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Monitoring of environmental contaminants in air and precipitation, annual report 2015

Summary – sammendrag

This report presents results from 2015 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 2015, og disse er sammenlignet med tidligere år.

4 emneord

Miljøkjemi
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Miljøovervåkning

4 subject words

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Front page photo

Zeppelin Observatory

Content

Summary

This report presents the data for 2015 from the Norwegian rural air- and precipitation chemistry monitoring network. The purpose of this monitoring is to increase the knowledge on long-range transported contaminants as a source for pollution in Norway. The monitoring also provides data for international conventions, programmes and networks. 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). Two classes of emerging organic pollutants (i.e. cyclic volatile methyl siloxanes and short and medium chained chlorinated paraffins) are included at one site (i.e. Zeppelin).

In 2015, the highest annual mean concentrations of heavy metals measured in precipitation were found at Svanvik in Sør-Varanger. The high levels at this site are due to emissions from smelters in Russia. The wet deposition, however, was generally highest in Southern Norway where the precipitation amounts are highest. In general, also the air concentrations of heavy metals were two-three times higher at Birkenes in southern Norway than those observed at Andøya and Zeppelin in the North. The same was seen for polycyclic aromatic hydrocarbons (PAHs), γ-hexachlorohexane (HCH) and DDTs. Higher levels in southern Norway are mainly due to closeness to the potential emission sources in continental Europe. For other legacy POPs as well as mercury, there were no large differences between the sites. This indicates that these pollutants have a large potential to be transported far from emission sources, and a lack of regional primary sources.

In 2015, the concentrations of cadmium and lead at Birkenes were substantially lower compared to 2014, but were in line with the concentrations observed in 2013. The concentrations observed in 2014 were unusually high due to extraordinary high precipitation amounts in 2014. In a longer perspective there has been a significant reduction of heavy metal concentrations 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 53-92%, except at Svanvik where no significant trend for this period has been observed. Similar reductions have also been observed for cadmium in precipitation, 20-72% from 1990. The concentration levels of mercury, hexachlorobenzene (HCB) and HCHs in precipitation in southern Norway (i.e. Lista + Birkenes observatories) have been significantly reduced since the beginning of the monitoring in 1990.

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 2015. 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 80% and 55%, respectively at Birkenes and Zeppelin. For cadmium, similar trends have been observed, with 61% and 55% reductions respectively. Weak significant decreasing trends were found for mercury with 13% and 8% respectively at Birkenes and Zeppelin.

POPs in air do not show as significant decreasing trends as the heavy metals. The largest reduction in concentration since the beginning of the monitoring has been observed for HCHs both at Birkenes and at Zeppelin. Reduced concentrations are also observed for DDTs,

chlordanes (CHLs), and polychlorinated biphenyls (PCBs), but trends are not as significant due to more fluctuating concentrations. In contrast, an increase in concentrations during the last five to ten years has been observed for HCB at Zeppelin and Birkenes. For the other POP classes (i.e. PBDEs, PFASs and HBCDs), no significant trends are seen.

In 2015, PAHs, γ-HCH, DDTs and Pentadecafluorooctanoic acid (PFOA) were highest in the south at Birkenes, while HCB was highest in the north at Zeppelin. For the other POPs no differences between the sites were observed.

The concentrations of HCHs, DDTs, CHLs, PCBs and PAHs were similar or just slightly lower in 2015 than previous years. This suggests that steady-state have been reached for these legacy POPs. In contrast, the concentrations of HCB and PBDEs were slightly higher than previous years. For HBCDs and PFAS most measurements were below detection limit.

For the cyclic volatile methyl siloxanes (cVMS) and short and medium chained chlorinated paraffins (S/MCCPs) the concentrations in 2015 were in agreement with the previous years, but the results for D5 and D6 indicate an increase of D5 in summer and winter and D6 in summer. As in 2013-2014, the concentrations of these contaminants 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, organochlorine pesticides (OCPs), polybrominated diphenyl ethers (PBDEs), and PFAS). This suggests ongoing emission of both cVMS and S/MCCPs. It also emphasizes the importance of continuous monitoring of these emerging POPs to follow their emission trends, but also to understand the influence of possible local emission on the levels measured at Zeppelin.

Sammendrag

Denne rapporten presenterer data fra 2015 for det nasjonale overvåkingsprogrammet for langtransporterte forurensinger med fokus på miljøgifter i luft og nedbør. Formålet med overvåkingen er å fremskaffe kunnskap om langtransport av miljøgifter som kilde til forurensning i Norge og ivareta rapportering til internasjonale konvensjoner, programmer og nettverk. Overvåkingsprogrammet 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 på én lokalitet (Zeppelin) siden 2013.

I 2015 ble den høyeste årlige gjennomsnittskonsentrasjonen i nedbør for de fleste tungmetallene observert på Svanvik i Sør-Varanger. Dette skyldes utslipp fra de nærliggende smelteverkene på russisk side. Våtavsetning er derimot generelt høyest i Sør-Norge der nedbørmengden er høyest. Konsentrasjonen av de fleste tungmetallene målt i luft på Birkenes er to til tre ganger høyere enn de som er observert ved Andøya og Zeppelin. Det samme er også tilfellet for de organiske miljøgiftene: PAHs, HCHs, og DDTs. En årsak kan være at Birkenes er nærmere utslippskildene på det europeiske kontinentet. For de andre internasjonalt regulerte organiske miljøgiftene samt kvikksølv 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.

I 2015 var konsentrasjonen av bly og kadmium i både luft og nedbør lavere enn de som ble observert i 2014 på fastlandstasjonene. Dette skyldes unormalt høy våtavsetning og store nedbørmengder i Sør Norge i 2014. I et lengre perspektiv har det 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 53-92%, unntatt på Svanvik der det ikke er noen signifikant trend for denne perioden. Det er også store reduksjoner for kadmium i nedbør, mellom 20 og 72% fra 1990. 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 2015. 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 80 og 55% hhv. på Birkenes- og Zeppelinobservatoriet. For kadmium er det lignende store reduksjoner, hhv. 61% og 55%. For elementært kvikksølv i luft er det en svak nedadgående trend på 13 og 8% på hhv. Birkenes og Zeppelin.

De organiske miljøgiftene i luft viser ikke en så tydelig nedadgående trend som tungmetallene. Den største reduksjonen observeres for HCHs og reduksjonen pågår fortsatt for HCH, DDT og klordaner i 2015. For PCB ses en reduksjon under det første tiåret av 2000-tallet, mens det har vært stabile konsentrasjoner uten reduksjon med noe årlige variasjoner de siste årene. For HCB er det derimot fortsatt observert en økning i luftkonsentrasjonen på Zeppelinobservatoriet de siste ti årene. En øking av HCB luftkonsentrasjoner er også observert på Birkenes de siste fem

årene. For de øvrige miljøgiftene (PBDE, PFAS og HBCD) har overvåkningen pågått i for få år eller så er konsentrasjonene under den analytiske deteksjonsgrensen for å kunne si noe om trender.

I 2015 var nivåene av PAH, γ-HCH, DDT og PFOA høyest på Birkenes i sør mens nivået av HCB var høyest på Zeppelin i nord. De andre komponentene skilte seg ikke mellom stasjonene.

Nivåene av HCH, DDT, klordaner, PCB og PAH var på samme nivå eller lavere enn tidligere år, hvilket bekrefter den generelle nedadgående trend for disse komponentene. Til sammenlikning, er nivåene av HCB og PBDE noe høyere enn tidligere år. HBCD og PFAS var hovedsakelig under deteksjonsgrensen.

Konsentrasjonen av siloksaner og klorinerte parafiner var på samme nivå i 2015 som 2013-2014. For D5 og D6 ble det observert noe høyere nivåer i 2015 enn tidligere. Selv om det er usikkerheter knyttet til måle- og analysemetodene, kan man observere at nivåene av disse uregulerte miljøgiftene er på samme konsentrasjonsnivå som PAH, det vil si opp til en faktor tusen ganger høyere enn de regulerte POPene (PCB, OCP, PBDE, PFAS). Dette viser viktigheten av å inkludere nye stoffer i overvåkingen og å fortsatte overvåking av disse nye stoffene for å følge utviklingen fremover.

1. The monitoring programme

Heavy metals and persistent organic pollutants (POPs) can undergo long-range environmental transport, are toxic, bioaccumulative and persistent in the environment. Due to their harmful impacts on the human health or on the environment, monitoring of these pollutants is of high priority for Norwegian authorities. For many of these contaminants, long-range transport via air is the most important source to pollution 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.

Several regional and global treaties have regulated the use and emission of heavy metals and POPs. Heavy metals are regulated by two multilateral agreements: i) the 1998 Aarhus Protocol on Heavy Metals under the Convention on Long-range Transboundary Air Pollution (CLRTAP) (UN/ECE, 1998a), and ii) the Minimata convention on mercury (UNEP, 2013). The use and production of POPs are regulated or banned on a global scale by the Stockholm Convention on POPs (Stockholm Convention, 2007) and on a European scale by the 1998 Aarhus Protocol on POPs; "the POP-protocol", under CLRTAP (UN/ECE, 1998b). The two conventions today includes 26 and 23 substances/substance groups respectively (UN/ECE, 2010, Stockholm Convention, 2013). In 2015, the Conference of the Parties to the Stockholm Convention adopted amendments to list three new POPs in the convention; hexachlorobutadiene, polychlorinated napthalenes and pentachlorophenol, including its salts and esters (Stockholm Convention, 2015). The global ban on these chemicals will enter into force in 2016. In addition four chemicals are under review for listing under the conventions: Decabromodiphenyl ether, dicofol, short-chained chlorinated paraffins (SCCPs), and pentadecafluorooctanoic acid (PFOA), it salts and PFOA-related compounds.

This report presents data from 2015 for environmental contaminants (heavy metals and POPs) in air and precipitation from the annual monitoring in Norwegian rural background environments. The data 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. The purposes of this monitoring programme are to i) obtain information of the atmospheric contribution of regulated and emerging contaminants to the Norwegian environment; ii) monitor any changes in the contaminants' levels over time and space, and iii) obtain data that can be used to regulate new chemicals. The documentation is also important for monitoring compliance with existing abatement strategies. Data and results from the national monitoring program are reported and used in several international fora, including: the GMP (Global Monitoring Programme) of the Stockholm Convention on POPs, EMEP (European Monitoring and Evaluation Programme) under the CLTRAP, 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). A subset of the data are also reported to the European Commission as defined in the air quality directive (EU, 2008), and to Miljøovervåkningen på Svalbard and Jan Mayen (MOSJ). Nationally the data are used to assess the achievement towards obtaining priority environmental goals for environmental pollution and the Arctic.

To document the long-range transport of air pollution, the monitoring stations/observatories have been placed/located, as far as possible, in areas that are not influenced by local sources.

Further, the number of observatories and the geographical distribution are selected in order to represent different parts of Norway. The observatories in this monitoring programme are to a large extent coordinated together with *the national measurement programme of long-range transported air pollutants for main components in air and precipitation* conducted by NILU on behalf of the Norwegian Environment Agency, and the Ministry of Climate and Environment (Aas 2015a).

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 observatory in southern Norway as part of the CAMP Programme under the OSPAR Convention (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 AMAP programme (http://www.amap.no). Both sites became part of the EMEP programme (http://www.emep.int) under the CLRTAP (http://www.unece.org/env/lrtap) in 1999, (Tørseth et al, 2012). In the end of 2009, a new monitoring station for heavy metals and POPs was established at Andøya as part of *the national Marine Pollution Monitoring Programme* for the Norwegian Environment Agency (Green et al., 2011) and it is now a part of the regular EMEP programme.

The measurements from 2015, presented in this report, are a compilation of results from three different national projects and programs:

- Measurements of heavy metals and POPs (except PAHs) in air at Birkenes, Andøya and Zeppelin, heavy metals in precipitation at Birkenes, and emerging substances (i.e. cyclic volatile methyl siloxanes and short and medium chained chlorinated paraffins) at Zeppelin are part of *The national monitoring programme of environmental contaminants* on behalf of The Norwegian Environment Agency
- Heavy metals in precipitation at Svanvik are measured as 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 PAHs 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.

No changes in the monitoring programme were made since 2013. From 2013-2015, the monitoring programme for environmental contaminants have included six observatories of which three include measurements of POPs. The locations of the observatories are shown in Figure 1.1, and the monitoring programme is described in Table 1.1. Further information of the sites, site descriptions are available at http://www.nilu.no/projects/ccc/sitedescriptions/. Information of sampling and analytical methods is given in Annex 3. All the data presented in this report are available at http://ebas.nilu.no/.

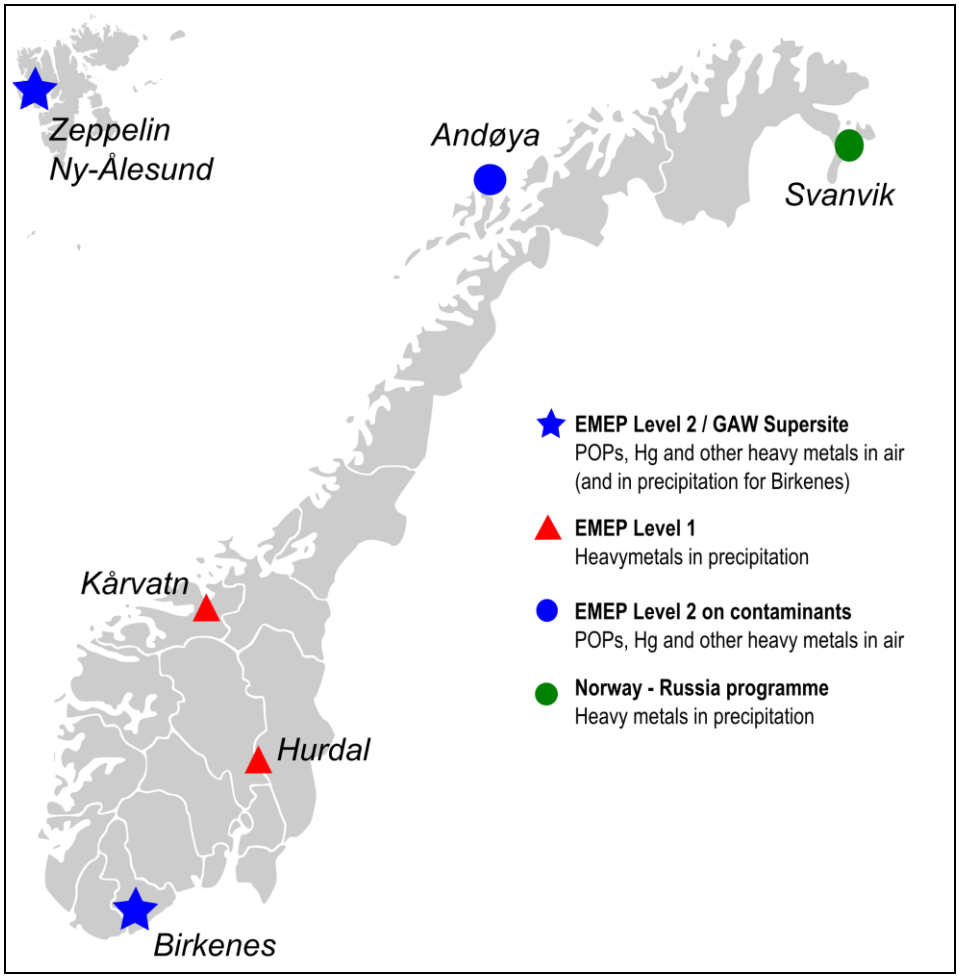

Figure 1.1: Norwegian background stations measuring environmental contaminants in 2015.

Table 1.1: Norwegian monitoring stations and the sampling programme of heavy metals and persistent organic pollutants, 2015

Station code and name		Lat	Long	hasl	Heavy metals		Persistent Organic Pollutants (POPs)*	
					precipitation	air and aerosols	precipitation	air and aerosols
NO0001R/ NO0002R	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, HBCDs, 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, HBCDs, 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. Measurements of heavy metals in air were included in the programme in 1991 at Lista, 1994 at Zeppelin, and 2010 at Andøya.

There has been no changes in the monitoring programme for heavy metals during the last years.

2.1 Heavy metals in precipitation

Calculations of annual mean concentrations in precipitation are weighted using the weekly concentrations and precipitation amounts to derive so called volume weighted concentrations (ng-µg/L). The volume weighted annual mean concentrations in precipitation for 2015 are presented in Table 2.1. The wet depositions are obtained by multiplying the concentrations with the precipitation amounts (ng-mg/m^2) and the results for 2015 are presented
Table 2.2. The results show that the highest annual mean concentrations of all heavy metals, but zink are observed at Svanvik. The high levels at Svanvik are due to high emissions from the smelters in Nikel (Russia) close to the Norwegian border. Significantly increased levels of the contaminants at the Norwegian side of the border (i.e. Svanvik) are observed when there is easterly wind from Russia and the Kola Peninsula. Further details and discussion of these data can be found in the annual report for the programme "*Russian-Norwegian ambient air monitoring in the border areas*" (Berglen et al., 2016).

The levels of lead, cadmium and zinc observed at Hurdal and Birkenes are comparable while lower levels are observed at Kårvatn, which is also furthest away from the main emission sources in continental Europe. For wet deposition, the highest levels are generally observed at Birkenes, except for Ni, As, Cu and Co that have very high levels in Svanvik.

Table 2.1: Volume weighted annual mean concentrations of heavy metals (µg/L) and mercury (ng/L) in precipitation in 2015.

Site	Pb	Cd	Zn	Ni	As	Cu	Co	Cr	Mn	V	Al	Hg
Birkenes	0.84	0.016	3.7	0.15	0.08	1.33	0.03	0.16	1.99	0.23	-	6.5
Hurdal	0.49	0.030	6.3	-	-	-	-	-	-	-	-	-
Kårvatn	0.26	0.010	2.2	-	-	-	-	-	-	-	-	-
Svanvik	1.93	0.084	5.0	29.3	1.49	33.5	0.89	0.36	-	0.47	35.2	-

Table 2.2: Total wet deposition of heavy metals (mg/m^2) and mercury (ng/m^2) in 2015.

Site	Pb	Cd	Zn	Ni	As	Cu	Co	Cr	Mn	V	Al	Hg
Birkenes	1614	31.5	7119	296	161	2548	61	316	3826	442	-	14024
Hurdal	591	36.3	7537	-	-	-	-	-	-	-	-	-
Kårvatn	373	14.7	3164	-	-	-	-	-	-	-	-	-
Svanvik	699	30.5	1807	10621	541	12171	322	130	-	171	12771	-

Calculated volume weighted monthly mean concentrations and wet depositions for all the elements are shown in Annex A.1.1-A.1.24. The monthly mean concentration for lead, cadmium and mercury are shown in Figure 2.1. For lead, there is no clear seasonal variation, but elevated levels are observed in April and August at Birkenes. The deposition of lead at Birkenes and Hurdal are highest in August (table A.1.14). For cadmium no clear seasonal variation was observed in neither concentration nor deposition. At Hurdal one high monthly episode was observed in both concentration and deposition in August. This was caused by one week with both high concentration and precipitation amounts. The reason for the high concentration this week is unclear. For mercury, high concentrations and deposition were observed in April and May at Birkenes.

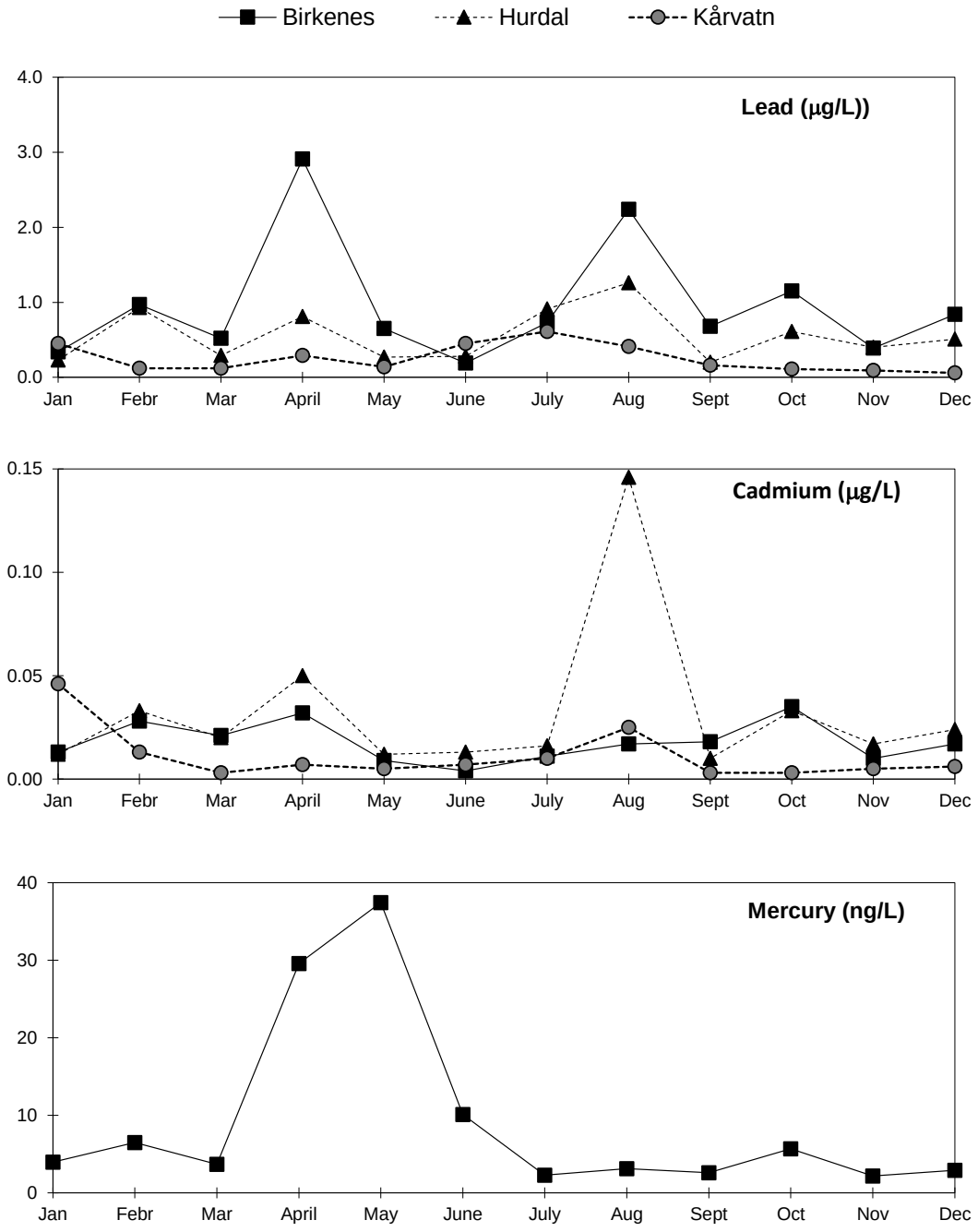

Figure 2.1: Volume weighted monthly mean concentrations of lead, cadmium and mercury in precipitation in 2015.

Figure 2.2 and Table A.1.25 show volume weighted annual mean concentrations in precipitation from 1980-2015. In 2015, the concentrations of cadmium and lead in precipitation at Birkenes were substantially lower than in 2014, but in line with the concentrations observed in 2013. The concentrations observed in 2014 were unusually high due to extraordinary high precipitation amounts in 2014. At Hurdal and Kårvatn, the cadmium and lead concentrations observed in 2015 are similar to those observed in 2014 while at Svanvik the concentrations of both elements have increased from 2014 to 2015. The annual mean concentration of lead at Svanvik is the highest since 2003. For mercury, the observed annual mean concentrations at Birkenes in 2015 was higher than in 2014 and the highest since 2010.

