylether/*n*-hexan (10:90, v:v). 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 acid treatment and silica fractionation. Before quantitative analysis, the extract was split in two; one for PBDE/TBA and one for HBCD analysis. The extract for PBDE/TBA was spiked with 20 µL of unlabelled TCN (100 pg/µL) as recovery standard, and the extract for HBCD analysis was spiked with 20 µL RS containing deuterated ß-HBCD (130 pg/µL).

Identification and quantification of the PBDEs and TBA was carried out using a HRGC/HRMS operating in EI mode using SIM for the respective compounds groups. In total, 17 PBDE congeners plus TBA were quantified.

For identification and quantification of HBCDs, 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. In total 3 HBCDs were quantified.

Analysis and quantificition PFAS

The filters were spiked with 20 µL of internal standards (IS) containing 13C-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 by acid treatment. Before quantitative analysis, 10 µL of unlabeled 3,7-dimethyl PFOA (0.1 ng/µL) was added as recovery standard. Identification and quantification of the PFAS was carried out using HPLC/MS-TOF with ESI in negative ion mode using full scan mass detection. In total, 13 PFAS were quantified.

Sampling and analysis 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.

Analysis and quantification of POPs in precipitation

The precipitation samples were spiked with 20 µL of IS containing 13C-labelled PCB/HCB/HCH/PAH congeners (0.1 ng/ µL) and then liquid extracted in cyclohexane for 4 h. After separation and removal of the water phase the solvent extract is split for further cleanup for PAHs and PCB/HCB/HCH separately. The PAH extract is cleaned by silica fractionation and the PCB/HCB/HCH extract is cleaned by acid treatment and silica fractionation.

Identification and quantification of the PCBs, HCB and HCHs was carried out using a HRGC/HRMS. The analyses were performed in EI mode for PCBs and HCB, and in NICI mode for HCHs. In total, 7 PCB congeners, HCB and 2 HCHs were quantified.

Identification and quantification of the PAHs was carried out using a GC/LRMS. The analyses were performed in EI mode using SIM. In total, 28 PAH and 7 methyl-PAH were quantified.

Quality assurance/Quality control (QA/QC)

All sampling equipment undergo routine controls and calibration of flow rates.
Field blank samples (n=3) and lab blank samples (n=12) were routinely included in order to control unintended contamination during storage, transport and analytical steps. Field blanks, consisting of pre-cleaned PUF plugs and filters, were sent to each station where they were exposed during the assembly and retrieval of the PUF plugs and filters in field, but kept unexposed in foil and air tight bags during the exposure time. They were then transported, stored, extracted, cleaned and analysed in the same way as and parallel with the real

samples. The lab blanks (solvent blanks) were obtained by extracting solvent and using the same clean-up and analytical procedures as real samples and field blanks. The
The analytical procedure was accompanied by a comprehensive quality control program based on the requirements of NILU's accreditation, according to EU standard EN 45001. The instrument limit of detection (LOD) was determined by calculating the signal-to-noise ratio (S/N) > 3 for solvent blanks (using n-hexane). Based upon average blank concentrations (for both laboratory and field blanks) the limit of quantification (LOQ) was calculated for all compounds with LOQ = average blank value plus 3 standard deviations (STD) of the blank concentrations.

All samples within the range LOQ>×>LOD are considered to have high uncertainties and reported <LOQ (Table S8). All raw data are openly accessible from the NILU database (http://ebas.nilu.no) for thorough examinations. All values below LOD were excluded from further statistical treatment (treated as not detected (<LOD))

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The Norwegian Environment Agency's primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

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

Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.