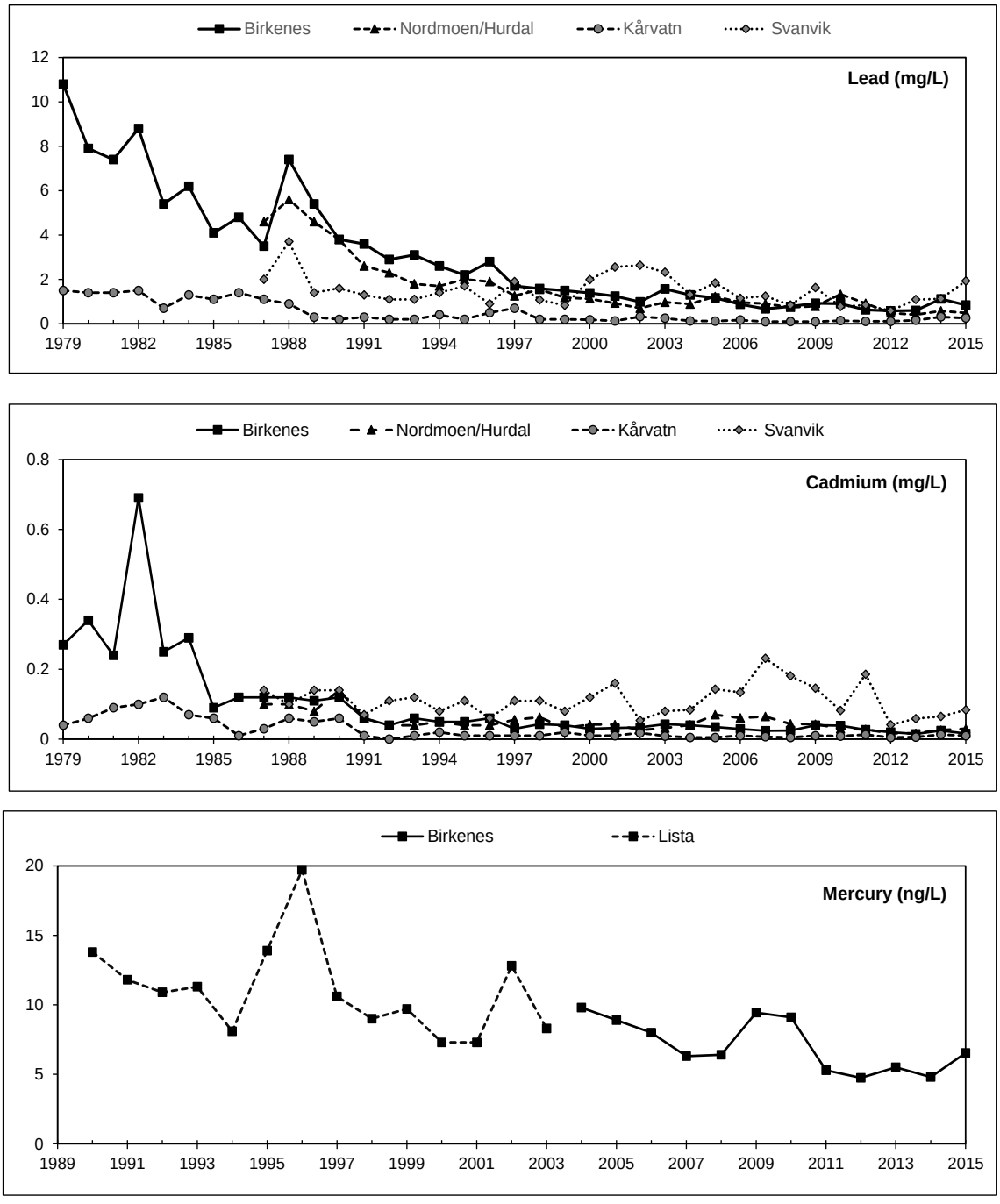

Figure 2.2: Time series of volume weighted annual mean concentrations of lead, cadmium and mercury in precipitation at Norwegian background stations.

In a long term perspective, the concentrations of lead in precipitation at Birkenes and Kårvatn have been largely reduced with more than 90% reduction between 1980 and 2015 and 53-92% reduction since 1990 (Table 2.4). These reductions are consistent with those observed at other EMEP sites with long-term measurements and can be explained by large European emission reductions of lead during this period (Tørseth et al, 2012). In contrast, at Svanvik, no significant trend has been observed since 1990 which can be explained by influence from other emission sources in the nearby area (e.g. Russian smelters). The levels of cadmium at Birkenes and Kårvatn have also been reduced with more than 90% since 1980, and between 20 and 72% since 1990. As for lead, this is also consistent with European emission reductions for cadmium (Tørseth et al., 2012). No significant reduction trends have been observed at Svanvik.

The concentrations of zinc in precipitation have been reduced by 70% since 1980 and 42% since 1990 at Birkenes. In contrast, a significant increase of zinc has been observed in precipitation at Hurdal and Kårvatn during the last period (Table 2.4). There are quite large annual variations in zinc, with increases at some sites for some years. This may be due to possible contamination of zinc during sampling or influence of local sources.

The trends for the concentrations are reflected in the trends for the wet deposition which gives similar results. There are no significant changes in precipitation amount so the trends in wet deposition is controlled by the trends in concentration.

When combining the datasets from Lista and Birkenes, mercury levels appear to have been significantly reduced (60%) since 1990. However, this reduction might have been influenced by different precipitation amounts and deposition rates at the two sites. The results from a trend analysis that combines the datasets is therefore somewhat uncertain. On the other hand, 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.

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. (2016).

2.2 Heavy metals in air

The annual mean concentrations of the heavy metals measured in air in 2015 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 in 2015 are two-three times higher than those observed at Andøya and Zeppelin. This is likely because Birkenes is closer to the emission sources at the European continent. For mercury, similar air concentrations are observed at all three 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 may be

distributed over greater geographical distances and is a global pollutant to a greater extent than the other heavy metals.

Table 2.3: Annual mean concentrations of heavy metals in air and aerosols in 2015, Unit: ng/m^3.

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
Birkenes II	0.16	0.025	0.73	0.01	0.50	0.73	-	0.19	0.21	4.0	1.51
Andøya	0.06	0.010	0.08	0.006	0.17	0.28	0.23	0.10	0.11	0.8	1.50
Zeppelin	0.07	0.010	0.16	0.009	0.29	0.26	0.49	0.11	0.06	1.4	1.49

As in previous years, the annual mean concentrations at Andøya and Zeppelin are comparable; some elements are higher at one of the sites while others are higher at the other site. These differences are due to individual episodes with high concentrations of heavy metals arriving to Zeppelin and Andøya, especially during the winter at Zeppelin in 2015, and these episodes are not coinciding at the two sites (Figure 2.3).

The episodes with high levels of cadmium and lead at Birkenes and Zeppelin are well correlated at the individual sites (Figure 2.3). This not necessarily because they have similar emission sources, but because the polluted air is well mixed, and the episodes with high levels are happening when the meteorology favors long range transport from the emission sources at the continent. For example, the large episode observed at Zeppelin 6-8 April 2015 is related to air masses arriving from Russia.

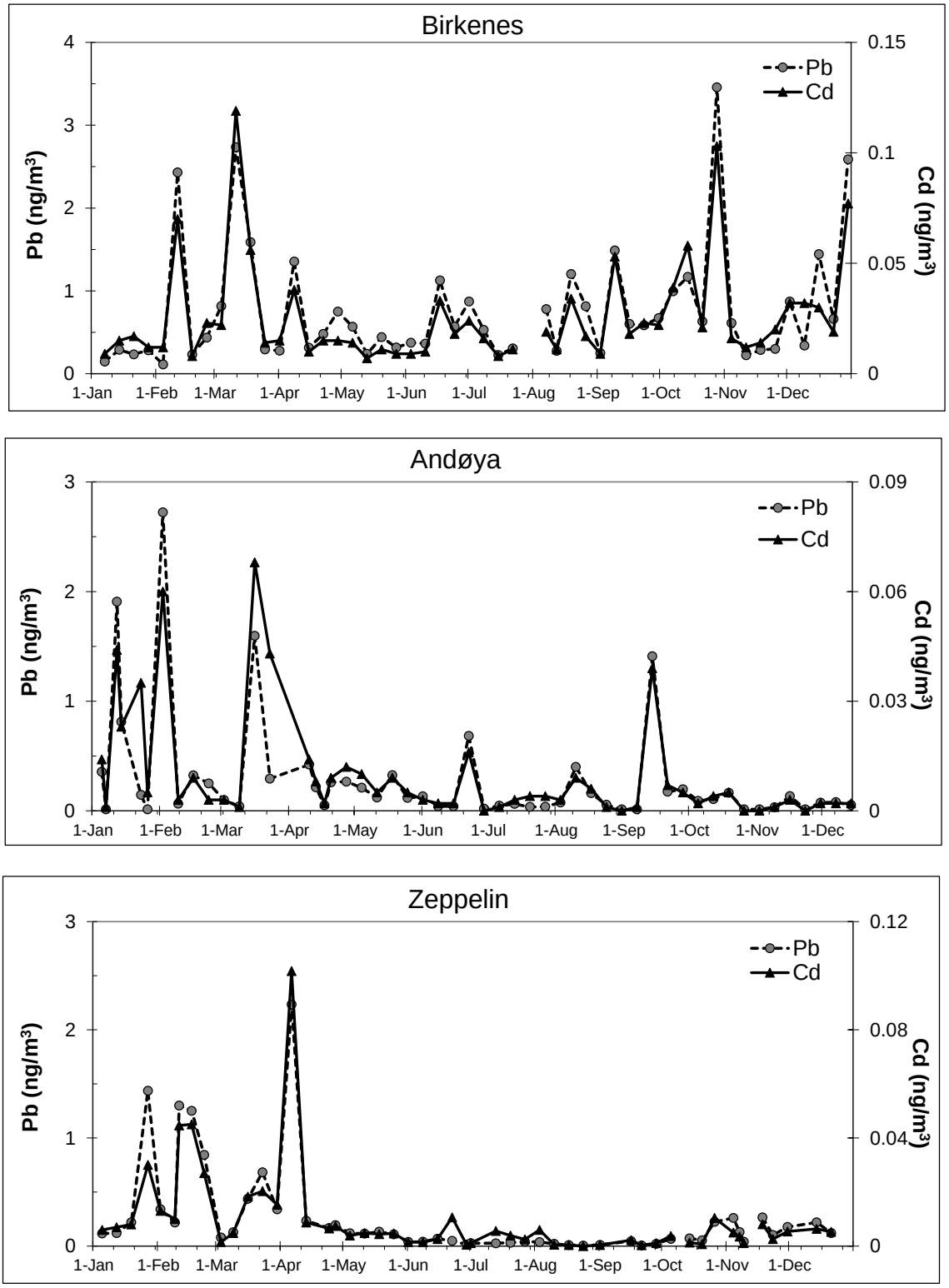

Figure 2.3: Weekly concentrations of lead and cadmium in air at Norwegian background stations in 2015, Unit: ng/m³.

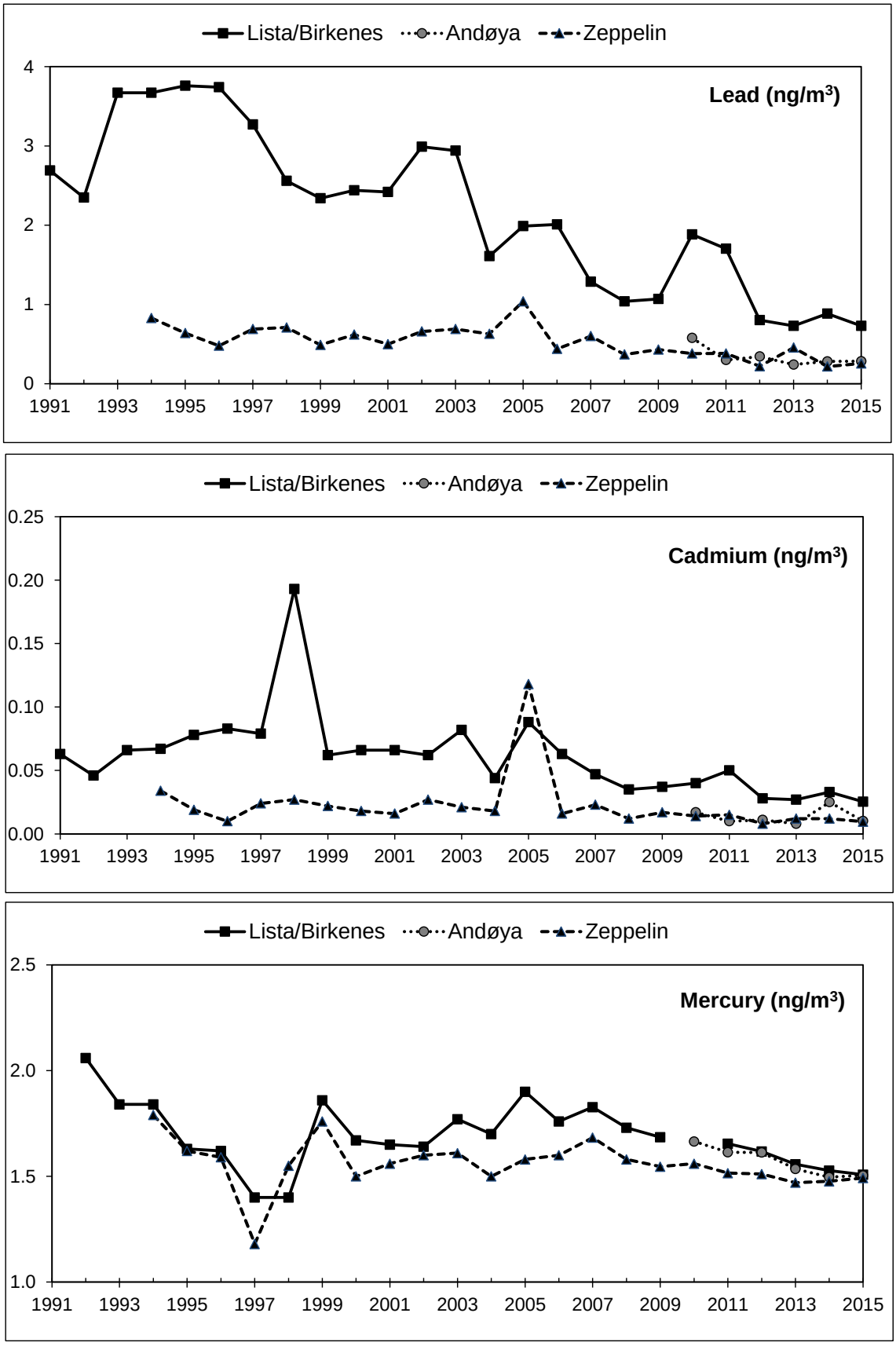

Figure 2.4: Time series of annual mean concentrations of lead, cadmium and mercury in air and aerosols, 1991-2015, Unit: ng/m³ (note that the y-axis for mercury begins at 1.0 ng/m³).

The air concentrations for lead, cadmium and mercury are similar or lower in 2015 than in 2014.

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 concentrations for almost all the elements (As, Cd, Co, Cr, Pb, Ni and V) for the period 1991 to 2015. At Zeppelin, there has also been a significant reduction since 1994 for several elements (As, Cd, Cu, Pb, V). The reduction for lead has been 80% and 55% respectively at Birkenes and Zeppelin (Table 2.4). For cadmium, there were similar trends, 61% and 55% reductions respectively. For mercury, small decreasing trends are observed at Birkenes (13%) and Zeppelin (8%). A larger decreasing trend is observed in precipitation than in air for mercury at Lista/Birkenes. The trends are however not directly comparable since Hg(g) is a global pollutant with long atmospheric lifetime, and the wet deposition of mercury on the other hand is scavenging oxidized gaseous mercury and particulate mercury.

Table 2.4: Trends in annual mean concentrations of heavy metals in air and precipitation using Mann Kendall test and Sen slope estimates. Numbers in red indicate positive trends.

	Air		*Precipitation*			
	Birkenes	*Zeppelin*	*Birkenes*	*Hurdal*	*Kårvatn*	*Svanvik*
	1991-2015	*1994-2015*	*1990-2015*	*1990-2015*	*1990-2015*	*1990-2015*
Pb	*-80%*	*-55%*	*-92%*	*-86%*	*-53%*	*not sign.*
Cd	*-61%*	*-55%*	*-72%*	*-51%*	*-20%*	*not sign.*
Zn	*not sign.*	*not sign.*	*-42%*	*83%*	*104%*	*not sign.*
Ni	*-59%*	*not sign.*	*-*	*-*	*-*	*147%*
Hg	*-13%*	*-8.2%*	*-60%*	*-*	*-*	*-*

3. Persistent organic pollutants (POPs)

This monitoring report includes 12 different classes of organic pollutants, of which eight are classified as POPs and four show POP-like characteristics. POPs are characterized by being persistent in the environment, bio-accumulative, toxic to humans and wildlife, and having potential for long-range atmospheric transport (Stockholm Convention, 2007). The monitored compounds additionally represent a range of different sources such as industrially produced chemicals used as pesticides, biocides, flame retardants, etc., and unintentionally produced chemicals generated as by-products of various industrial/combustion processes. The industrially produced POPs are released to the environment in different ways depending on their application; from industrial point sources; by direct spreading in the nature (e.g. pesticides); by emission/release from products in which they are used; and waste.

POPs in air have been monitored at Zeppelin since 1991, while the monitoring started later at Birkenes and Andøya (see details in section 3.1). The pollutant classes included in the monitoring at each observatory are presented together with heavy metals in Table 1.1. In general, HCB, HCHs, DDTs, PCBs, PBDEs and PFAS are monitored at all three observatories while CHLs, hexabromocyclo-dodecane (HBCD) and PAHs are only monitored at Birkenes and Zeppelin. In addition, two groups of emerging organic pollutants have been included in the monitoring programme at Zeppelin since 2013; i.e. cyclic volatile methylsiloxanes (cVMS) and short and medium chained chlorinated paraffins (SCCP, MCCP) (see Chapter 4).

Sampling of POPs and S/MCCPs is continuously done on a weekly basis throughout the year with specific sampling lengths for each observatory and class of pollutant. For example, PCB, HCB, DDT, HCH are sampled on a weekly basis at all three observatories, but with different sampling length at the individual observatory (e.g. 24-72 h). The sampling methodologies have been optimized to achieve maximum detection while minimizing the influence of possible sampling artefacts, such as breakthrough and degradation. Sampling of the cVMS does not follow the weekly sampling frequency, instead they were sampled in one summer and one winter campaign in 2015. Details on sampling and analyses 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 Figure 3.1, and as monthly mean concentrations in Figure 3.2 - Figure 4.3. Exceptions are those classes for which more than 50% of the observations are below detection limits. 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)

HCB is produced both as an unintentional by-product and as an intentionally made chemical mainly used as a fungicide for crop seed as well as to make fireworks, ammunition, and synthetic rubber. The intentional use and production of HCB is regulated by the Aarhus Protocol on POPs under the CLRTAP (UN/ECE, 1998b) and the Stockholm Convention on POPs (Stockholm Convention, 2007). Intentional production and use of HCB is therefore assumed to have ceased globally. However, HCB may still be unintentionally produced and released as a by-product during manufacture of other chemicals as well as through incomplete combustion from old dumpsites.

HCB has been monitored at Birkenes and Zeppelin since 1993, and at Andøya since 2009. It was detected in all samples from all sites in 2015. The weekly concentrations ranged between: 33-79 pg/m^3 at Birkenes; 12-57 pg/m^3 at Andøya; and 71-130 pg/m^3 at Zeppelin (including one high episode 13-15 July). The reason for the high individual episode at Zeppelin is unknown as the air masses for the specific period are local. The annual mean concentrations of HCB in 2015 were, as previous years, 1.5-three times higher at Zeppelin (86 pg/m^3) than at Birkenes (56 pg/m^3) and Andøya (28 pg/m^3).

The annual mean concentration for 2015 at Zeppelin is the highest since 1999. This result is in agreement with the increasing trend observed at Zeppelin since the beginning of 2000 (Figure 3.1). The levels of HCB measured at Zeppelin during the last years are similar to the levels measured in the end of 1990s, but are still below those observed in the beginning-middle of 1990s. Also at Birkenes the annual mean concentration in 2015 is higher than in 2014 and the highest since 2009. The time-trend from the last five years also indicate a small increase at this site. The reason for the increasing trends is unknown, suggestions are increased re-emissions from deposited HCB due to higher temperature and ice-free winters, or a continuous release of HCB in some parts of the world, but these hypothesis need further research to be proven (Hung et al., 2010). In contrast, at Andøya the annual mean concentration in 2015 is consistent with those observed during the last six years (Figure 3.1). The stable concentrations at Andøya might be influenced by breakthrough of HCB in the sampler at this site due to a higher sample volume compared to Birkenes and Zeppelin.

The high concentrations observed for HCB at Zeppelin during the last years are in line to what has been observed at Station Nord on Greenland. Such high concentrations have also been observed at Kosetice, Czech Republic in central Europe while the concentrations at other sites in Europe are two to three times lower and similar to those observed at Birkenes (Halse 2011, Aas 2015b).

No clear seasonal variations of HCB concentrations are seen at Zeppelin (Figure 3.2) although the individual lowest concentrations are observed during the coldest season (i.e. January and February) and the individual highest concentrations are observed during spring and summer. In contrast, seasonal variations are observed at both Andøya and Birkenes. In 2015, these variations were smaller than in 2014, with summer concentrations (June-August) being a factor of 1.5 to two lower than winter concentrations (October-March) (Figure 3.2). The seasonal variations at Birkenes and Andøya may be a result of higher emissions from combustions during colder periods and thereby higher levels in wintertime or as a result of increased breakthrough

in the sampler during warmer periods and thereby underestimations of the summer concentrations.

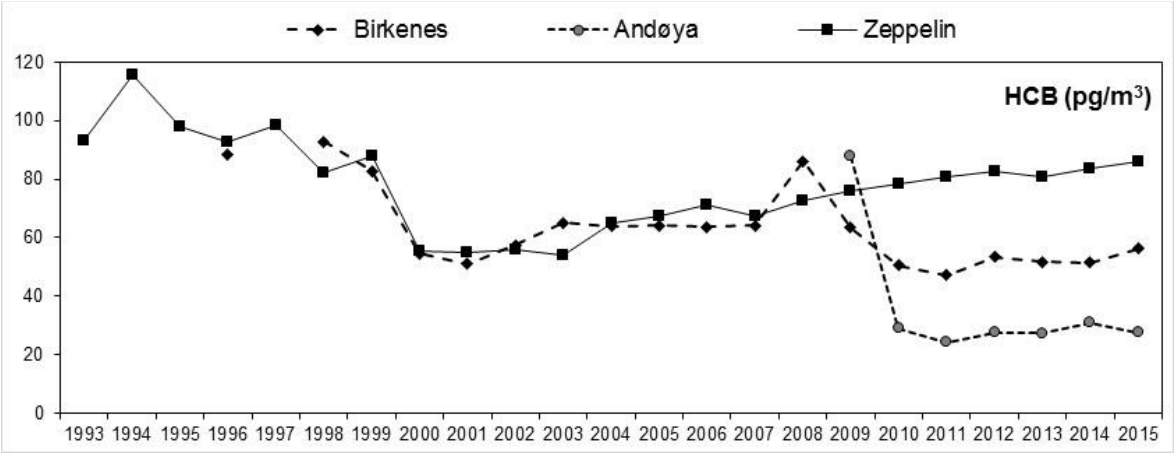

Figure 3.1: Annual mean concentrations of HCB (pg/m³) in air.

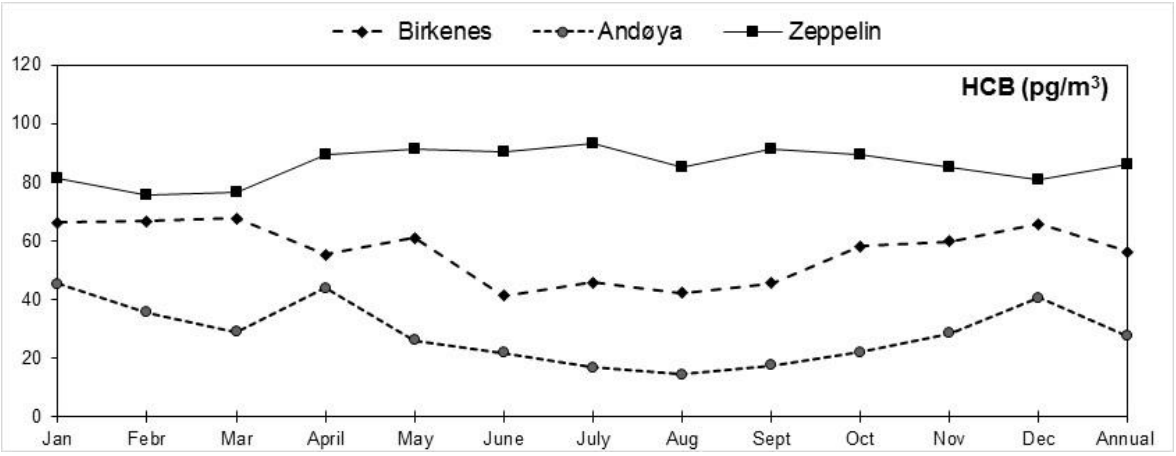

Figure 3.2: Monthly and annual mean concentrations (pg/m³) of HCB in air for 2015.

3.1.2 Hexachlorohexanes (HCHs)

HCHs are intentionally produced chemicals that have been and are to some extent still used as insecticides worldwide. The technical mixture consists of five stable isomers: α-, ß-, γ-, δ-, and ε-HCH. γ-HCH, also known as lindane, has been used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies. The production and use of HCHs are regulated regionally and globally by the Aarhus protocol on POPs (UN/ECE, 1998b) and the Stockholm Convention on POPs (Stockholm Convention, 2007). However, the Stockholm Convention still accept the production and use of lindane/γ-HCH for pharmaceutical control of head lice and scabies and as a result it is still allowed in some countries.

Two HCH isomers; α- and γ-HCHs, have been monitored at Birkenes since 1991, at Zeppelin since 1993, and at Andøya since 2010. Both isomers were above detection limit in all samples from all sites in 2015. The weekly concentrations of sum HCHs (α+γ) in 2015 ranged from: 2.6-

21 pg/m^3 at Birkenes (including one high episode 3-4 July); 3.0-8.5 pg/m^3 at Andøya (including one high episode 21-24 August); and 3.2-7.8 pg/m^3 at Zeppelin. The reason for the high episodes at Birkenes and Andøya are unknown, but may be related to air masses from the European continent and Russia during the specific periods. The annual mean concentrations of sum HCHs (4.4-6.6 pg/m^3) and the individual isomers in 2015 were in the same range at all observatories and in agreement or slightly lower than in 2014 continuing the decreasing trends from previous years (Figure 3.3:). Overall, HCHs are the POPs that have shown the largest reduction in air concentrations since the beginning of the air monitoring at Zeppelin and Birkenes (a factor of 15 and 25). The two isomers are declining with similar pattern at both observatories although a somewhat larger reduction is observed for γ-HCH than for α-HCH. As previous years, the average ratios of α-/γ-HCH were found to decrease from north to south; 7.0 at Zeppelin; 5.2 at Andøya; and 1.8 at Birkenes. Even lower ratios are observed at more southern sites in continental Europe (Aas 2015). The lower ratios in the south might be a result of γ-HCH being less prone to long-range transport and more efficiently scavenged by wet deposition which in turn is a result of its lower Henry's law constant. Lower ratios in summertime and higher in wintertime at Birkenes suggests higher emission of lindane/γ-HCH from secondary sources together with less scavenging during the warmer and dryer period.

The concentrations observed in Norway are similar to those observed in Sweden while up to an order lower than those observed at some sites in continental Europe (Aas 2015).

Strong seasonality of the HCHs concentrations was observed at Birkenes, with up to three times higher concentrations during late summer than wintertime. A similar seasonality, although less strong, was also observed at Andøya and Zeppelin with a tendency of lower concentrations in wintertime (December-March) (Figure 3.4). The seasonality was less pronounced for γ-HCH than for α-HCH. Higher concentrations during warmer periods may be due to re-volatilization from soil or other environmental surface media during warmer periods (i.e. secondary emissions) (Halse 2012).

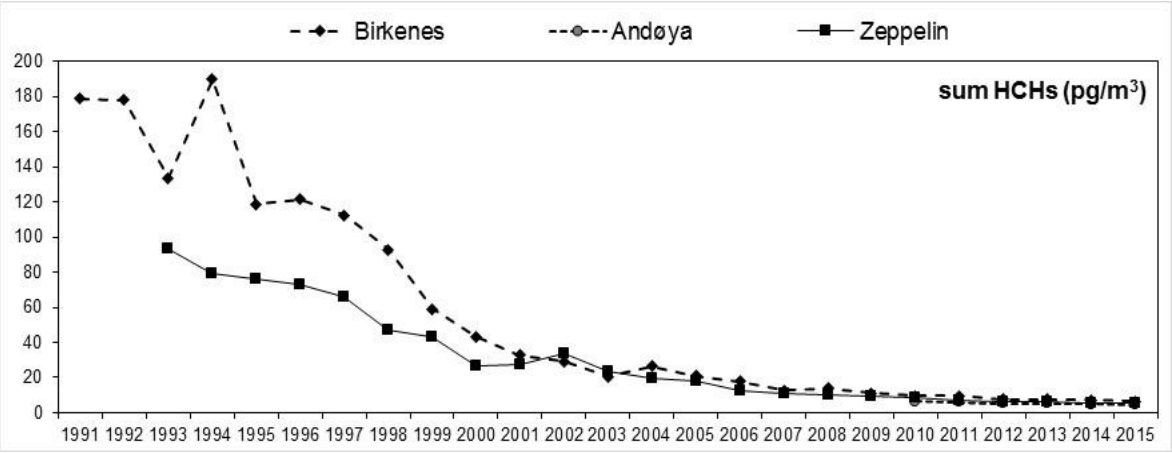

Figure 3.3: Annual mean concentrations of sum HCHs (pg/m^3) in air.

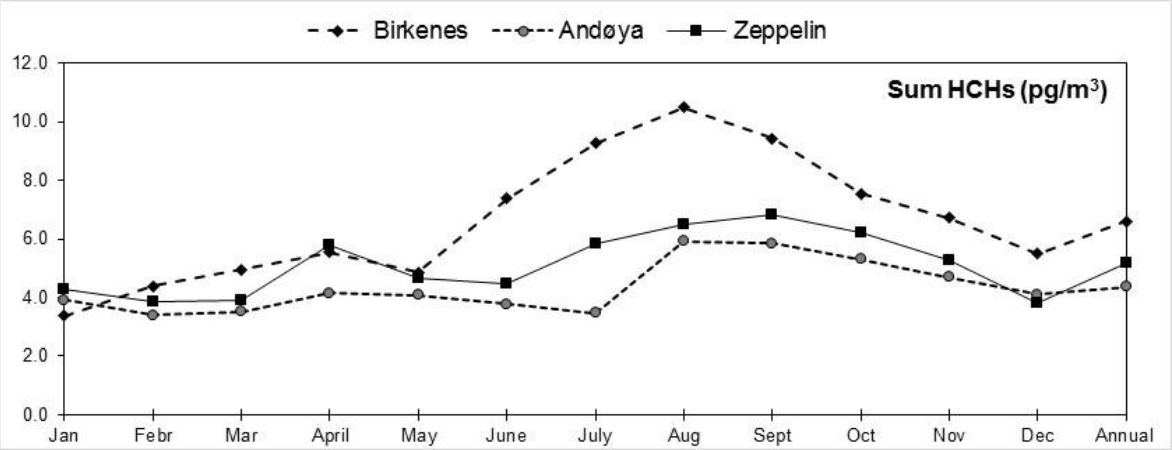

Figure 3.4: Monthly and annual mean concentrations (pg/m^3) of sum HCHs in air for 2015.

3.1.3 DDTs

DDTs are intentionally produced chemicals that have been used worldwide as a pesticide to protect humans and agricultural crops from vector-borne diseases. The production and use of DDTs were banned in Europe, US and Canada during 1970s to 2000 and is further regulated by the Aarhus protocol (UN/ECE, 1998b) and the Stockholm Convention on POPs (Stockholm Convention, 2007), but is still in use in some parts of the world for disease (primarily malaria) vector control. For example, the World Health Organization (WHO) recommends indoor residual spraying with DDT as one of three primary means of malaria control, the others being use of insecticide treated bednets and prompt treatment of confirmed cases with artemisinin-based combination therapies (WHO, 2006). The Conference of the Parties to the Stockholm Convention on POPs evaluates the continued need for DDT for disease vector control approximately every second year in consultation with WHO.

The six DDT congeners; o,p'- and p,p'- DDT, DDD, and DDE, have been monitored at Zeppelin since 1994, and at Birkenes and Andøya since 2010. The detection frequencies in 2015 varied among the individual congeners and between the sites. For example, only p,p'-DDE was detected in all samples at all sites, while low detection (i.e. low concentrations) was observed for p,p'-and o,p'-DDD at Birkenes and Zeppelin. p,p'-DDE was also the most abundant congener at all sites. The weekly concentrations of sum DDTs in 2015 ranged between: 0.4-8.6 pg/m^3 at Birkenes (including two high episodes 30-31 October and 6-7 November); 0.08-2.5 pg/m^3 at Andøya (including one high episode 21-24 August); and 0.07-2.0 pg/m^3 at Zeppelin. The reasons for the high episodes are unknown.

The annual mean concentrations of sum DDTs and the individual congeners in 2015 were as previous years higher at Birkenes (1.5 pg/m^3) compared to Andøya (0.6 pg/m^3) and Zeppelin (0.5 pg/m^3) (Figure 3.5:). The annual mean concentrations of sum DDT at all stations were lower than in 2014, but in the same ranges as have been observed since 2010. This suggests that the concentrations of DDTs have reached steady-state after the long-term declining trends. This is consistent for all congeners. Although the concentrations observed at Birkenes are higher than at Andøya and Zeppelin, they are still one to two orders of magnitude lower than the concentrations found on the European continent (Halse 2011, Pribylova 2012, Aas 2015). The reason for higher concentrations at Birkenes compared to the more northern Norwegian sites

may be explained by closer distances to possible emission sources, but more research is needed before any firm conclusions can be drawn. The indicator ratio (p,p'-DDE+p,p'-DDD/p,p'-DDT) were high (>10) at all sites throughout the year indicating input only from aged DDT.

A strong seasonality of the DDT concentrations was observed at Zeppelin and Andøya with five to ten times higher concentrations in wintertime (December-February) compared to warmer months (May-September) (Figure 3.6). This seasonality was seen for sum DDTs as well as o,p'- and p,p'-DDE and DDT, but not for DDD. The same seasonality, although weaker, was observed at Birkenes and Andøya.

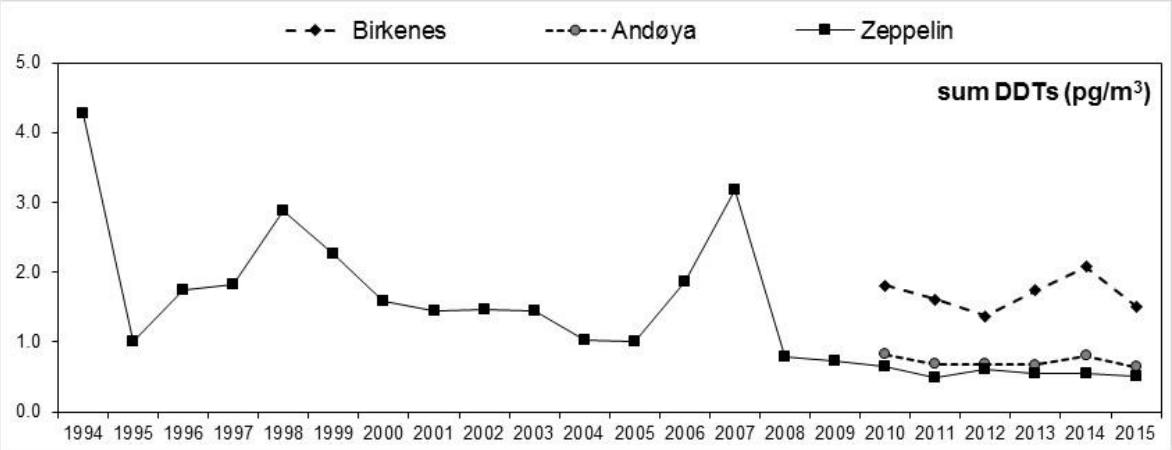

Figure 3.5: Annual mean concentrations of sum DDTs (pg/m^3) in air.

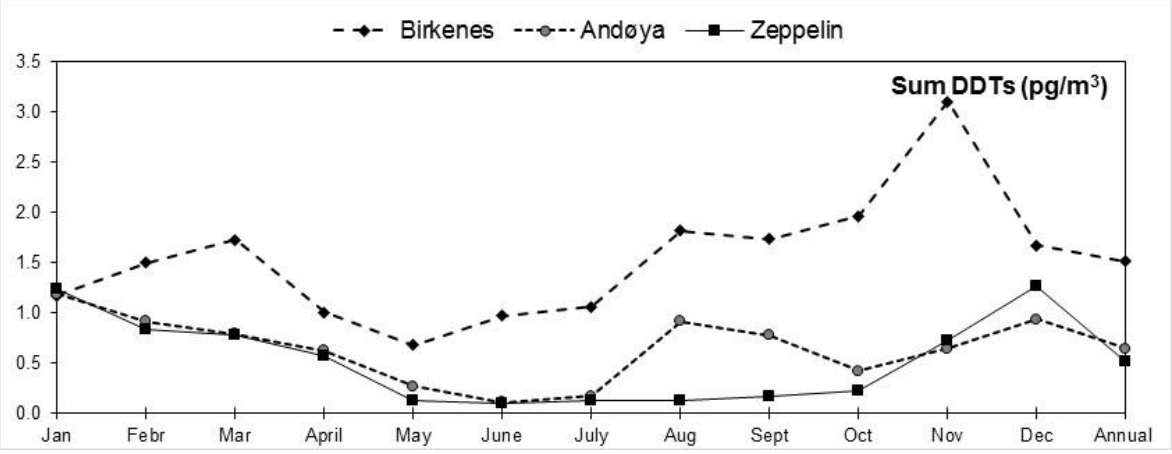

Figure 3.6: Monthly and annual mean concentrations (pg/m^3) of sum DDTs in air for 2015.

3.1.4 Chlordanes (CHLs)

CHLs are intentionally produced chemicals that have been used extensively as pesticides (insecticides). The use and production of CHLs have been banned under the Aarhus protocol (UN/ECE, 1998b) and the Stockholm Convention on POPs (Stockholm Convention, 2007).

The four stereoisomers of chlordane (i.e. cis- and trans-chlordane (CD), and cis- and trans-nonachlor (NO)) have been monitored at Zeppelin since 1993, at Birkenes since 2010 and are not included at Andøya. All the four isomers were detected in all samples at both sites. The major components were cis-CD and trans-NO contributing ~40% each to the sum CHLs. The weekly concentrations of sum CHLs in 2015 ranged between: 0.3-2.0 pg/m^3 at Birkenes; and 0.4-1.4 pg/m^3 at Zeppelin.

The annual mean concentrations of sum CHLs in 2015 were in the same range at the two sites (Figure 3.7), but two to three orders lower than concentrations recently observed in continental Europe (Aas 2015). The concentrations of sum CHL and the individual stereoisomers at Zeppelin and Birkenes in 2015 were the lowest observed since the start of the monitoring and are in agreement with the small decreasing trends observed during the last years as well as the significant reduction of air concentrations observed at Zeppelin since the beginning of 1990s (Figure 3.7:). The ratio of trans-CD and cis-CD was low at both Birkenes and Zeppelin (0.2-0.7 compared to 1.17 in technical mixture) indicating input only from aged CHLs, since trans-CD degrades faster than cis-CD in the environment.

No seasonality was observed for the concentrations of sum CHLs at Birkenes, instead the concentrations fluctuated over the year (Figure 3.8). Higher concentrations in summertime (June-September) than in wintertime (January-March) were however observed for three of the isomers; cis-CD, trans- and cis-NO. Although a small concentration range also at Zeppelin, the lowest concentrations of sum CHLs were consistently observed during summertime and the highest during wintertime. A similar trend was seen for the individual isomers (especially trans-CD that were four-five times lower in summer than in winter) with exception of cis-NO which in contrast had highest concentrations in summertime.

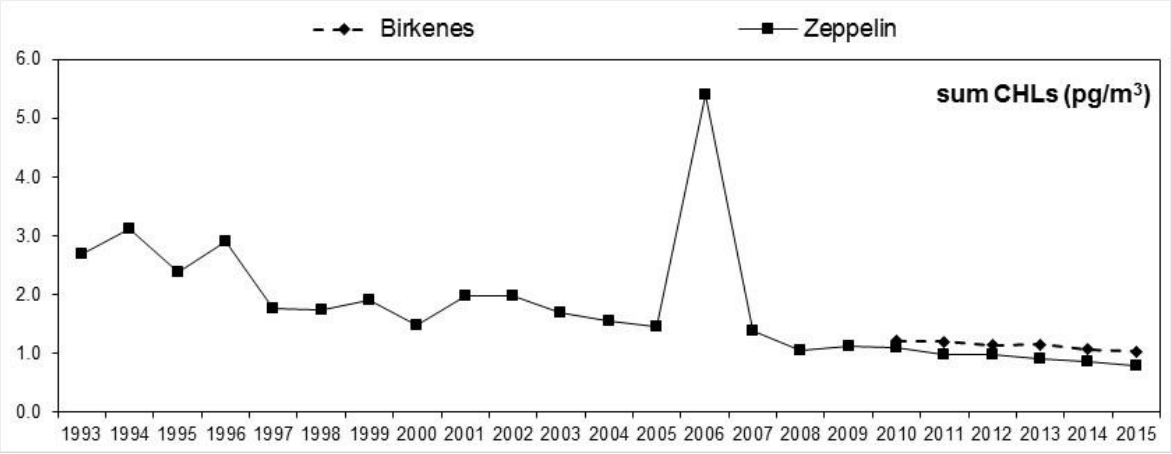

Figure 3.7: Annual mean concentrations of sum CHLs (pg/m^3) in air.

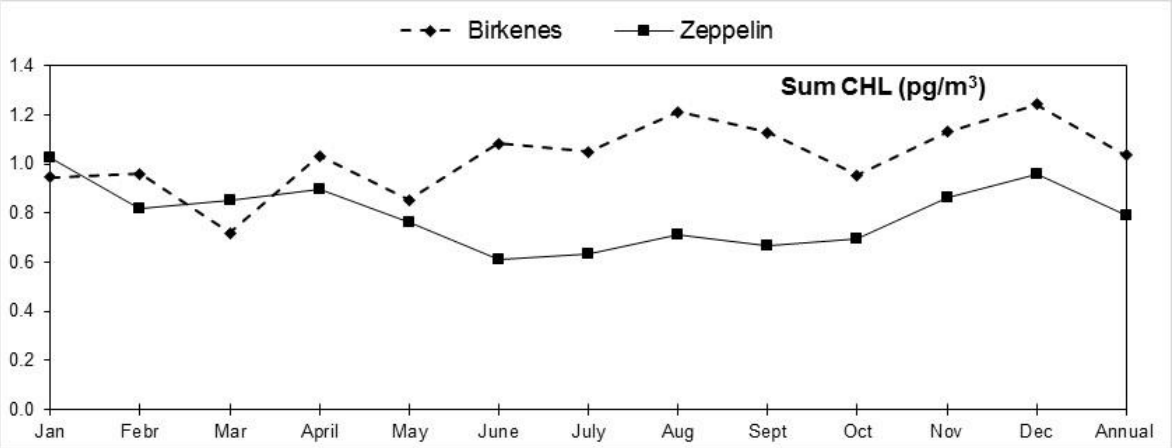

Figure 3.8: Monthly and annual mean concentrations (pg/m3) of sum CHL in air for 2015.

3.1.5 Polychlorinated biphenyls (PCBs)

PCBs are industrially produced chemicals that have been used in a variety of industrial applications. They have been banned from active use in most countries since the mid-1970s and were further banned by the Aarhus protocol (UN/ECE, 1998b) and the Stockholm Convention 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-32) were measured at all three observatories in 2015. These 32 congeners 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. Data are reported for sum of 32 PCBs (sum PCB-32) as well as PCB-7 (sum PCB-7).

PCBs have been monitored at Zeppelin since 2001 and Andøya since 2009. At Birkenes, the seven indicator PCBs have been monitored since 2004 and all the 32 since 2010.

In 2015, some of the PCB samples were influenced by a PCB contamination during lab procedures (for details see Annex 3). All contaminated samples were consequently blank adjusted with the levels of contamination found in blank samples. These corrections resulted in levels and patterns similar to previous years, but any possible high levels or anomalies to previous years for individual PCBs in this report should be treated cautiously.

The detection frequencies varied among PCB congeners as well as between sites. Generally, high detection frequencies were observed for tri-penta PCBs (until PCB 114) at all sites while some of the penta-hepta PCBs (from PCB 118) were detected to lower extent. As previous years, the tri- and tetra-PCBs were the most common PCBs, comprising 70-80% of sum PCB. The weekly concentrations of sum PCB-32 during 2015 ranged between: 3.0-31 pg/m^3 at Birkenes (including two high episodes 3-4 July and 6-7 November); 1.9-21 pg/m^3 at Andøya (including one-two episodes in August and September); and 6.2-28 pg/m^3 at Zeppelin (excluding one high outlier).

The annual mean concentrations of sum PCB-32 and PCB-7 in 2015 were a factor of two higher at Birkenes and Zeppelin than at Andøya (Figure 3.9:). Reasons for this is unknown. The annual mean concentration at Zeppelin in 2015 is higher than in 2014 while similar as previous years at Birkenes and Andøya. In fact, no decline of the PCBs has been observed since 2010. This suggests that a steady-state condition has been reached for the PCBs.

Up to one order of magnitude higher concentrations of PCB-7 are reported to EMEP from sites in Germany and Czech Republic (Aas 2015).

No clear seasonality was observed for sum PCB-32 and sum PCB-7 at any of the observatories. As previous years the lowest concentrations at Andøya were consistently observed in summertime (June-September) and the highest in wintertime (January-March). In contrast, at Zeppelin the lowest concentrations were consistently found in wintertime (October-January) and the highest individual concentrations were observed in summertime (May-August).

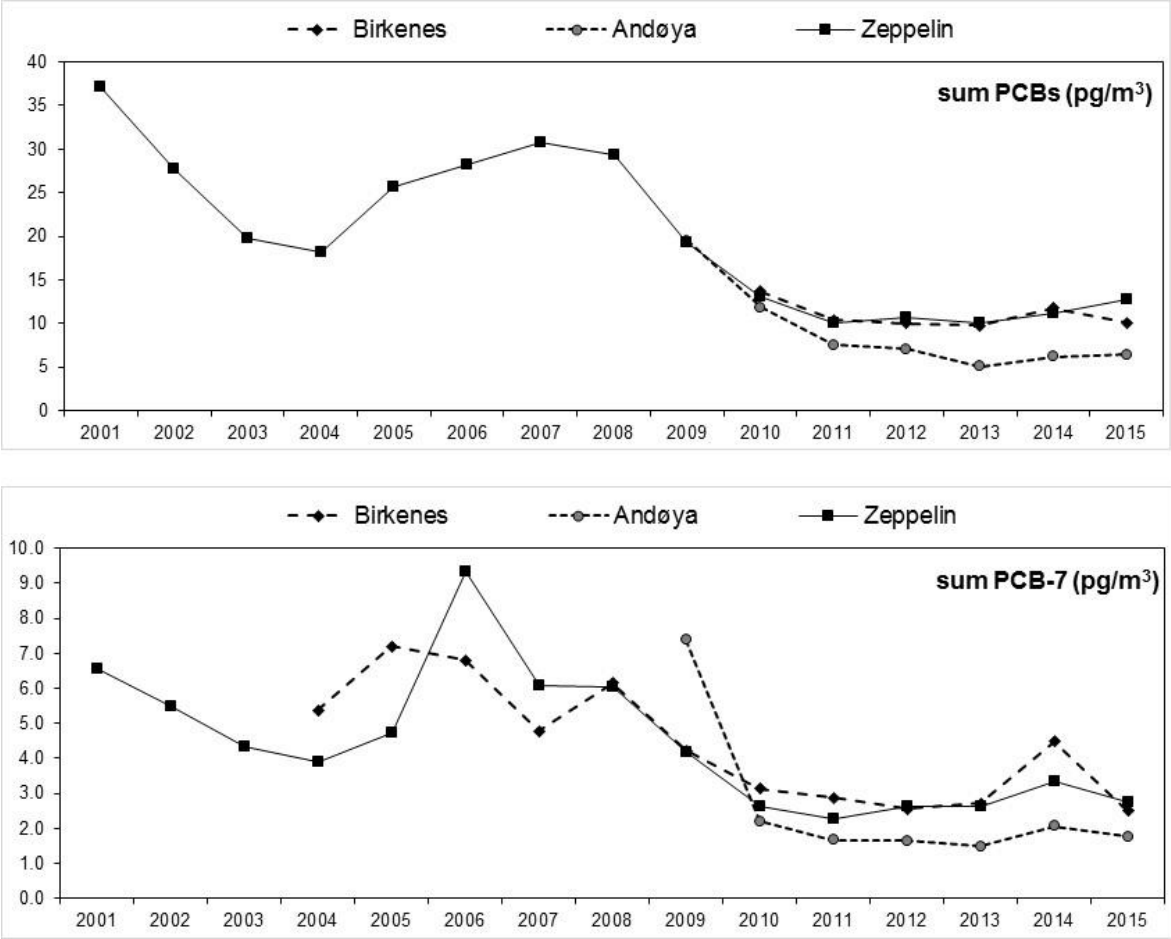

Figure 3.9: Annual mean concentrations of sum PCB-32 and sum PCB-7 (pg/m^3) in air.

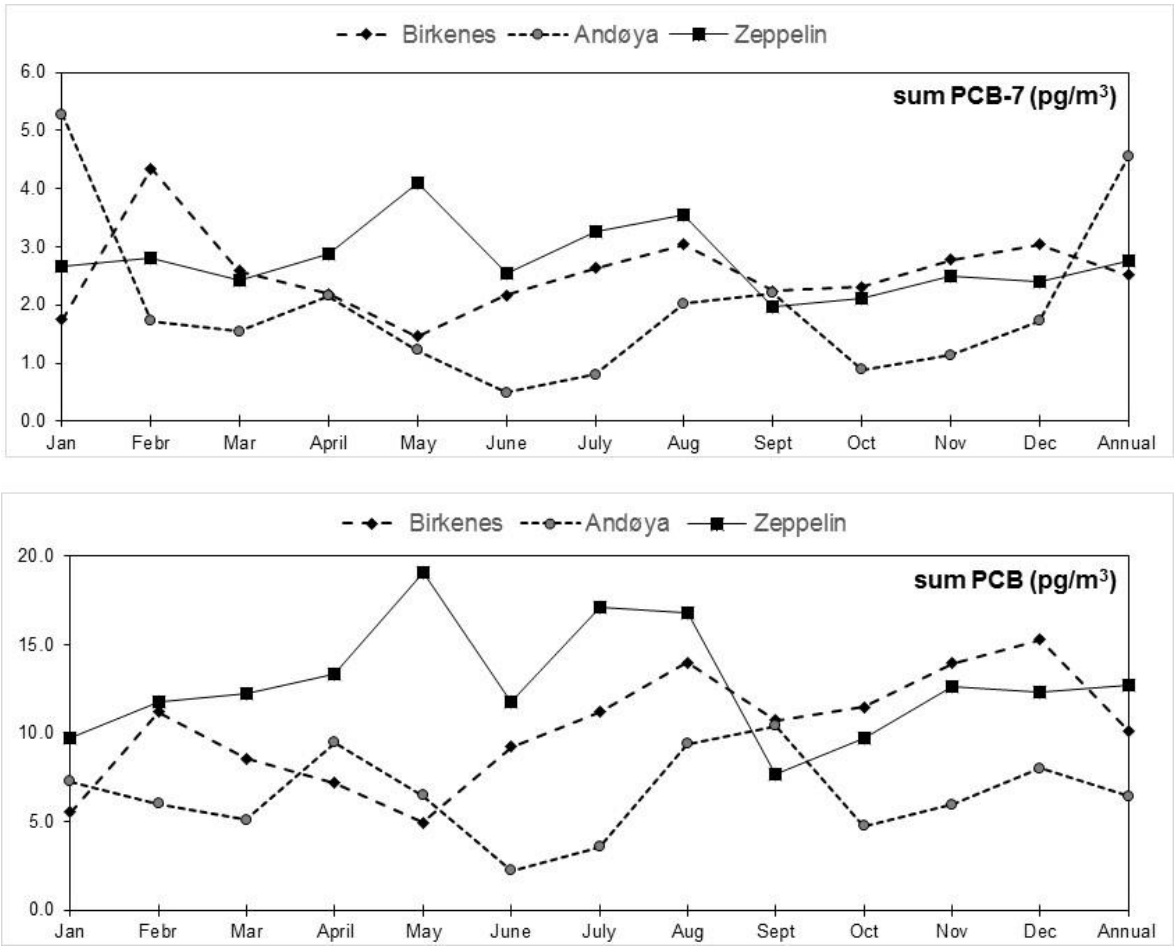

Figure 3.10: Monthly and annual mean concentrations (pg/m^3) of sum PCB-32 and sum PCB-7 in air for 2015.

3.1.6 Polybrominated diphenyl ethers (PBDEs)

PBDEs are industrially produced chemicals that have been and still are used as flame retardants in a wide range of applications including plastics, textiles and electrical and electronic products. The production and use of the commercial PBDE mixtures: penta- and octa-BDE, are regulated by the Aarhus protocol (UN/ECE, 2010) and the Stockholm Convention on POPs (Stockholm Convention, 2013) and are today banned in most countries worldwide. On the other hand, the commercial PBDE mixture, deca-BDE, has not yet been subjected to the same restrictions and is still in use globally. 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. Deca-BDE is currently also being considered for inclusion as a POP in the Stockholm Convention (Stockholm Convention, 2015). A restriction on the manufacturing, use and placing on the market of deca-BDE is further under discussion in the EU.

PBDEs theoretically comprise 209 congeners with different degrees of bromination from tetra- to deca-BDE. 17 of these congeners (=sum PBDEs) have been monitored at Zeppelin since 2006, at Birkenes since 2008, and at Andøya since 2009.

In 2015, some of the PBDE samples were influenced by a contamination for individual PBDEs (47, 66 and 99). The contaminated samples were consequently blank adjusted with the levels

of contamination found in blanks. These corrections resulted in levels and patterns similar to previous years, but any possible high levels or anomalies to previous years for individual PBDEs in this report should be taken cautiously.

The detection frequencies varied among PBDE congeners as well as between sites. Only three of the 17 measured congeners were observed frequently at all sites (i.e. BDE-28, -47, -99). The other congeners, including BDE-209, were below detection limit in more than half of the samples at all sites. The low detection frequency for most of these compounds indicates low concentrations at the monitoring sites. In contrast, the low detection frequency for BDE-209 is instead affected by analytical challenges related to possible contamination that causes elevated detection limits of BDE-209. This is a common issue for analytical laboratories. Despite this, the most abundant congeners were BDE-209 and BDE-47 representing on average 45-75% and 10-35% of sum BDEs. The weekly concentrations of sum PBDEs ranged between: 0.5-8.0 pg/m^3 at Birkenes (including three episodes); 0.08-2.3 pg/m^3 at Andøya (including three-four high episodes); and 0.1-7.4 pg/m^3 at Zeppelin (including three high episodes).

The annual mean concentrations of sum PBDEs in 2015 were two-three times higher at Zeppelin (1.16 pg/m^3) and Birkenes (1.50 pg/m^3) than at Andøya (0.58 pg/m^3) (Figure 3.11:). Higher concentrations at Zeppelin and Birkenes were observed for several congeners while BDE-209 was only higher at Birkenes. The concentrations of sum PBDEs and the individual congeners in 2015 were higher than in 2014 at all sites, but the variability is within annual variability during the last eight years. The lack of significant long-term trends for sum PBDEs and BDE-209 suggest steady-state conditions for the PBDEs.

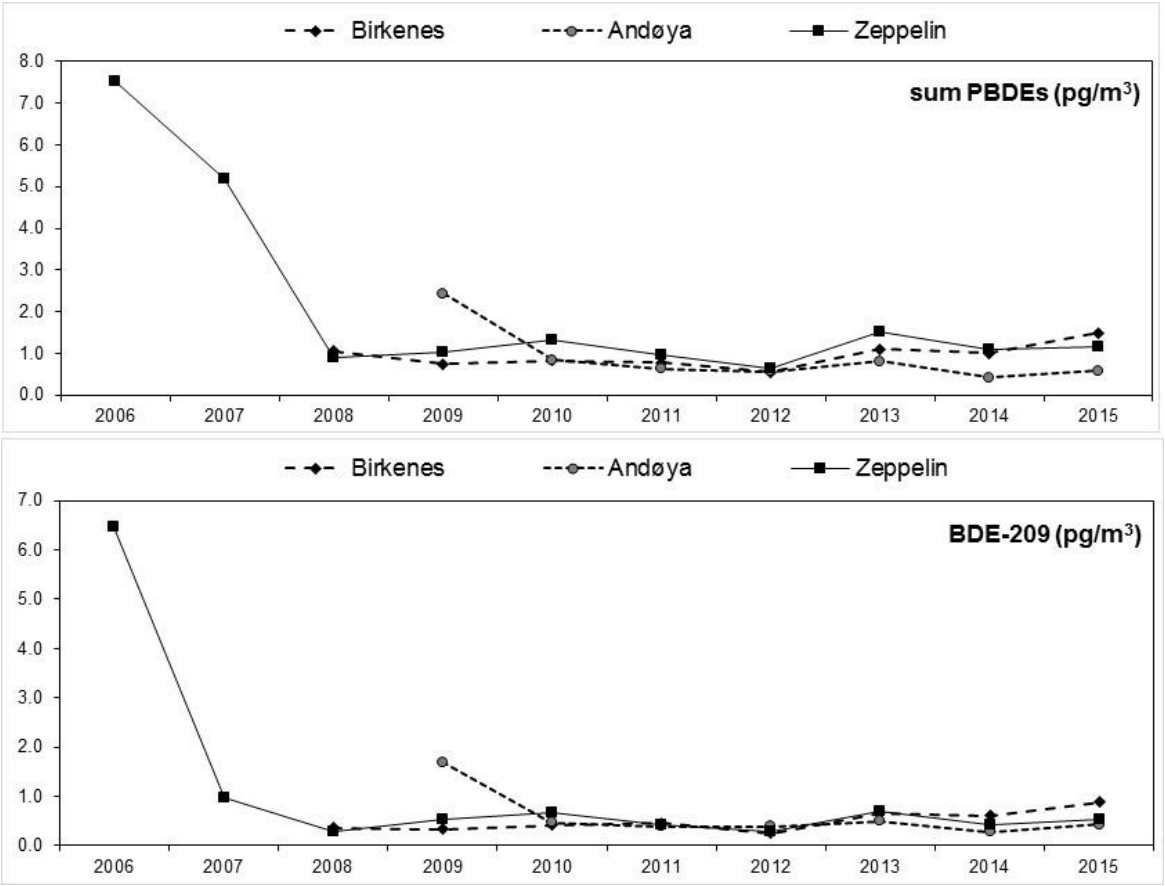

Figure 3.11: Annual mean concentrations of sum PBDEs and BDE-209 (pg/m^3) in air.

The concentrations of sum PBDEs are similar to those observed in the Canada's Western sub-arctic region (Yu et al., 2015), but lower than those measured in Longyearbyen in 2012-2013 (Salamova et al., 2014).

No clear seasonality was observed for sum PBDEs nor for the individual congeners (including BDE-209) at any site, instead the concentrations fluctuated from month to month (Figure 3.12). High levels in February, July and November at Zeppelin as well as February, March and August at Birkenes are due to individual high observations during these months and not a trend for the whole month. The reason for these individual high levels are not known.

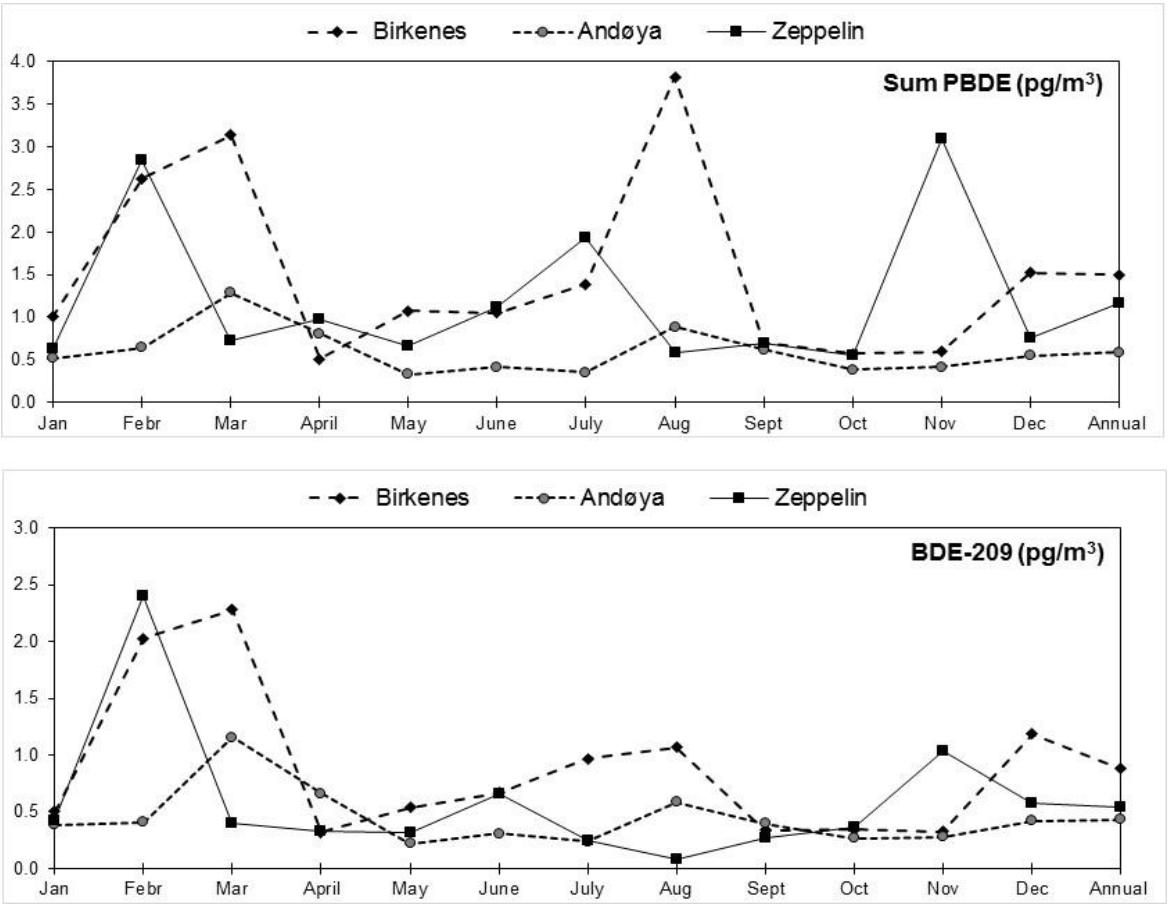

Figure 3.12: Monthly and annual mean concentrations (pg/m^3) of sum PBDE and BDE-209 in air for 2015.

3.1.7 Tribromoanisol (TBA)

TBA is a halogenated natural product (HNP) produced by marine phytoplankton, macro algae, bacteria and some benthic invertebrates or by transformation of bromophenols (natural or used for wood preservation and as an additive fire retardant). It shows POP like characteristics, such as toxic properties, half-lives exceeding the 2 d half-life criterion for long-range transport according to the Stockholm Convention, and have similar structure to other brominated pollutants. As such, it has retrieved attention during the last years both in research and assessment work under AMAP (Wong et al., 2011; Bidleman et al., 2014). AMAP has recognized HNPs (including TBA) as a group of contaminants of emerging concern in the Arctic. Air

measurements of TBA are good indicators for general changes in the HNP picture of oceans as TBA is relatively volatile and transferred from seawater to air.

TBA has been monitored at Birkenes and Zeppelin since 2007 and at Andøya since 2010. TBA was detected in all samples at all sites in 2015 and the weekly concentrations ranged between: 0.9-12 pg/m^3 at Birkenes; 0.8-15 pg/m^3 at Andøya; and 1.4-26 pg/m^3 at Zeppelin. The annual mean concentrations of TBA in 2015 were 4.1, 4.6, and 6.7 pg/m^3 at Birkenes, Andøya and Zeppelin respectively (Figure 3.13:). These are higher than the concentrations in 2014, but are consistent with previous year.

The same seasonal trends were observed at all sites, lowest concentrations during spring and increasing concentrations during the summer and autumn (Figure 3.14). This is in agreement with previous years. The higher levels in summertime may be a consequence of increased algal bloom during this period.

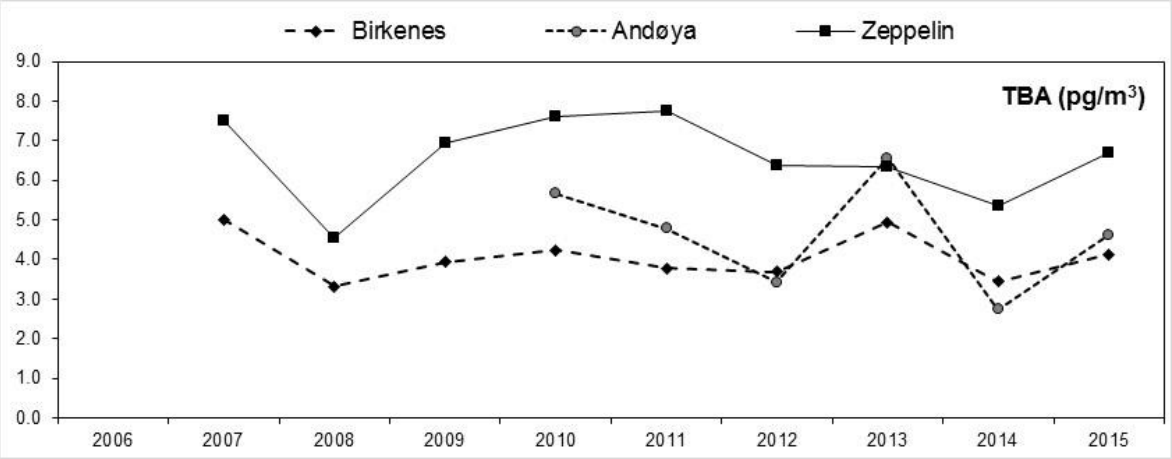

Figure 3.13: Annual mean concentrations of TBA (pg/m3) in air.

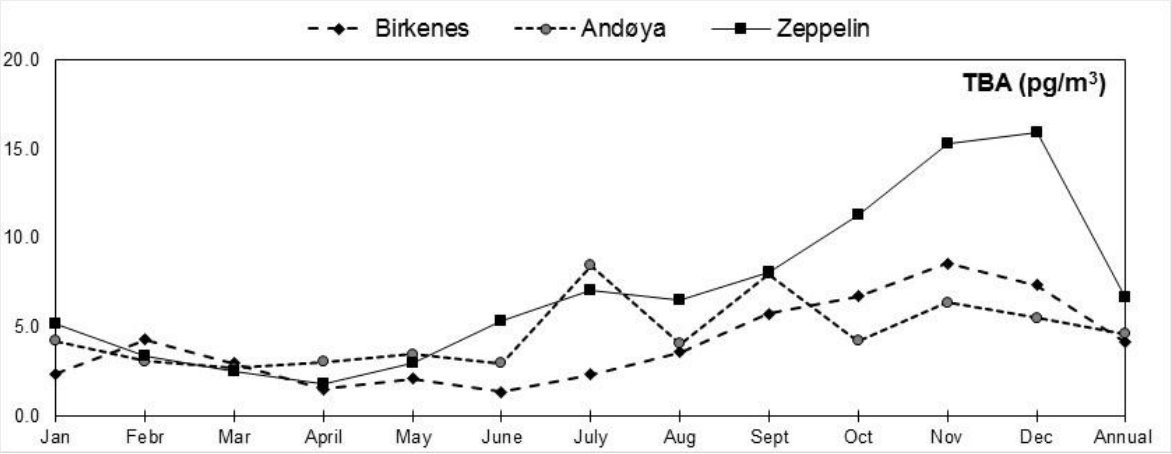

Figure 3.14: Monthly and annual mean concentrations (pg/m^3) of TBA in air for 2015.

3.1.8 Hexabromocyclododecane (HBCD)

HBCD is an additive brominated flame retardant, with many applications. The main use is in extruded and expanded polystyrene used for thermal insulation in building and construction materials. HBCD was listed in the Stockholm Convention on POPs in 2013 with a time-limited exception for production and use in some polystyrene applications. The global ban entered into force in November 2014 (Stockholm Convention, 2013).

The three main diastereomers: α-, ß-, and γ-HBCD (=sum HBCDs) have been monitored at Birkenes and Zeppelin since 2006, but are not included at Andøya. The HBCDs are detected with a low frequency at both sites. Very low concentrations (i.e. levels below detection limit) are observed in a majority of the samples: 60-80% for α- and γ-HBCD, and >90% for ß-HBCD. As a result the monthly and annual mean concentrations will only reflect the analytical limit of detection (i.e. no real air concentrations) and no annual or monthly mean concentrations for 2015 and the previous years are therefore included in this report.

3.1.9 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are mainly produced through incomplete combustion of organic materials, both through antropogenic (i.e. industrial and domestic use) and natural causes. They are regulated in the Aarhus protocol on POPs (UN/ECE, 1998b) and the EU air quality directive (AQD) (EU, 2004). They show POP like characteristics, but are less persistent than those classified as POPs.

Seven methyl-PAH and 32 PAHs (=sum PAHs) including the 16 EPA-PAHs (=sum PAH-16) were measured at Birkenes and Zeppelin during 2015. PAHs have been monitored at Zeppelin since 1994, at Birkenes since 2009, and at Andøya between 2009 and 2012. The detection frequencies varied among PAH compounds and between the sites. Generally, more compounds had low detection frequency and were below detection limit at Zeppelin (~70%) than at Birkenes (~25%). The range of weekly concentrations were smaller than in 2014: 0.7-18 pg/m^3 at Birkenes (including two high episodes: 20-21 January and 29-30 February); and 0.4-9.1 pg/m^3 at Zeppelin. The two high episodes at Birkenes are associated with air masses coming from southern Scandinavia and continental Europe. The annual mean concentrations of sum PAHs and sum PAH-16 in 2015 were, as previous years, about two times higher at Birkenes than at Zeppelin (Figure 3.15:). In contrast to 2014, the annual mean concentrations at Zeppelin and Birkenes in 2015 were lower than those observed in 2013-2014. At Birkenes the observed concentrations were the lowest since the monitoring started in 2009. The levels of benzo(a)pyrene at both stations are two 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 for all PAHs at Zeppelin and Birkenes with up to one order of magnitude higher concentrations in wintertime (November-March) than in summertime (Figure 3.16). The same seasonality was seen both for sum PAHs and the individual PAHs.

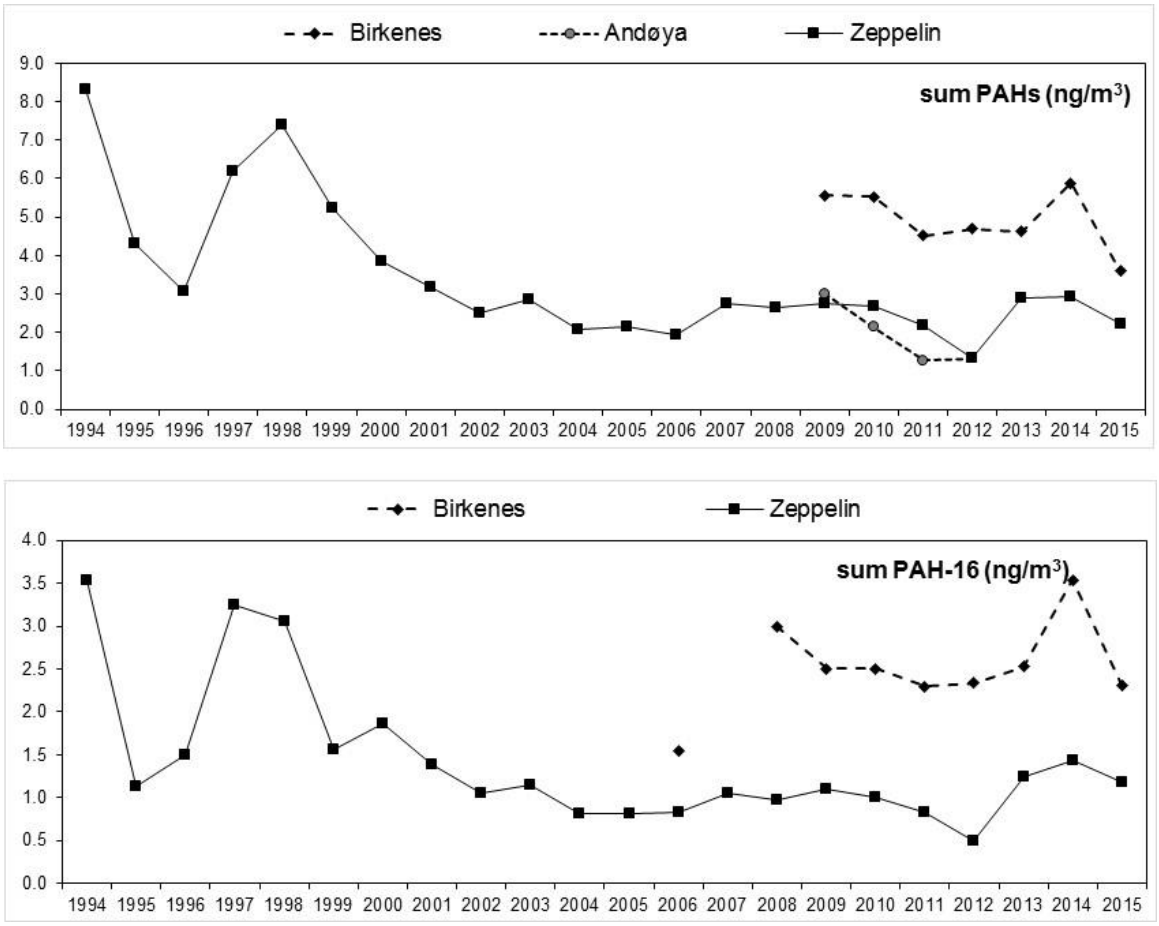

Figure 3.15: Annual mean concentrations of sum PAH and sum PAH-16 (ng/m^3) in air.

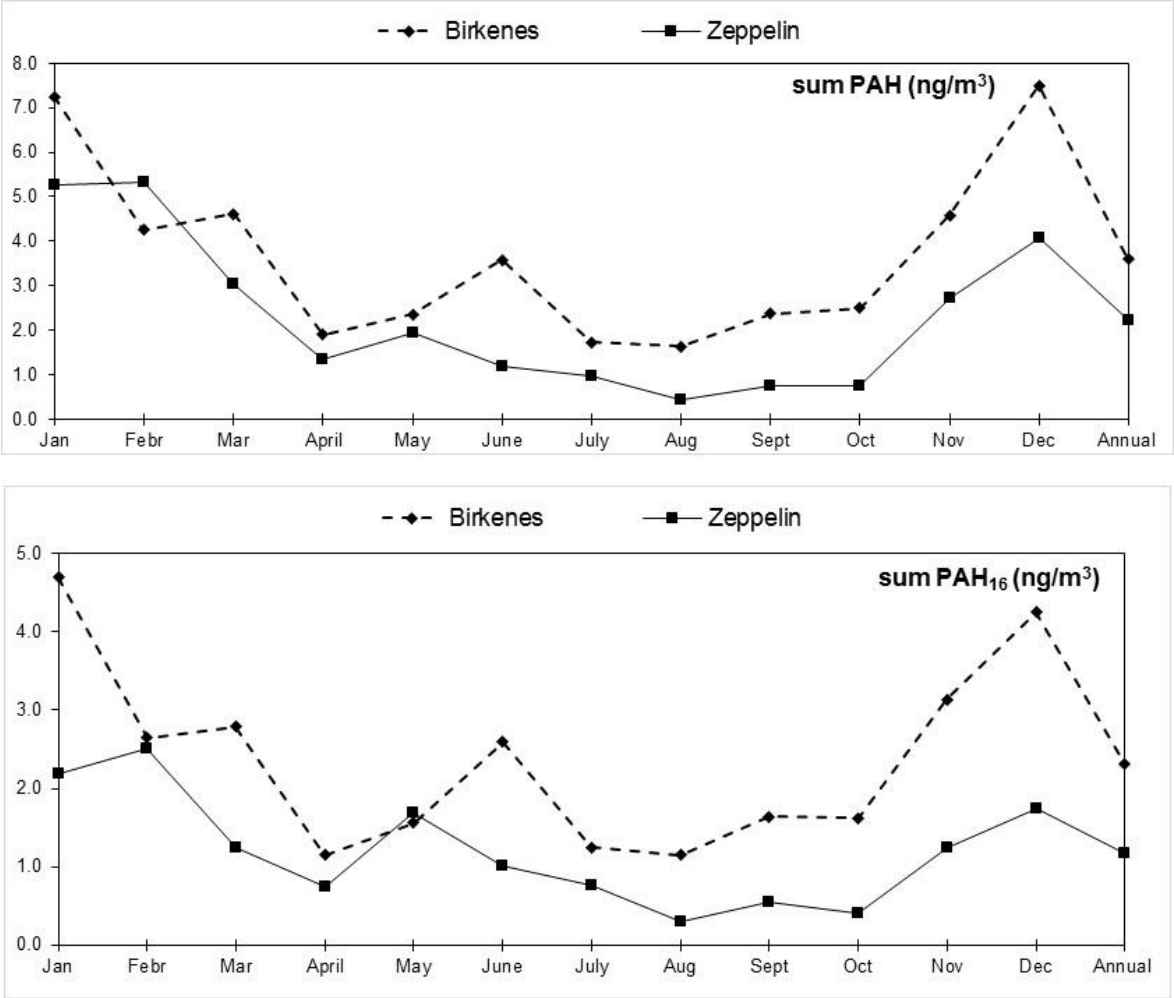

Figure 3.16: Monthly and annual mean concentrations (ng/m³) of sum PAH and sum PAH-16 in air for 2015.

3.1.10 Per- and Polyfluorinated Alkyl Substances (PFASs)

PFASs comprise a large and complex group of industrially produced chemicals: Ionic compounds like perfluoroalkyl sulfonates (PFSO) and perfluoroalkyl carboxylic acids (PFCAs); and neutral, volatile compounds like fluorotelomer alcohols (FTOHs) and N-alkylated fluorooctane sulphonamides and sulfonamidoethanols (FOSAs/FOSEs). During the last 50 years, PFAS compounds such as PFOS, perfluorooctanoic acid (PFOA) and their related products, have been widely used in consumer products. Currently, PFOS together with its salt and perfluorooctane sulfonyl fluoride (PFOS-F) is the only PFAS that is regulated by the Stockholm Convention on POPs (Stockholm Convention, 2013) and the Aarhus protocol (UN/ECE, 2010). However, PFOA is currently being considered for listing as a POP under the Stockholm Convention. In Norway, both PFOS and PFOA are banned, and the C9-C14 PFCAs are on the Norway's Priority List of Hazardous substances ("Prioritetslisten") (Norwegian Environment Agency, 2015)

The monitoring included 12 ionic PFAS compounds (=sum PFASs) at all three stations in 2015: 6:2 FTS (6:2 fluorotelomer sulfonic acid), PFBS (perfluorobutane sulfonic acid), PFHxS (perfluorohexane sulfonic acid), PFOS (perfluorooctane sulfonic acid), PFDcS (perfluorodecane sulfonic acid), PFHxA (perfluoro¬hexanoic acid), PFHpA (perfluoroheptanoic acid), PFOA, PFNA

(perfluorononanoic acid), PFDA (perfluorodecanoic acid,previously called PFDcA), PFUnDA (perfluoroundecanoic acid, previously called PFUnA) and FOSA (perfluorooctane sulphonamide, previously called PFOSA). These 12 PFASs have been monitored at Birkenes and Zeppelin since 2006 and at Andøya since 2009.

Most of the monitored PFASs were below the analytical detection limit in all samples at all sites. Only PFOA was frequently above the detection, with detection frequencies of 60% at Birkenes, 70% at Andøya and 80% at Zeppelin. The weekly concentrations of PFOA ranged from <0.02-0.68 pg/m^3 at the three stations. Homogeneous annual mean concentrations of PFOA were found at all sites; 0.11 pg/m^3 at Birkenes, 0.10 pg/m^3 at Andøya, and 0.11 pg/m^3 at Zeppelin. In addition, PFHxA was detected in ~20% of the samples at Birkenes, Zeppelin and Andøya, and PFHpA and PFNA to some extent (15-20%) at Zeppelin and Andøya respectively. The provided concentrations in Annex 2 should be taken with caution and considered as an upper limit.

As most of the PFASs are below detection limits it is not appropriate to compare the annual mean concentrations of sum PFAS in order to look for time-trends. Nor are the seasonal variations being captured when most of the PFAS compounds are below detection in a majority of the samples. For the compound with detection; i.e. PFOA, the annual mean concentrations in 2015 were the lowest observed since the start of the monitoring in 2006 and 2009 respectively (Figure 3.17). The highest concentrations of PFOA are observed in summertime at Birkenes and Andøya (Figure 3.18). In contrast, at Zeppelin the monthly variations fluctuate over the year.

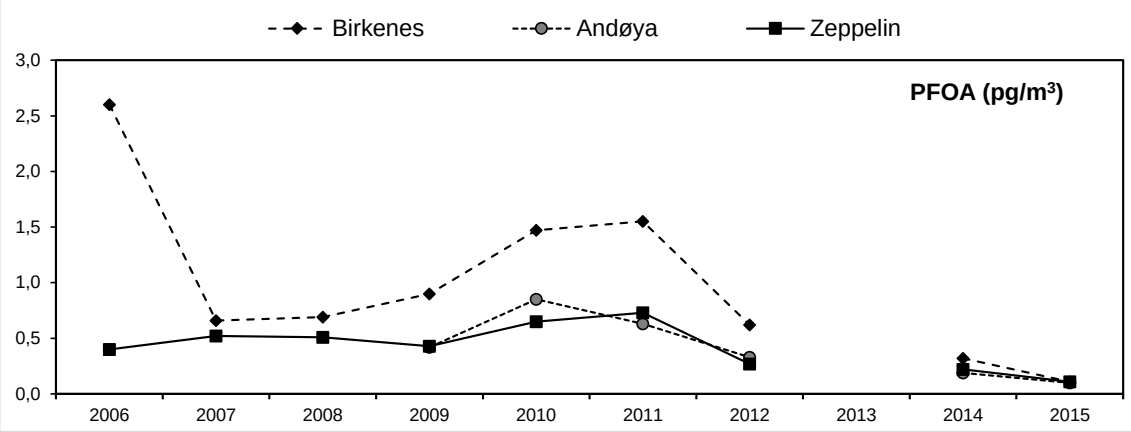

Figure 3.17: Annual mean concentrations of PFOA (pg/m^3) in air.

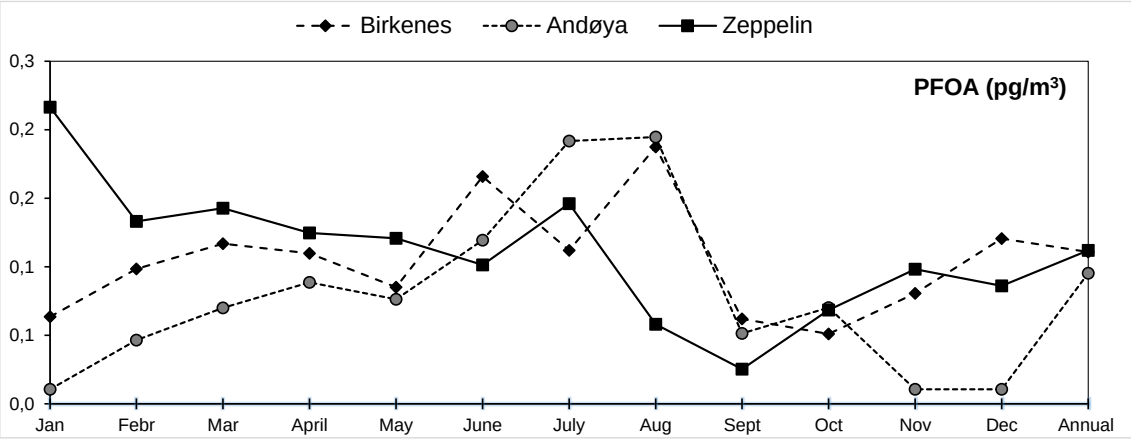

Figure 3.18: Monthly and annual mean concentrations (pg/m^3) of PFOA in air for 2015.

The annual mean concentrations of sum PFASs in 2015 were similar at Andøya and Zeppelin. This is a result of most compounds being below the detection limit at these sites and as such the annual mean concentration reflects the analytical limit of detection. The higher annual mean concentration observed at Birkenes is a result of more compounds being detected at this site and thereby contributing to the sum PFASs concentrations. Higher detection at Birkenes might indicate current use and ongoing emission from anthropogenic applications in populated areas. The lower annual and monthly mean concentrations for sum PFASs in 2015 compared to previous years are results of improved analytical procedures and lowered limits of detection. The concentrations of most of the PFASs have consistently been below the analytical detection limit during all years of monitoring. The higher sum PFAS concentrations detected in the past reflects that the analytical detection limits at the time were higher. In calculations for annual and monthly mean concentrations the concentrations below detection limits are assigned a value equal to LOD/2. As such, improving the LOD results in fictive lower annual and monthly concentrations for sum PFASs.

3.2 Persistent organic pollutants in precipitation

Precipitation samples were as previous years collected at Birkenes and analysed for HCB, α- and γ-HCH, and the seven indicator PCBs (PCB-7) (Annex 3, and Table A.2.6). HCB and HCHs have been monitored since 1992 while PCB-7 since 2006.

The annual mean concentrations of HCB in precipitation in 2015 were similar to those observed during the last eight years. A significant reduction of HCB concentrations was observed during the 1990s and the beginning of 2000 while the concentrations seem to have reached a plateau during the last eight to eleven years (Figure 3.19). No seasonal variability was observed for HCB (Figure 3.20).

The annual mean concentration for sum HCHs was the lowest since the beginning of the monitoring (in 1992) and as in air they followed the decreasing time-trend at Birkenes. A clear seasonality is observed with the highest concentrations during spring- and summertime and the

lowest concentrations during wintertime (December-March). This seasonality is similar to that found for air concentrations at Birkenes.

The annual mean concentration of PCB-7 in 2015 was higher than that observed in 2014, but the same as the previous four years. The highest concentrations were observed in wintertime (November-December), but no clear seasonality was observed.

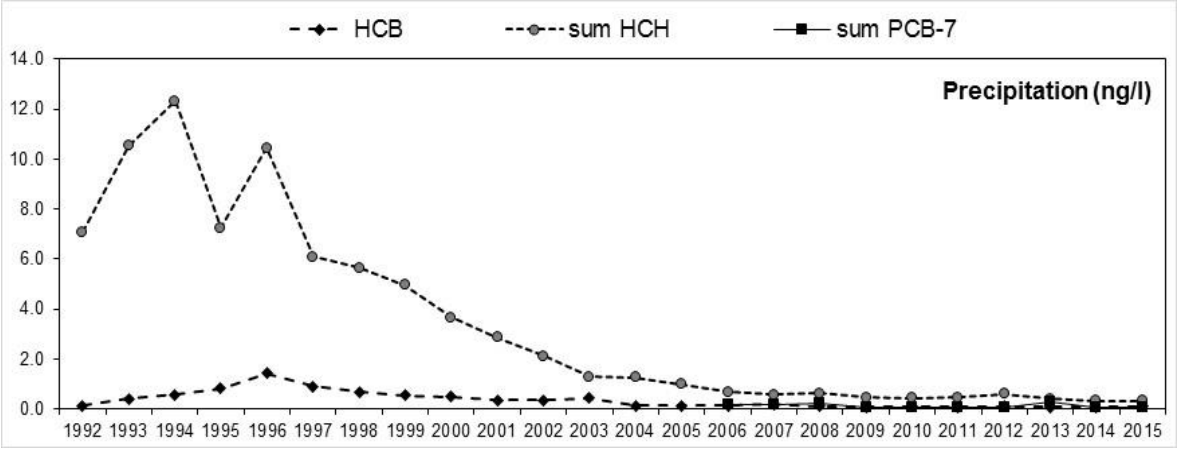

Figure 3.19: Annual mean concentrations of HCB, sum HCH and sum PCB-7 (ng/l) in precipitation.

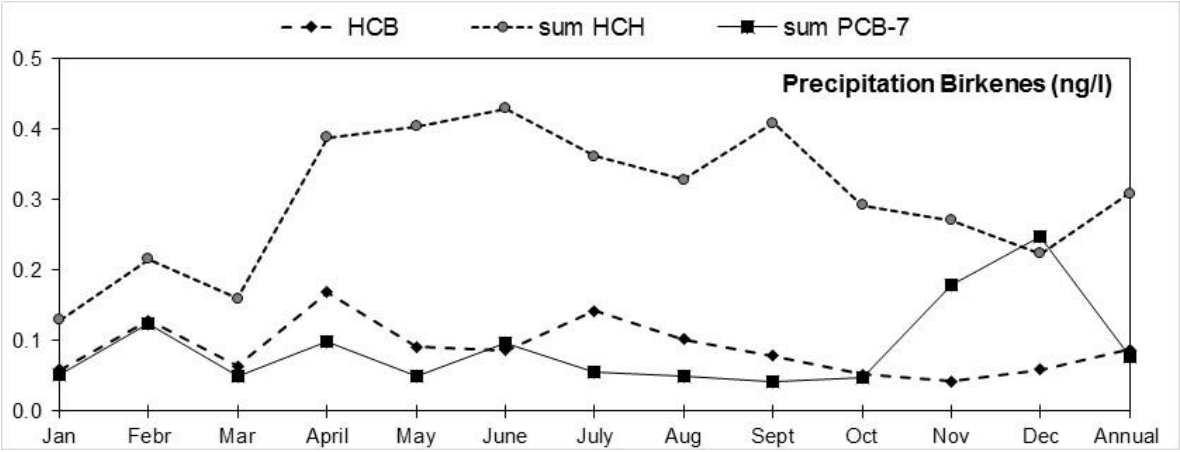

Figure 3.20: Monthly and annual mean concentrations (ng/l) of HCB, sum HCH and sum PCB-7 in precipitation at Birkenes, 2015.

4. Emerging contaminants

4.1 Cyclic volatile methyl siloxanes (cVMS)

cVMS represent a subgroup of a large class of compounds called dimethylsiloxanes, or more commonly referred to as cyclic volatile methyl siloxanes. These compounds are produced in large volumes worldwide and are used in various applications, particularly in cosmetics and personal-care products where they are often referred to as cyclomethicones, although various other trade names exist (Wang et al., 2013). Currently, there are no regulations on the production and use of cVMS within industrial and consumer products. However, the cyclic oligomers octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) have drawn increased attention in recent years from regulatory agencies and the scientific community regarding their environmental persistence (P), bioaccumulation (B), toxicity (T), and long range transport (LRT) potential (Brooke et al., 2009a; Brooke et al., 2009b; Brooke et al., 2009c; Canada, 2008a; Canada, 2008b). There has been much discussion between regulatory agencies, industry, and the scientific community regarding the PBT properties of siloxanes, but proposals for restrictions on use of these chemicals have recently been submitted. For example; on April 15, 2015, the United Kingdom submitted a restriction proposal that D4 and D5 use in wash-off personal care products must not exceed 0.1% within the EU, and the ECHA Member State Committee (MSC) came to an agreement on April 22, 2015 that D4 and D5 meet the criteria for very bioaccumulative (vB) and persistent (vP) substances defined in the REACH Regulation (EC) No 1907/2006 (ECHA, 2015). In addition, D4 and D5 are on Norway's priority substances list with the aim to stop emissions of these compounds by 2020 (Norwegian Environment Agency, 2015). Long-range transport of cVMS to Arctic regions has been suggested by a few studies that have reported their presence in Arctic air (Genualdi et al., 2011; Krogseth et al., 2013), and was supported by mechanistic model simulations (Krogseth et al., 2013). However, it is also important to further study the possible influences of local sources and emissions within the Arctic itself, mainly from increased anthropogenic activities in the area. In addition, despite being present in Arctic air, the cVMS are considered to have a minimal potential to deposit to surface media through wet and dry gaseous or particle deposition due to their inherent volatility (Wania, 2003; Xu and Wania, 2013). cVMS have nonetheless been detetected in arctic biota at Svalbard (Warner et al. 2010; Verreault et al. 2010)

In 2015, measurements of cVMS were carried out in one summer campaign and one winter campaign. Each campaign consisted of seven samples with a sampling time of two to four days each, in total each monitoring campaign covered a period of two to three weeks. All samples from both campaigns were above limits of quantification and the results from these campaigns are presented in Table 4.1. In addition, previous results from air monitoring conducted in 2014, 2013 (Nizzetto et al. 2015; Nizzetto et al., 2014) and 2011 (Krogseth et al., 2013) are included for comparison purposes. The reported concentrations have been corrected for sorbent related degradation during storage using methodology reported by Krogseth et al. (2013), but the data should be considered semi-quantitative. D4 is presented as a range (lower-upper boundary), as it might be present only as a result of storage artifacts.

The annual mean concentrations for 2015 based on the two sampling campaigns were 2.58 ± 1.49 ng/m^3 for D5 and 1.15 ± 0.87 ng/m^3 for D6. These are the highest concentrations observed

so far at Zeppelin (Nizzetto et al., 2014; Krogseth et al., 2013) (Figure 4.1). The measured air concentrations of D5 and D6 are three times higher than the legacy POPs and about one time higher than the PAHs. The highest average concentrations during 2015 were observed in winter time for D5 (3.66 ± 1.27 ng/m3) and in summer time for D6 (1.91 ± 0.50 ng/m3) (Table 4.1, Figure 4.1). The average summer concentrations for both D5 and D6 are more than two times higher than those observed in 2013 and 2011. In contrast, the average winter concentrations are in the same range for all years.

Seasonality in atmospheric concentrations of cVMS can be investigated for 2011, 2013 and 2015 (Figure 4.1). Higher concentrations are observed for D5 during wintertime compared to the summertime. This is attributed to the lower atmospheric concentration of hydroxyl radicals during this time of year, resulting in lower photodegradation (McLachlan et al., 2010). However, the concentrations of D6 have been higher in summertime compared to in wintertime in 2015 as well as in 2013. These findings are opposite to observations in 2011 and were not expected based on known emission profiles and atmospheric behaviour of D5 and D6. Warner et al. (2010) observed higher concentrations of D6 compared to D5 in fish collected near the community of Ny Ålesund located below the Zeppelin station. Although this suggests that a different emission profile for D5 and D6 may occur locally to the aquatic environment, it is unclear if this source will impact atmospheric measurements and is only speculative at this point. These findings highlight the need for future monitoring campaigns to evaluate differences in annual seasonal patterns for D6 as well as to evaluate the influence of possible local sources on the air measurements. This would also contribute to increased understanding of the atmospheric behaviour of D6 which is less well understood than that of D5.

The upper boundary limits for D4 in 2015 (2.06 ± 0.66 ng/m^3) were similar to those reported in 2013 (1.27 ± 0.11 ng/m^3) and 2011 (1.48 ± 0.31 ng/m^3). The data for D4 should be treated with caution as the measured concentrations of D4 might have been affected by degradation effects during storage as shown by Kierkegaard et al. (2013). Thus no firm conclusions can be made regarding the presence of D4 in Arctic air nor any trends in concentration based on findings in this monitoring study.

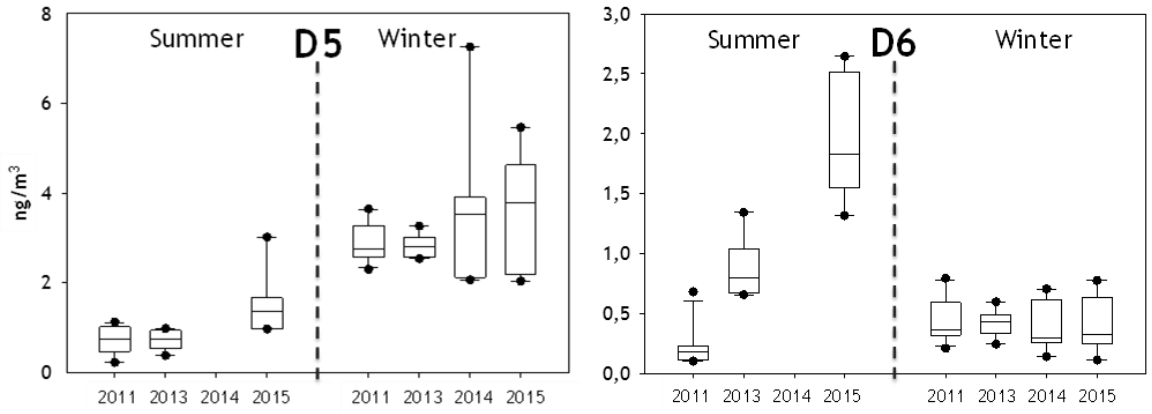

Figure 4.1: Measured concentrations (point estimates) of D5 and D6 at Zeppelin during 2011-2015. The box-plots represent a storage-corrected point-estimate with a 25-75% confidence interval of the storage correction, while the error bars and points represent 5-95 percentile and min/max, respectively.

Table 4.1: Air concentrations of D5 and D6 (ng/m3) from Zeppelin in summer and winter 2015. Concentrations reported represent average of two parallel samples. Data for D4 is reported as a range (lower-upper boundary), and concentrations of D4 are expected to be somewhere below this boundary.

Date		Air concentrations (ng/m³)				
		D4	D5		D6	
Start	***End***	***Range (lower-upper boundary)***	***Point estimate***	***Range (low-high estimate)***	***Point estimate***	***Range (low-high estimate)***
18.07.2015	20.07.2015	n.d-1,58	1,35	0,81-2,25	1,63	0,82-3,24
20.07.2015	23.07.2015	n.d-3,20	3,02	1,90-4,79	2,65	1,42-4,92
23.07.2015	27.07.2015	n.d-1,79	1,50	1,01-2,23	1,89	1,11-3,20
27.07.2015	30.07.2015	n.d-1,22	1,03	0,74-1,42	1,32	0,85-2,04
30.07.2015	03.08.2015	n.d-2,20	1,67	1,29-2,15	2,52	1,79-3,55
03.08.2015	06.08.2015	n.d-1,49	0,97	0,81-1,17	1,55	1,20-1,99
06.08.2015	10.08.2015	n.d-1,51	0,97	0,87-1,10	1,83	1,56-2,14
23.11.2015	25.11.2015	n.d-2,06	4,30	2,79-6,62	0,78	0,43-1,38
25.11.2015	30.11.2015	n.d-1,93	2,18	1,52-3,13	0,11	0,07-0,18
30.11.2015	02.12.2015	n.d-2,65	4,63	3,45-6,21	0,33	0,22-0,48
02.12.2015	04.12.2015	n.d-2,91	5,46	4,23-7,05	0,63	0,45-0,89
04.12.2015	07.12.2015	n.d-2,61	3,21	2,61-3,94	0,31	0,24-0,41
07.12.2015	09.12.2015	n.d-2,65	3,79	3,24-4,44	0,35	0,28-0,43
09.12.2015	11.12.2015	n.d-1,09	2,03	1,81-2,29	0,25	0,21-0,29

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

Chlorinated paraffins (CPs), also referred to as polychlorinated n-alkanes, are semivolatile organic compounds (SVOCs) 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; short chained CPs (SCCPs) with C10-C13, medium chain CPs (MCCPs) with C14-C17, and long chain CPs (LCCPs) with C18-C30. Some of the CPs have been found to be toxic, persistent in the environment, subject to long-range transport and bioaccumulative. Due to their harmful properties SCCPs are included in the Aarhus protocol on POPs (UN/ECE, 2010) and on Norway's priority list (Norwegian Environment Agency, 2015). They are currently also being reviewed by the Stockholm Convention on POPs for a possible inclusion as a POP (Stockholm Convention, 2015). In addition, SCCPs has received wide attention due to their high toxicity to certain aquatic organisms and rodents (UNEP, 2010). Despite this, information regarding levels and distribution of SCCPs in the environment remain limited, mainly due to analytical challenges (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 (C10-C13) and MCCPs (C14-C17) were included in the monitoring programme at Zeppelin in 2013. The monitoring data for M/SCCPs from 2013-2015 are among the first measurements of M/SCCPs in Arctic air. Sampling has been done on a weekly basis in parallel 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, resulting in relatively high LOD values (10-50% of detected masses). In 2015, the LOD for MCCPs were higher than previous years due to elevated levels of MCCPs in both lab and field blanks. This resulted in about 60% of the measurements for MCCPs were below LOD while only 2% of the measurements for SCCPs were below LOD. The presented data should be considered as semi-quantitative.

The annual mean concentrations for 2015 were 420 pg/m^3 for SCCPs and 130 pg/m^3 for MCCPs (Figure 4.2). The high annual mean concentration for MCCPs is a combination of higher LOD in 2015 than previous years and higher individual levels detected occasionally over the year. The levels of S/MCCPs are one to three orders of magnitude higher than the concentrations of most of the other studied POPs, but one order of magnitude lower than concentrations of sum PAHs and sum PAH-16. The annual mean concentrations of SCCPs does not show any significant difference between the three years monitored so far (Figure 4.2). The concentrations of SCCPs and MCCPs measured at Zeppelin in 2013-2015 in this study are similar to those observed in rural air in Canada, but almost three orders of magnitude lower than recent results from urban to rural sites in China and India (Wang et al., 2013, Chaemfa et al., 2014). The monthly mean concentrations in 2015 fluctuated from month to month and were influenced by individual high episodes (Figure 4.3).

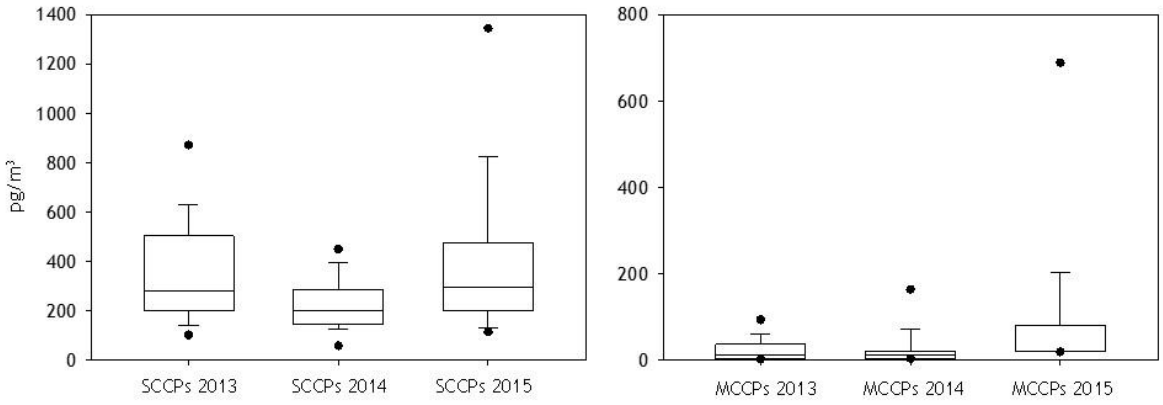

Figure 4.2: Measured concentrations of SCCPs and MCCPs at Zeppelin during 2013-2015. The box-plots represents a range from 25-75% confidence interval while the error bars and points represent 5-95 percentile and min/max, respectively.

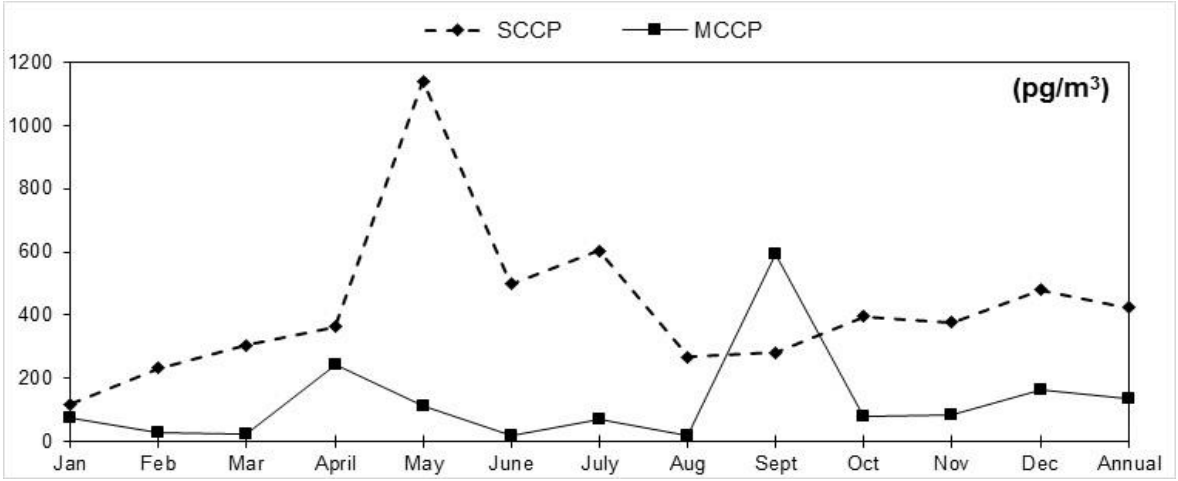

Figure 4.3: Monthly mean concentrations (pg/m³) of short- and medium chained chlorinated paraffins (S/MCCP) in air at Zeppelin, 2015.

5. Conclusions for organic pollutants

The overall annual mean concentrations for the different organic pollutant classes and observatories in 2015 are presented in Table 5.1. In summary, the results from the air monitoring in 2015 show that the concentrations of most legacy POPs in air and precipitation are declining or have stabilized during the last years. The exception is HCB for which an increase in concentrations during the last ten years has been observed at Zeppelin, Svalbard and at Birkenes during the last five years. Figure 5.1 shows that the total concentrations of legacy POPs (excluding PAHs) have been constant during the last six years with stable or fluctuating concentrations for the individual classes from year to year.

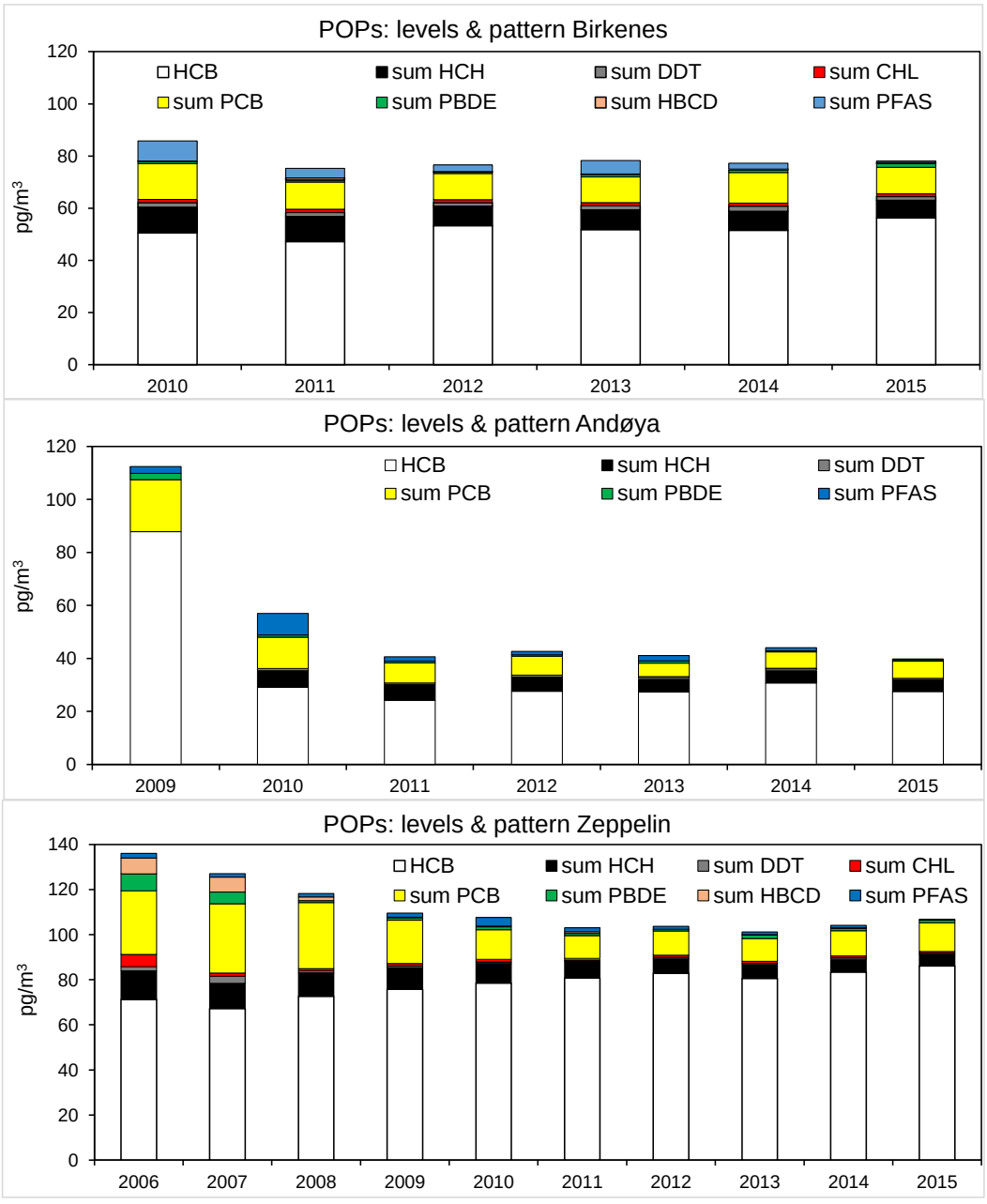

Figure 5.1: Annual mean concentrations in air of sum of regulated POPs (including eight POP classes monitored at Birkenes and Zeppelin, and six POP classes monitored at Andøya) with the pattern of the individual POP classes.

Of all the monitored organic pollutants, the highest concentrations in 2015 were found for D5, followed by D6, SCCP, PAHs, MCCPs and the legacy POPs (Table 5.2 and Figure 5.1). HCB was found at highest level 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, TBA) were observed in similar levels at all observatories. The concentrations of the emerging contaminants cVMS and SCCP/MCCPs were up to three orders of magnitude higher than the concentrations of the legacy POPs (Figure 5.2). The observation of high levels of emerging pollutants at Zeppelin at Svalbard, 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, 2015

pg/m^3	HCB	sum HCH	sum DDT	sum CHL	sum PCB-32	sum PCB-7	sum PBDE	TBA	Sum HBCD'	sum PAH	sum PAH-16	sum PFAS	SCCP	MCCP	cVMS (D4)**	cVMS (D5)	cVMS (D6)
Birkenes	56	6.6	1.5	1.0	10.1	2.5	1.5	4.1	0.2	3600	2300	0.8					
Andøya	28	4.4	0.6		6.4	1.8	0.6	4.6				0.3					
Zeppelin	86	5.2	0.5	0.8	12.7	2.8	1.2	6.7	0.1	2200	1200	0.5	420	130	1900	2600	1200

*More than 50% of the samples below detection limit.

**Uncertainity of data, to be treated with care.

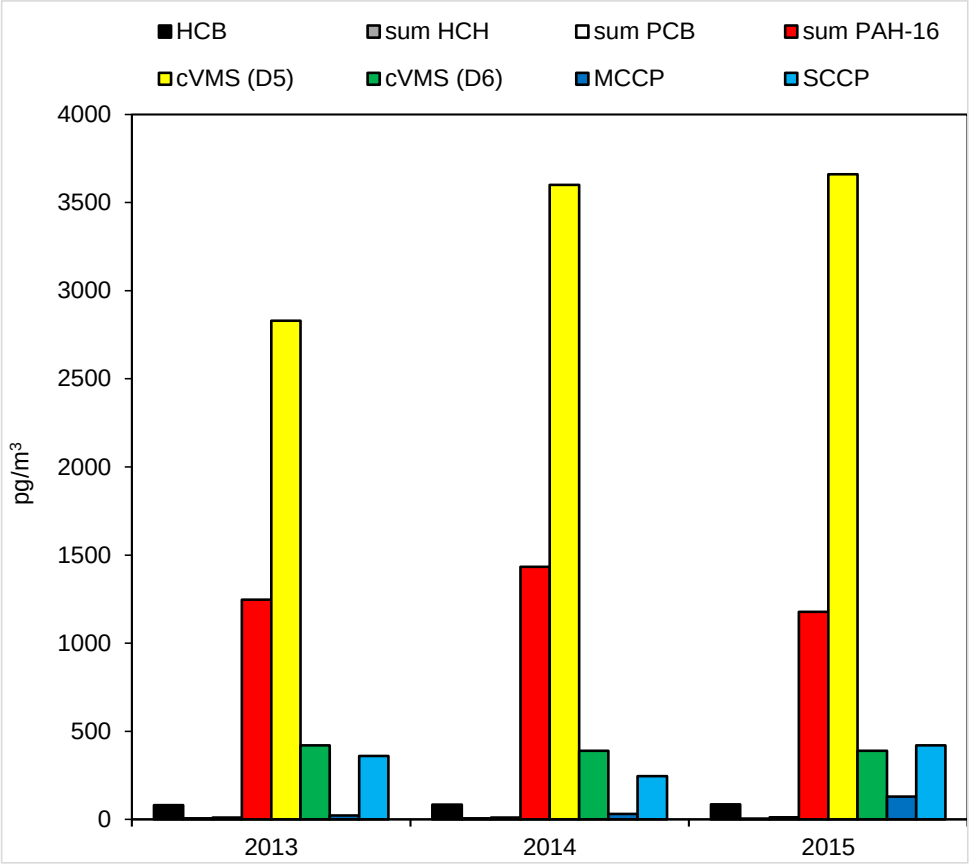

Figure 5.2: Comparison of annual mean concentrations at Zeppelin for the non-regulated cVMS and S/MCCPs and four classes of regulated POPs.

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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 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.34	0.97	0.52	2.91	0.65	0.19	0.73	2.24	0.68	1.15	0.39	0.84	0.84
Hurdal	0.23	0.93	0.29	0.81	0.27	0.28	0.91	1.26	0.2	0.61	0.4	0.51	0.49
Kårvatn	0.45	0.12	0.12	0.29	0.14	0.45	0.61	0.41	0.16	0.11	0.09	0.06	0.26
Svanvik	0.81	0.45	0.78	0.68	0.45	1.41	1.69	10.84	1.71	1.61	1.76	2.01	1.93

Table A.1.2: Monthly and annual volume weighted mean concentrations of cadmium in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.013	0.028	0.021	0.032	0.009	0.004	0.011	0.017	0.018	0.035	0.01	0.017	0.016
Hurdal	0.012	0.033	0.02	0.05	0.012	0.013	0.016	0.146	0.01	0.033	0.017	0.024	0.03
Kårvatn	0.046	0.013	0.003	0.007	0.005	0.007	0.01	0.025	0.003	0.003	0.005	0.006	0.01
Svanvik	0.098	0.038	0.045	0.035	0.02	0.038	0.096	0.624	0.071	0.016	0.044	0.033	0.084

Table A.1.3: Monthly and annual volume weighted mean concentrations of zinc in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OKT	NOV	DES	2015
Birkenes	4.4	6.3	6.3	11.6	2.6	1.3	2.2	3.4	2.6	5.7	2.3	3.7	3.7
Hurdal	7	11	7.3	36.3	4.6	6.4	5.2	3.5	2.9	14.3	5.6	7.7	6.3
Kårvatn	1.5	1.4	1	2	2.2	4	2.3	4.3	1.7	2.2	1.7	2.6	2.2
Svanvik	3.7	7.6	13.9	3.1	6.2	3.2	4.9	6	4.2	3.4	16.5	2.7	5

Table A.1.4: Monthly and annual volume weighted mean concentrations of nickel in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.14	0.18	0.22	0.44	0.03	0.08	0.1	0.21	0.19	0.19	0.08	0.16	0.15
Svanvik	32.1	17.77	6.03	19.39	9.03	27.75	103.5	75.67	57.64	7.16	14.07	4.67	29.27

Table A.1.5: Monthly and annual volume weighted mean concentrations of arsenic in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.04	0.1	0.07	0.1	0.05	0.05	0.09	0.08	0.11	0.17	0.07	0.1	0.08
Svanvik	1.31	0.4	0.34	0.7	0.39	0.95	3	9.09	1.97	0.36	0.45	0.24	1.49

Table A.1.6: Monthly and annual volume weighted mean concentrations of copper in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.53	1.02	0.92	10.52	0.91	0.5	1.09	1.85	1.53	1.18	0.57	1.66	1.33
Svanvik	51.62	16.83	14.03	22.43	8.21	32.38	111.69	80.76	65.19	9.97	19.28	8.2	33.54

Table A.1.7: Monthly and annual volume weighted mean concentrations of cobalt in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.01	0.01	0.01	0.06	0.01	0.02	0.02	0.05	0.08	0.02	0.01	0.02	0.03
Svanvik	1.13	0.55	0.19	0.62	0.32	0.81	3.12	2.22	1.71	0.21	0.38	0.14	0.89

Table A.1.8: Monthly and annual volume weighted mean concentrations of chromium in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.23	0.06	0.07	0.32	0.07	0.1	0.18	0.21	0.27	0.07	0.04	0.13	0.16
Svanvik	0.21	0.14	0.21	0.3	0.23	0.33	0.95	0.64	0.62	0.16	0.22	0.2	0.36

Table A.1.9: Monthly and annual volume weighted mean concentrations of manganese in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.5	0.61	0.69	2.74	1.13	1.69	2.44	3.41	4.19	3.54	0.48	0.89	1.99

Table A.1.10: Monthly and annual volume weighted mean concentrations of vanadium in precipitation at Norwegian background stations 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	0.08	0.12	0.08	0.31	0.11	0.14	0.12	0.29	0.53	0.27	0.08	0.24	0.23
Svanvik	1.55	0.67	0.45	0.5	0.28	0.34	0.58	0.72	0.85	0.22	0.35	0.32	0.47

Table A.1.11: Monthly and annual volume weighted mean concentrations of aluminium in precipitation at Svanvik, 2015. Unit: µg/l.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Svanvik	16.97	9.24	8.79	45.01	29.61	36.93	68.37	39.52	61.69	26.35	40.36	9.28	35.19

Table A.1.12: Monthly and annual average volume weighted mean concentrations of mercury in precipitation at Birkenes in 2015. Unit: ng/L

Station	Jan	Febr	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	2015
Birkenes	4.0	6.5	3.7	29.6	37.5	10.1	2.3	3.1	2.6	5.7	2.2	2.9	6.5

Table A.1.13: Annual and monthly total precipitation in 2015, measured using the bulk collector which is used for sampling of heavy metals. Unit mm.

	Jan	Febr	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	2015
Birkenes	281	158	99	36	203	78	147	190	387	62	87	192	1920
Hurdal	154	77	80	24	197	59	96	126	198	16	82	85	1196
Kårvatn	105	114	139	154	104	164	150	64	142	55	92	138	1422
Svanvik	11	5	18	40	62	49	25	37	34	45	7	32	363

Table A.1.14: Monthly- and annual wet deposition of lead at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	95	153	52	105	132	15	108	426	263	71	34	161	1614
Hurdal	36	72	24	20	53	16	87	159	39	10	33	43	591
Kårvatn	48	14	17	44	15	74	91	26	23	6	8	8	373
Svanvik	8	2	14	27	28	69	43	397	57	72	12	64	699

Table A.1.15: Monthly- and annual wet deposition of cadmium at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	3.7	4.4	2.1	1.1	1.8	0.3	1.6	3.2	7	2.2	0.9	3.3	31.5
Hurdal	1.9	2.5	1.6	1.2	2.4	0.8	1.5	18.4	2	0.5	1.4	2	36.3
Kårvatn	4.9	1.5	0.5	1.1	0.6	1.1	1.5	1.6	0.5	0.1	0.5	0.8	14.7
Svanvik	1	0.2	0.8	1.4	1.2	1.9	2.4	22.9	2.4	0.7	0.3	1.1	30.5

Table A.1.16: Monthly- and annual wet deposition of zinc at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	1230	999	620	417	527	102	317	652	990	351	200	715	7119
Hurdal	1080	846	582	887	905	382	496	444	566	236	456	658	7537
Kårvatn	155	157	145	303	231	663	351	273	241	122	160	363	3164
Svanvik	39	41	248	125	383	154	124	218	140	154	110	85	1807

Table A.1.17: Monthly- and annual wet deposition of nickel at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	40	29	22	16	6	6	15	40	72	12	7	31	296
Svanvik	338	94	108	781	557	1349	2614	2774	1933	321	94	148	10621

Table A.1.18: Monthly- and annual wet deposition of arsenic at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	13	16	7	4	10	4	13	16	43	10	6	19	161
Svanvik	14	2	6	28	24	46	76	333	66	16	3	8	541

Table A.1.19: Monthly- and annual wet deposition of copper at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	149	161	91	379	185	39	160	352	590	73	49	318	2548
Svanvik	543	89	251	903	506	1574	2821	2961	2186	447	128	260	12171

Table A.1.20: Monthly- and annual wet deposition of cobalt at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	2	2	1	2	3	2	2	9	32	1	0	4	61
Svanvik	12	3	3	25	20	39	79	81	57	9	3	5	322

Table A.1.21: Monthly- and annual wet deposition of chromium at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	65	10	7	12	14	8	26	39	103	5	4	25	316
Svanvik	2	1	4	12	14	16	24	24	21	7	1	6	130

Table A.1.22: Monthly- and annual wet deposition of manganese at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	140	97	69	99	230	132	359	648	1622	218	42	171	3826

Table A.1.23: Monthly- and annual wet deposition of vanadium at Norwegian background stations 2015. Unit: µg/m^2.

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Birkenes	22	19	8	11	22	11	18	55	207	16	7	46	442
Svanvik	16	4	8	20	17	17	15	26	29	10	2	10	171

Table A.1.24: Monthly and annual wet deposition of mercury at Birkenes in 2015. Unit: ng/m^3

Station	Jan	Febr	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	2015
Birkenes	984	911	319	1054	5840	934	377	690	1430	562	314	611	14024

Table A.1.25: Annual average volume weighed mean concentration of heavy metals in precipitation at Norwegian background sites, 1976, aug 1978-june 1979; 1980 (febr - dec), 1981-2015

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	0.6	0.015	5.3	0.21	0.05	1.00	0.02	0.06	0.21		5.5
	2014	1.12	0.025	5.0	0.16	0.1	1.35	0.01	0.06	0.21		4.8
	2015	0.84	0.016	3.7	0.15	0.08	1.33	0.03	0.16	0.23		6.5

Table A.1.25, 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
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								
	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								
	2014	0.58	0.026	6.4								
	2015	0.49	0.03	6.3								
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								

Table A.1.25, 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
Kårvatn	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								
	2014	0.31	0.013	2.9								
	2015	0.26	0.010	2.2								
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			
	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	

Table A.1.25, 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
	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	
	2014	1.13	0.065	5.2	17.7	1.21	28.7	0.52	0.22	0.48	22	
	2015	1.93	0.084	5	29.3	1.49	33.5	0.89	0.36	0.47	35	

Table A.1.26: 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.1.26, 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
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.1.27: Monthly and annual averge mean concentrations of heavy metals in PM10 and mercury in gas phase at Birkenes in 2015. Unit: ng/m³

	As	Cd	Cr	Co	Cu	Pb	Ni	V	Zn	Hg(g)
Jan	0.07	0.017	0.23	0.007	0.20	0.25	0.13	0.05	1.7	1.46
Febr	0.12	0.027	0.30	0.009	0.39	0.79	0.12	0.09	2.9	1.57
March	0.19	0.050	0.95	0.024	0.62	1.27	0.25	0.22	6.2	1.47
Apr	0.17	0.019	0.26	0.018	0.44	0.62	0.19	0.15	2.7	1.59
May	0.10	0.011	0.20	0.011	0.69	0.45	0.15	0.17	3.5	1.29
June	0.18	0.017	0.94	0.017	0.63	0.59	0.17	0.14	4.5	1.43
July	0.12	0.015	1.44	0.011	0.36	0.48	0.20	0.27	1.7	1.58
Aug	0.18	0.021	0.66	0.023	0.50	0.77	0.31	0.49	4.2	1.57
Sept	0.19	0.025	0.39	0.009	0.38	0.73	0.19	0.25	4.5	1.59
Oct	0.36	0.044	0.86	0.015	0.64	1.21	0.24	0.29	5.6	1.44
Nov	0.17	0.024	0.77	0.008	0.41	0.67	0.13	0.10	4.7	1.51
Dec	0.12	0.031	1.74	0.019	0.66	0.93	0.20	0.28	5.9	1.62
2015	0.16	0.025	0.73	0.014	0.50	0.73	0.19	0.21	4.0	1.51

Table A.1.28: Monthly and annual averge mean concentrations of heavy metals in aerosols and mercury in gas phase at Andøya in 2015. Unit: ng/m³

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
Jan	0.09	0.022	0.10	0.007	0.29	0.51	0.34	0.14	0.14	1.6	1.57
Febr	0.13	0.019	0.17	0.014	0.21	0.84	0.42	0.28	0.34	1.5	1.58
March	0.09	0.029	0.13	0.012	0.30	0.51	0.57	0.18	0.15	1.8	1.47
Apr	0.05	0.009	0.04	0.007	0.05	0.24	0.32	0.04	0.08	0.6	1.56
May	0.08	0.007	0.05	0.008	0.10	0.19	0.22	0.04	0.08	0.7	1.47
June	0.09	0.005	0.05	0.004	0.10	0.18	0.03	0.08	0.14	0.7	1.49
July	0.03	0.003	0.07	0.004	0.07	0.05	0.10	0.08	0.10	0.3	1.50
Aug	0.04	0.004	0.09	0.006	0.24	0.15	0.14	0.13	0.12	0.5	1.54
Sept	0.05	0.012	0.07	0.005	0.37	0.40	0.25	0.09	0.10	1.0	1.49
Oct	0.02	0.003	0.05	0.003	0.09	0.09	0.02	0.03	0.06	0.4	1.52
Nov	0.02	0.001	0.05	0.001	0.07	0.05	0.07	0.01	0.04	0.2	1.48
Dec	0.02	0.002	0.08	0.002	0.20	0.07	0.29	0.03	0.03	0.3	1.46
2015	0.06	0.010	0.08	0.006	0.17	0.28	0.23	0.10	0.11	0.8	1.50

Table A.1.29: Monthly and annual averge mean concentrations of heavy metals in aerosols and mercury in gas phase at Zeppelin mountain in 2015. Unit: ng/m³

	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg(g)
Jan	0.07	0.013	0.18	0.009	0.20	0.47	0.46	0.11	0.06	1.0	1.56
Febr	0.19	0.025	0.53	0.023	0.50	0.72	1.35	0.34	0.13	4.8	1.52
March	0.06	0.012	0.13	0.006	0.15	0.33	0.47	0.08	0.05	1.0	1.53
Apr	0.24	0.028	0.14	0.010	0.20	0.65	0.51	0.12	0.08	2.0	1.39
May	0.03	0.004	0.10	0.006	0.20	0.12	0.30	0.07	0.04	0.7	1.34
June	0.02	0.003	0.06	0.006	0.64	0.04	0.49	0.11	0.03	2.4	1.67
July	0.02	0.003	0.08	0.003	0.14	0.03	0.15	0.05	0.03	0.4	1.73
Aug	0.01	0.002	0.04	0.002	0.04	0.02	0.06	0.01	0.02	0.3	1.53
Sept	0.01	0.001	0.09	0.004	0.08	0.02	0.18	0.04	0.02	0.2	1.37
Oct	0.02	0.004	0.13	0.015	0.59	0.10	0.51	0.10	0.05	1.00	1.37
Nov	0.03	0.004	0.15	0.012	0.36	0.16	0.46	0.09	0.07	1.0	1.40
Dec	0.03	0.006	0.11	0.011	0.22	0.17	0.45	0.06	0.06	0.6	1.52
2015	0.07	0.010	0.16	0.009	0.29	0.26	0.49	0.11	0.06	1.4	1.49

Table A.1.30: 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		
	2014	0.21	0.033	0.18	0.025	0.59	0.88		0.40	0.45	4.5	1.53		
	2015	0.16	0.025	0.73	0.014	0.50	0.73		0.19	0.21	4.0	1.51		

Table A.1.30, cont.

Site	Year	As	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Hg (g)	Hg (part)	RGM Apr-May
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		
	2014	0.07	0.025	0.10	0.037	0.25	0.28	0.46	0.13	0.15	1.3	1.50		
	2015	0.06	0.010	0.08	0.006	0.17	0.28	0.23	0.10	0.11	0.8	1.50		
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		
	2014	0.05	0.012	0.14	0.012	0.22	0.22	0.60	0.14	0.06	1.7	1.48		
	2015	0.07	0.010	0.16	0.009	0.29	0.26	0.49	0.11	0.06	1.4	1.49		

Annex 2

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

Table A.2.1: Monthly and annual mean concentrations (pg/m^3) for organochlorine pesticides (OCPs) in air at Birkenes, 2015.

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
HCB	66.14	66.78	67.58	55.28	61.00	41.39	45.80	42.31	45.52	58.28	59.83	65.79	56.31
α-HCH	2.50	2.60	3.20	3.08	3.30	4.45	5.00	6.22	6.39	5.55	3.81	3.57	4.15
γ-HCH	0.87	1.80	1.75	2.46	1.55	2.94	4.27	4.27	3.04	2.00	2.92	1.94	2.47
sum HCHs	3.37	4.40	4.95	5.54	4.86	7.39	9.27	10.49	9.43	7.56	6.74	5.51	6.62
cis-CD	0.36	0.35	0.27	0.39	0.36	0.47	0.46	0.55	0.46	0.41	0.41	0.45	0.42
cis-NO	0.02	0.02	0.02	0.04	0.03	0.05	0.05	0.06	0.06	0.03	0.03	0.03	0.04
trans-CD	0.22	0.24	0.17	0.20	0.14	0.14	0.14	0.14	0.14	0.14	0.23	0.27	0.18
trans-NO	0.34	0.35	0.26	0.41	0.33	0.42	0.40	0.46	0.47	0.37	0.46	0.49	0.40
sum CHLs	0.95	0.96	0.72	1.03	0.85	1.08	1.05	1.21	1.13	0.95	1.13	1.24	1.04
pp-DDT	0.09	0.13	0.16	0.12	0.10	0.22	0.26	0.46	0.28	0.30	0.29	0.15	0.21
op-DDT	0.12	0.16	0.21	0.15	0.09	0.17	0.20	0.36	0.27	0.23	0.26	0.18	0.20
pp-DDE	0.84	1.09	1.23	0.64	0.42	0.51	0.56	0.91	1.10	1.34	2.43	1.21	1.01
op-DDE	0.08	0.09	0.09	0.07	0.04	0.03	0.03	0.04	0.04	0.06	0.08	0.08	0.06
pp-DDD	<0.02	<0.01	<0.02	<0.02	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
op-DDD	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.03	<0.02	0.19	<0.02	<0.03	<0.02
sum DDTs	1.17	1.49	1.73	1.00	0.68	0.97	1.06	1.82	1.73	1.96	3.10	1.67	1.51

Table A.2.2: Monthly and annual mean concentrations (pg/m^3) for PCBs in air at Birkenes, 2015

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-18	0.97	1.52	1.52	1.37	0.93	0.85	0.85	1.19	1.16	1.38	1.57	0.91	1.184
PCB-28	0.53	0.82	0.87	0.68	0.37	0.56	0.60	0.96	0.80	0.87	0.91	0.61	0.706
PCB-31	0.49	0.78	0.80	0.64	0.42	0.53	0.58	0.85	0.71	0.76	0.84	0.56	0.656
PCB-33	0.29	0.46	0.47	0.38	0.21	0.30	0.33	0.51	0.40	0.48	0.52	0.34	0.386
PCB-37	0.04	0.06	0.06	0.04	0.05	0.05	0.06	0.07	0.06	0.08	0.04	0.07	0.058
PCB-47	0.41	0.69	0.57	0.61	0.61	1.17	1.30	1.50	0.97	0.67	0.76	0.52	0.813
PCB-52	0.56	1.02	0.79	0.68	0.50	0.68	0.84	1.06	0.84	0.81	0.97	0.74	0.785
PCB-66	0.13	0.25	0.20	0.17	0.10	0.17	0.20	0.29	0.21	0.23	0.24	0.21	0.200
PCB-74	0.08	0.16	0.13	0.10	0.06	0.10	0.12	0.17	0.13	0.15	0.15	0.12	0.121
PCB-99	0.12	0.34	0.17	0.14	0.10	0.13	0.16	0.22	0.21	0.18	0.18	0.18	0.174
PCB-101	0.29	0.84	0.41	0.36	0.27	0.40	0.51	0.52	0.33	0.26	0.43	0.62	0.427
PCB-105	0.02	0.28	0.04	0.03	0.04	0.03	0.04	0.04	0.03	0.04	0.03	0.04	0.053
PCB-114	0.005	0.015	0.005	0.007	0.026	0.007	0.009	0.006	0.006	0.005	0.006	0.005	0.009
PCB-118	0.08	0.62	0.12	0.10	0.07	0.10	0.13	0.13	0.08	0.10	0.11	0.18	0.149
PCB-122	0.005	0.007	0.005	0.007	0.027	0.007	0.009	0.004	0.005	0.006	0.006	0.003	0.008
PCB-123	0.005	0.011	0.005	0.007	0.026	0.006	0.009	0.004	0.005	0.006	0.006	0.003	0.008
PCB-128	0.011	0.108	0.018	0.016	0.021	0.012	0.025	0.015	0.011	0.007	0.015	0.039	0.025
PCB-138	0.09	0.46	0.13	0.13	0.07	0.14	0.19	0.11	0.06	0.10	0.10	0.29	0.153
PCB-141	0.02	0.08	0.03	0.03	0.02	0.04	0.04	0.04	0.01	0.02	0.02	0.16	0.044
PCB-149	0.18	0.45	0.26	0.22	0.17	0.28	0.37	0.32	0.19	0.12	0.29	0.73	0.292
PCB-153	0.17	0.51	0.23	0.20	0.14	0.23	0.31	0.22	0.12	0.14	0.21	0.50	0.244
PCB-156	0.004	0.046	0.007	0.007	0.013	0.006	0.011	0.006	0.004	0.007	0.007	0.022	0.012
PCB-157	0.002	0.010	0.003	0.003	0.011	0.003	0.004	0.002	0.003	0.003	0.002	0.003	0.004
PCB-167	0.002	0.023	0.004	0.006	0.012	0.004	0.004	0.003	0.004	0.004	0.006	0.018	0.007
PCB-170	0.010	0.032	0.012	0.013	0.020	0.015	0.033	0.010	0.005	0.011	0.010	0.037	0.017

Table A.2.2, cont.

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-180	0.03	0.08	0.05	0.04	0.02	0.06	0.06	0.04	0.01	0.03	0.03	0.11	0.046
PCB-183	0.01	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.003	0.009	0.03	0.016
PCB-187	0.04	0.07	0.05	0.03	0.02	0.06	0.08	0.07	0.04	0.01	0.05	0.08	0.050
PCB-189	0.002	0.002	0.003	0.005	0.016	0.006	0.006	0.003	0.003	0.003	0.003	0.002	0.005
PCB-194	0.002	0.008	0.005	0.006	0.017	0.004	0.007	0.003	0.005	0.009	0.005	0.007	0.007
PCB-206	0.002	0.002	0.003	0.004	0.017	0.005	0.005	0.003	0.003	0.004	0.003	0.003	0.005
PCB-209	0.005	0.006	0.011	0.009	0.013	0.006	0.006	0.006	0.009	0.006	0.006	0.006	0.007
sum Trichlor	3.13	4.82	5.15	4.23	2.44	3.19	3.68	5.05	4.44	5.42	5.89	3.45	4.20
sum Tetrachlor	1.32	2.36	1.87	1.61	1.52	3.76	4.48	5.58	4.07	3.65	4.48	2.98	3.13
sum pentachlor	0.51	2.10	0.74	0.63	0.49	1.13	1.45	1.65	1.06	1.00	1.24	1.55	1.11
sum hexachlor	0.48	1.69	0.67	0.59	0.39	0.98	1.34	1.48	1.05	1.28	2.16	6.86	1.53
sum heptachlor	0.09	0.21	0.13	0.09	0.05	0.16	0.23	0.20	0.09	0.08	0.16	0.41	0.15
sum PCB-7	1.75	4.35	2.59	2.19	1.46	2.17	2.64	3.04	2.25	2.31	2.77	3.04	2.51
sum PCB	5.54	11.19	8.58	7.18	4.93	9.24	11.19	13.96	10.72	11.46	13.94	15.27	10.14

Table A.2.3: Monthly and annual mean concentrations (pg/m^3) for PBDEs and TBA in air at Birkenes, 2015

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
BDE-28	0.010	0.010	0.021	0.007	0.036	0.012	0.010	0.012	0.011	0.007	0.006	0.010	0.012
BDE-47	0.05	0.06	0.21	0.05	0.33	0.09	0.18	0.10	0.12	0.07	0.07	0.08	0.12
BDE-49	0.008	0.011	0.026	0.007	0.019	0.009	0.010	0.018	0.013	0.014	0.013	0.013	0.013
BDE-66	0.007	0.008	0.021	0.005	0.010	0.006	0.007	0.009	0.005	0.007	0.005	0.005	0.008
BDE-71	0.006	0.006	0.028	0.006	0.006	0.006	0.007	0.006	0.058	0.006	0.066	0.006	0.017
BDE-77	0.002	0.002	0.005	0.001	0.001	0.002	0.002	0.003	0.001	0.001	0.001	0.001	0.002
BDE-85	0.002	0.004	0.010	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.003	0.003
BDE-99	0.03	0.05	0.07	0.02	0.04	0.03	0.09	0.04	0.06	0.03	0.03	0.06	0.045
BDE-100	0.010	0.011	0.044	0.010	0.015	0.010	0.026	0.010	0.014	0.010	0.010	0.013	0.015
BDE-119	0.003	0.003	0.009	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
BDE-138	0.008	0.012	0.031	0.014	0.007	0.010	0.008	0.007	0.007	0.007	0.007	0.007	0.010
BDE-153	0.013	0.022	0.025	0.012	0.006	0.010	0.006	0.008	0.009	0.007	0.006	0.012	0.011
BDE-154	0.014	0.026	0.018	0.010	0.005	0.008	0.007	0.007	0.007	0.006	0.005	0.012	0.010
BDE-183	0.042	0.092	0.026	0.010	0.007	0.032	0.006	0.022	0.007	0.011	0.010	0.031	0.024
BDE-196	0.13	0.14	0.18	0.02	0.02	0.08	0.02	1.54	0.02	0.02	0.02	0.02	0.180
BDE-206	0.17	0.15	0.13	0.02	0.03	0.08	0.04	0.97	0.02	0.02	0.02	0.06	0.145
BDE-209	0.50	2.03	2.28	0.32	0.54	0.67	0.97	1.07	0.34	0.34	0.33	1.19	0.882
sum BDE	1.00	2.63	3.14	0.51	1.08	1.05	1.39	3.82	0.70	0.57	0.60	1.53	1.50
TBA	2.35	4.29	2.97	1.51	2.09	1.33	2.33	3.60	5.76	6.75	8.58	7.37	4.13

Table A.2.4: Monthly and annual mean concentrations (pg/m^3) for HBCDs in air at Birkenes, 2015

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
α-HBCD	<0.05	0.14	0.03	<0.02	<0.03	0.03	<0.01	<0.02	<0.08	0.04	<0.07	<0.05	*0.05*
β-HBCD	<0.26	<0.11	<0.04	<0.08	<0.07	<0.03	<0.02	<0.03	<0.06	<0.03	<0.06	<0.15	*0.08*
γ-HBCD	<0.16	<0.08	<0.02	<0.02	<0.02	<0.01	<0.01	<0.05	<0.04	0.03	<0.04	<0.12	*0.05*
Sum HBCD	<0.48	*0.33*	*0.09*	<0.11	<0.12	*0.07*	<0.04	<0.10	<0.17	0.10	<0.16	<0.32	*0.18*

Table A.2.5: Monthly and annual mean concentrations (ng/m^3) for PAHs in air at Birkenes, 2015

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Naphthalene	0.352	0.224	0.267	0.088	0.082	0.093	0.083	0.083	0.096	0.134	0.156	0.521	0.176
2-Methylnaphthalene	0.140	0.083	0.142	0.068	0.049	0.053	0.037	0.038	0.048	0.076	0.076	0.267	0.087
1-Methylnaphthalene	0.117	0.067	0.082	0.041	0.032	0.030	0.025	0.025	0.032	0.057	0.059	0.238	0.065
Biphenyl	0.373	0.286	0.301	0.100	0.094	0.091	0.043	0.045	0.075	0.119	0.164	0.962	0.216
Acenaphthylene	0.017	0.024	0.018	0.007	0.006	0.042	0.002	0.003	0.007	0.009	0.082	0.050	0.021
Acenaphthene	0.290	0.095	0.120	0.108	0.187	0.137	0.110	0.045	0.061	0.061	0.129	0.159	0.125
Dibenzofuran	1.482	0.917	1.072	0.379	0.438	0.572	0.227	0.210	0.361	0.434	0.789	1.474	0.674
Fluorene	1.232	0.651	0.582	0.257	0.377	0.569	0.234	0.192	0.350	0.358	0.648	1.236	0.543
Dibenzothiophene	0.050	0.014	0.010	0.009	0.019	0.037	0.020	0.030	0.026	0.010	0.016	0.018	0.021
Phenanthrene	1.730	0.991	0.990	0.476	0.615	1.056	0.581	0.584	0.760	0.623	1.341	1.271	0.894
Anthracene	0.015	0.023	0.032	0.005	0.004	0.049	0.003	0.003	0.007	0.009	0.031	0.014	0.015
3-Methylphenanthrene	0.132	0.067	0.067	0.029	0.040	0.059	0.034	0.043	0.055	0.039	0.089	0.080	0.059
2-Methylphenanthrene	0.149	0.078	0.072	0.035	0.047	0.069	0.037	0.048	0.064	0.046	0.102	0.094	0.067
2-Methylanthracene	0.008	0.004	0.007	0.002	0.003	0.005	0.001	0.002	0.002	0.002	0.007	0.003	0.004
9-Methylphenanthrene	0.045	0.027	0.033	0.014	0.019	0.025	0.014	0.017	0.022	0.017	0.038	0.036	0.025
1-Methylphenanthrene	0.107	0.059	0.059	0.030	0.031	0.051	0.022	0.024	0.039	0.040	0.080	0.075	0.049
Fluoranthene	0.402	0.274	0.294	0.102	0.126	0.215	0.106	0.105	0.131	0.149	0.294	0.371	0.208
Pyrene	0.205	0.119	0.154	0.045	0.063	0.129	0.053	0.064	0.074	0.086	0.169	0.196	0.110
Benzo(a)fluorene	0.023	0.013	0.013	0.003	0.006	0.011	0.004	0.004	0.007	0.007	0.016	0.025	0.011
Retene	0.072	0.040	0.041	0.041	0.030	0.056	0.030	0.023	0.052	0.063	0.085	0.070	0.049
Benzo(b)fluorene	0.010	0.006	0.007	0.002	0.004	0.007	0.002	0.002	0.003	0.004	0.009	0.013	0.006
Benzo(ghi)fluoranthene	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	<0.005	0.007
Cyclopenta(cd)pyrene	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	0.002
Benz(a)anthracene	0.031	0.021	0.025	0.003	0.003	0.013	0.003	0.004	0.007	0.008	0.023	0.038	0.015
Chrysene	0.169	0.064	0.079	0.014	0.023	0.082	0.020	0.025	0.052	0.042	0.079	0.094	0.060

Table A.2.5. cont.

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Benzo(b)fluoranthene	0.092	0.056	0.071	0.014	0.024	0.079	0.018	0.013	0.039	0.051	0.061	0.094	0.050
Benzo(k)fluoranthene	0.023	0.019	0.028	0.004	0.007	0.022	0.005	0.004	0.009	0.014	0.020	0.036	0.016
Benzo(a)fluoranthene	0.005	0.005	0.006	0.001	0.001	0.004	0.001	0.001	0.001	0.002	0.003	0.010	0.003
Benzo(e)pyrene	0.076	0.036	0.044	0.010	0.016	0.060	0.012	0.010	0.029	0.033	0.039	0.059	0.035
Benzo(a)pyrene	0.019	0.018	0.027	0.003	0.003	0.024	0.005	0.005	0.006	0.009	0.011	0.030	0.013
Perylene	0.004	0.003	0.003	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.003	0.004	0.002
Inden(123-cd)pyrene	0.052	0.033	0.051	0.010	0.014	0.037	0.009	0.008	0.018	0.031	0.041	0.070	0.030
Benzo(ghi)perylene	0.063	0.034	0.048	0.011	0.017	0.044	0.011	0.010	0.022	0.033	0.044	0.066	0.032
Anthanthrene	0.003	0.004	0.003	0.001	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.003	0.002
Coronene	0.026	0.015	0.022	0.004	0.006	0.011	0.005	0.005	0.008	0.014	0.017	0.031	0.013
Dibenzo(ae)pyrene	0.009	0.008	0.007	0.002	0.003	0.007	0.002	0.002	0.005	0.006	0.007	0.010	0.005
Dibenzo(ai)pyrene	0.005	0.010	0.005	0.003	0.004	0.007	0.001	0.002	0.002	0.003	0.003	0.004	0.004
Dibenzo(ah)pyrene	0.005	0.010	0.005	0.003	0.005	0.008	0.002	0.002	0.002	0.003	0.004	0.005	0.004
Dibenzo(ah)anthracene	0.009	0.005	0.005	0.002	0.002	0.007	0.001	0.002	0.003	0.003	0.006	0.010	0.005
Sum PAH	7.25	4.26	4.61	1.89	2.36	3.57	1.72	1.64	2.37	2.50	4.58	7.50	3.59
Sum PAH16	4.70	2.65	2.79	1.15	1.56	2.60	1.24	1.15	1.64	1.62	3.14	4.26	2.31

Table A.2.6: Monthly and annual mean concentrations (pg/m^3) for PFAS in air at Birkenes, 2015

Birkenes	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
6:2 FTS	<0.03	*0.04*	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	*0.06*	*0.04*	*0.04*
PFBS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
PFDA	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
PFDcS	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
PFHpA	<0.07	<0.07	*0.07*	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
PFHxA	<0.10	<0.10	*0.13*	*0.11*	<0.10	*0.13*	*0.14*	0.15	<0.10	<0.10	<0.10	<0.10	*0.12*
PFHxS	<0.02	<0.02	*0.02*	<0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	*0.02*
PFNA	<0.07	<0.07	<0.07	<0.07	<0.07	*0.10*	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	*0.07*
PFOA	*0.06*	0.10	0.12	0.11	0.09	0.17	0.11	0.19	*0.06*	*0.05*	*0.08*	0.12	0.11
PFOS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
FOSA	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
PFUnDA	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
sum PFAS	*0.73*	*0.77*	*0.81*	*0.71*	*0.68*	*0.89*	*0.84*	*0.90*	*0.73*	*0.71*	*0.77*	*0.79*	*0.80*

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 and annual mean concentrations (ng/l) for HCB, HCHs and PCBs in precipitation at Birkenes, 2015

ng/l	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
HCB	0.06	0.13	0.06	0.17	0.09	0.09	0.14	0.10	0.08	0.05	0.04	0.06	0.09
α-HCH	0.05	0.07	0.07	0.12	0.10	0.11	0.12	0.10	0.14	0.13	0.09	0.07	0.10
γ-HCH	0.08	0.14	0.09	0.27	0.30	0.32	0.24	0.22	0.27	0.17	0.18	0.15	0.21
sum HCH	0.13	0.22	0.16	0.39	0.40	0.43	0.36	0.33	0.41	0.29	0.27	0.22	0.31
PCB-28	0.005	0.015	0.006	0.014	0.006	0.004	0.007	0.006	0.004	0.003	0.003	0.007	0.006
PCB-52	0.006	0.015	0.007	0.012	0.005	0.015	0.006	0.006	0.004	0.004	0.009	0.014	0.007
PCB-101	0.009	0.020	0.010	0.018	0.010	0.021	0.011	0.010	0.009	0.009	0.046	0.066	0.017
PCB-118	0.007	0.018	0.005	0.012	0.007	0.025	0.009	0.007	0.006	0.006	0.013	0.017	0.009
PCB-138	0.008	0.018	0.007	0.015	0.007	0.013	0.008	0.007	0.006	0.009	0.040	0.050	0.013
PCB-153	0.010	0.023	0.009	0.020	0.011	0.015	0.011	0.011	0.009	0.011	0.053	0.076	0.018
PCB-180	0.005	0.015	0.004	0.010	0.005	0.004	0.004	0.004	0.003	0.006	0.015	0.018	0.007
sum PCB-7	0.051	0.124	0.049	0.099	0.050	0.097	0.055	0.050	0.041	0.047	0.179	0.247	0.076

Table A.2.8: Monthly and annual mean concentrations (pg/m^3) for organochlorine pesticides (OCPs) in air at Andøya, 2015

Andøya	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
HCB	45.3	35.6	29.0	43.8	26.1	21.8	16.7	14.4	17.5	22.1	28.4	40.5	27.5
α-HCH	3.20	2.80	2.94	3.52	3.39	3.37	2.91	3.61	4.45	4.57	4.05	3.61	3.54
γ-HCH	0.71	0.61	0.57	0.63	0.70	0.40	0.56	2.31	1.41	0.73	0.65	0.49	0.82
sum HCHs	3.91	3.41	3.51	4.15	4.09	3.77	3.47	5.92	5.86	5.31	4.70	4.10	4.36
pp-DDT	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
op-DDT	0.15	0.13	0.12	0.09	0.06	0.02	0.03	0.36	0.17	0.07	0.10	0.13	0.12
pp-DDE	0.82	0.57	0.52	0.39	0.15	0.06	0.08	0.32	0.44	0.25	0.42	0.65	0.40
op-DDE	0.09	0.08	0.08	0.06	0.03	0.01	0.01	0.03	0.04	0.03	0.05	0.08	0.05
pp-DDD	0.09	0.06	0.05	0.04	0.03	0.01	0.03	0.18	0.10	0.05	0.06	0.05	0.06
op-DDD	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01
sum DDTs	1.18	0.92	0.79	0.62	0.27	0.11	0.17	0.92	0.77	0.42	0.64	0.94	0.64

Table A.2.9: Monthly and annual mean concentrations (pg/m^3) for PCBs in air at Andøya, 2015

Andøya	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-18	1.378	1.233	0.888	0.849	0.501	0.236	0.283	0.457	0.998	0.452	0.726	0.838	0.739
PCB-28	0.772	0.575	0.471	0.496	0.354	0.135	0.216	0.474	0.771	0.272	0.392	0.475	0.454
PCB-31	0.698	0.565	0.454	0.471	0.348	0.143	0.201	0.439	0.652	0.257	0.359	0.439	0.422
PCB-33	0.457	0.345	0.249	0.276	0.182	0.072	0.114	0.254	0.390	0.148	0.209	0.243	0.248
PCB-37	0.073	0.032	0.025	0.033	0.023	0.007	0.014	0.038	0.060	0.017	0.024	0.029	0.032
PCB-47	0.537	0.453	0.476	0.434	0.746	0.439	0.622	1.325	0.795	0.522	0.387	0.296	0.604
PCB-52	0.650	0.567	0.520	0.578	0.412	0.183	0.262	0.600	0.659	0.317	0.400	0.473	0.471
PCB-66	0.177	0.116	0.103	0.135	0.082	0.035	0.065	0.168	0.181	0.071	0.082	0.097	0.111
PCB-74	0.117	0.079	0.074	0.090	0.060	0.022	0.037	0.102	0.122	0.046	0.056	0.071	0.073
PCB-99	0.144	0.120	0.114	0.121	0.087	0.034	0.061	0.132	0.160	0.067	0.079	0.103	0.101
PCB-101	0.302	0.267	0.260	0.466	0.221	0.082	0.158	0.407	0.368	0.151	0.172	0.299	0.256
PCB-105	0.028	0.017	0.018	0.022	0.014	0.006	0.008	0.025	0.031	0.009	0.015	0.019	0.018
PCB-114	0.006	0.006	0.002	0.002	0.002	0.002	0.005	0.005	0.005	0.002	0.002	0.002	0.004
PCB-118	0.152	0.073	0.070	0.112	0.052	0.019	0.043	0.094	0.109	0.038	0.047	0.080	0.076
PCB-122	0.005	0.006	0.002	0.007	0.001	0.003	0.005	0.005	0.004	0.002	0.002	0.001	0.004
PCB-123	0.005	0.006	0.002	0.001	0.001	0.002	0.005	0.005	0.006	0.002	0.002	0.001	0.003
PCB-128	0.009	0.010	0.010	0.025	0.009	0.003	0.003	0.020	0.014	0.005	0.002	0.016	0.010
PCB-138	0.168	0.080	0.073	0.171	0.057	0.025	0.041	0.151	0.096	0.036	0.044	0.138	0.091
PCB-141	0.015	0.017	0.017	0.040	0.018	0.005	0.005	0.045	0.028	0.004	0.008	0.043	0.020
PCB-149	0.167	0.139	0.143	0.217	0.131	0.054	0.103	0.294	0.231	0.094	0.095	0.215	0.155
PCB-153	0.174	0.140	0.128	0.267	0.102	0.041	0.075	0.250	0.176	0.067	0.073	0.210	0.139
PCB-156	0.005	0.005	0.004	0.012	0.005	0.002	0.003	0.005	0.003	0.003	0.002	0.010	0.005
PCB-157	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.002	0.002	0.001	0.001	0.001	0.002
PCB-167	0.003	0.003	0.002	0.007	0.004	0.002	0.003	0.002	0.003	0.002	0.002	0.006	0.003
PCB-170	0.007	0.008	0.006	0.017	0.007	0.002	0.004	0.014	0.004	0.004	0.004	0.015	0.007

Table A.2.9, cont.

Andøya	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-180	0.021	0.018	0.020	0.066	0.023	0.006	0.011	0.048	0.028	0.007	0.010	0.048	0.024
PCB-183	0.009	0.008	0.008	0.008	0.010	0.002	0.006	0.021	0.012	0.003	0.007	0.015	0.009
PCB-187	0.028	0.023	0.029	0.022	0.028	0.007	0.017	0.064	0.043	0.016	0.020	0.043	0.029
PCB-189	0.002	0.003	0.001	0.001	0.001	0.002	0.004	0.003	0.003	0.002	0.002	0.001	0.002
PCB-194	0.002	0.002	0.002	0.003	0.002	0.002	0.004	0.003	0.003	0.002	0.002	0.003	0.002
PCB-206	0.001	0.002	0.001	0.001	0.001	0.002	0.003	0.002	0.002	0.002	0.001	0.001	0.002
PCB-209	0.003	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002
sum Trichlor	4.54	3.80	2.89	2.94	1.94	0.85	1.26	2.67	4.43	1.67	2.59	2.87	2.72
sum Tetrachlor	1.48	1.28	1.29	2.27	2.12	0.98	1.61	4.02	3.52	1.70	1.81	1.82	1.20
sum pentachlor	0.61	0.48	0.47	1.13	0.63	0.20	0.38	1.22	1.17	0.43	0.54	0.80	0.65
sum hexachlor	0.53	0.38	0.38	2.42	1.68	0.17	0.27	1.24	1.15	0.90	0.95	2.34	0.98
sum heptachlor	0.06	0.05	0.06	0.17	0.10	0.02	0.03	0.21	0.11	0.03	0.05	0.18	0.09
sum PCB-7	5.28	1.72	1.54	2.16	1.22	0.49	0.80	2.02	2.21	0.89	1.14	1.72	1.77
sum PCB	7.27	5.60	5.09	9.45	6.48	2.21	3.56	9.37	10.39	4.74	5.94	8.02	6.43

Table A.2.10: Monthly and annual mean concentrations (pg/m^3) for PBDEs in air at Andøya, 2015

Andøya	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
BDE-28	0.007	0.006	0.004	0.004	0.005	0.004	0.005	0.006	0.006	0.004	0.004	0.004	0.005
BDE-47	0.035	0.072	0.033	0.036	0.035	0.030	0.031	0.091	0.107	0.036	0.031	0.041	0.047
BDE-49	0.004	0.007	0.004	0.005	0.005	0.004	0.004	0.007	0.005	0.005	0.005	0.004	0.005
BDE-66	0.008	0.005	0.003	0.004	0.003	0.003	0.003	0.005	0.004	0.003	0.003	0.004	0.004
BDE-71	0.004	0.004	0.004	0.005	0.004	0.004	0.007	0.020	0.004	0.004	0.029	0.005	0.008
BDE-77	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
BDE-85	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
BDE-99	0.015	0.063	0.013	0.011	0.011	0.011	0.013	0.103	0.040	0.012	0.010	0.014	0.026
BDE-100	0.007	0.015	0.007	0.007	0.007	0.006	0.007	0.017	0.011	0.006	0.006	0.007	0.009
BDE-119	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
BDE-138	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
BDE-153	0.004	0.010	0.004	0.004	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.004
BDE-154	0.003	0.008	0.003	0.003	0.002	0.002	0.002	0.004	0.003	0.002	0.002	0.003	0.003
BDE-183	0.005	0.006	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004
BDE-196	0.015	0.010	0.014	0.021	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.016	0.014
BDE-206	0.018	0.018	0.030	0.036	0.012	0.013	0.017	0.021	0.014	0.016	0.016	0.017	0.018
BDE-209	0.383	0.410	1.154	0.660	0.218	0.309	0.235	0.586	0.399	0.267	0.277	0.420	0.430
sum BDE	0.520	0.643	1.284	0.808	0.330	0.415	0.353	0.889	0.620	0.383	0.412	0.551	0.584
TBA	4.21	3.07	2.67	3.03	3.47	2.96	8.47	4.06	7.97	4.21	6.36	5.49	4.619

Table A.2.11: Monthly and annual mean concentrations (pg/m^3) for PFAS in air at Andøya, 2015

Andøya	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
6:2 FTS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*0.02*	<0.01	*0.02*	*0.04*	<0.01	*0.02*
PFBS	<0.007	*0.008*	<0.007	<0.007	<0.007	*0.008*	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	*0.007*
PFDA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.044	<0.03	<0.03	<0.03	<0.03	*0.03*
PFDcS	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	*<0.04*
PFHpA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.031	<0.03	<0.03	*<0.03*
PFHxA	<0.04	<0.04	<0.04	<0.04	*0.05*	*0.05*	0.06	0.11	*0.04*	<0.04	<0.04	<0.04	*0.05*
PFHxS	<0.007	<0.007	<0.007	<0.007	<0.007	*0.008*	*0.017*	<0.007	<0.007	*0.008*	<0.007	<0.007	*0.008*
PFNA	<0.03	<0.03	0.093	<0.03	*0.037*	<0.03	*0.034*	*0.116*	<0.03	<0.03	<0.03	<0.03	*0.05*
PFOA	<0.02	*0.05*	0.07	0.09	0.08	0.12	0.19	0.20	*0.05*	0.07	*<0.02*	*<0.02*	0.10
PFOS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
FOSA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
PFUnDA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Sum PFAS	<0.15	*0.20*	*0.34*	*0.29*	*0.26*	*0.33*	*0.38*	*0.51*	*0.26*	*0.28*	*0.25*	*<0.15*	*0.33*

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 and annual mean concentrations (pg/m^3) for organochlorine pesticides in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
HCB	81.52	75.63	76.68	89.19	91.12	90.29	93.03	85.07	91.10	89.32	85.21	80.79	86.09
α-HCH	3.61	3.30	3.31	5.01	4.06	4.03	5.25	5.67	6.18	5.54	4.54	3.25	4.53
γ-HCH	0.66	0.56	0.62	0.79	0.60	0.44	0.59	0.84	0.65	0.69	0.72	0.57	0.64
sum HCHs	4.28	3.86	3.93	5.81	4.66	4.47	5.84	6.51	6.83	6.23	5.26	3.82	5.17
cis-CD	0.41	0.30	0.33	0.37	0.31	0.28	0.29	0.34	0.31	0.33	0.36	0.35	0.33
cis-NO	0.02	0.01	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.03	0.03	0.03	0.03
trans-CD	0.23	0.20	0.18	0.14	0.09	0.05	0.05	0.07	0.06	0.08	0.15	0.20	0.12
trans-NO	0.37	0.31	0.32	0.36	0.32	0.25	0.25	0.26	0.25	0.26	0.33	0.37	0.30
sum CHLs	1.03	0.82	0.85	0.90	0.76	0.61	0.63	0.71	0.67	0.70	0.87	0.96	0.79
pp_DDT	0.10	0.07	0.06	0.05	0.02	0.01	0.02	0.02	0.02	0.03	0.08	0.11	0.05
op_DDT	0.17	0.14	0.15	0.13	0.03	0.02	0.03	0.02	0.03	0.05	0.10	0.16	0.09
pp_DDE	0.84	0.52	0.47	0.32	0.06	0.04	0.06	0.07	0.08	0.12	0.47	0.89	0.32
op_DDE	0.11	0.09	0.07	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.09	0.05
pp_DDD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
op_DDD	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
sum DDTs	1.24	0.84	0.77	0.58	0.13	0.10	0.12	0.13	0.16	0.22	0.72	1.27	0.52

Table A.2.13: Monthly and annual mean concentrations (pg/m^3) for PCBs in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-18	2.09	2.35	2.03	2.17	2.94	1.74	2.39	2.75	0.91	1.61	2.19	1.57	2.027
PCB-28	1.28	1.41	1.18	1.46	2.82	1.44	1.94	2.25	0.86	1.21	1.54	1.03	1.517
PCB-31	1.14	1.31	1.09	1.30	2.63	1.33	1.79	2.06	0.76	1.09	1.43	0.96	1.393
PCB-33	0.81	0.93	0.79	0.95	2.15	1.12	1.50	1.74	0.57	0.87	1.11	0.65	1.089
PCB-37	0.09	0.10	0.09	0.11	0.36	0.19	0.21	0.20	0.08	0.09	0.13	0.10	0.144
PCB-47	0.30	0.33	0.32	0.33	1.12	0.29	0.32	0.35	0.17	0.23	0.34	0.30	0.358
PCB-52	0.74	0.81	0.77	0.82	0.84	0.53	0.67	0.78	0.43	0.50	0.70	0.65	0.677
PCB-66	0.18	0.19	0.17	0.21	0.26	0.16	0.18	0.17	0.10	0.10	0.15	0.16	0.166
PCB-74	0.11	0.12	0.12	0.15	0.16	0.07	0.10	0.10	0.06	0.07	0.10	0.11	0.105
PCB-99	0.13	0.16	0.17	0.18	0.09	0.06	0.07	0.07	0.06	0.07	0.10	0.14	0.107
PCB-101	0.30	0.31	0.29	0.32	0.25	0.26	0.29	0.24	0.27	0.17	0.15	0.34	0.267
PCB-105	0.03	0.03	0.03	0.04	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.03	0.021
PCB-114	0.002	0.004	0.004	0.005	0.001	0.005	0.007	0.002	0.001	0.001	0.002	0.003	0.003
PCB-118	0.10	0.11	0.10	0.12	0.05	0.06	0.07	0.05	0.06	0.04	0.04	0.10	0.074
PCB-122	0.002	0.004	0.003	0.003	0.001	0.005	0.007	0.002	0.001	0.002	0.002	0.001	0.003
PCB-123	0.006	0.004	0.004	0.004	0.001	0.005	0.007	0.002	0.001	0.001	0.001	0.001	0.003
PCB-128	0.010	0.011	0.004	0.012	0.006	0.005	0.018	0.010	0.015	0.009	0.003	0.012	0.010
PCB-138	0.08	0.06	0.02	0.06	0.05	0.10	0.10	0.08	0.13	0.07	0.03	0.11	0.078
PCB-141	0.02	0.01	0.01	0.01	0.01	0.03	0.01	0.02	0.04	0.02	0.00	0.02	0.019
PCB-149	0.13	0.11	0.06	0.11	0.10	0.17	0.16	0.12	0.21	0.11	0.05	0.19	0.131
PCB-153	0.13	0.10	0.05	0.09	0.08	0.15	0.16	0.12	0.19	0.11	0.03	0.15	0.116
PCB-156	0.005	0.004	0.003	0.003	0.002	0.006	0.004	0.004	0.007	0.005	0.002	0.009	0.005
PCB-157	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.002
PCB-167	0.001	0.003	0.002	0.002	0.001	0.002	0.003	0.003	0.004	0.002	0.002	0.007	0.003
PCB-170	0.006	0.005	0.004	0.005	0.003	0.007	0.012	0.010	0.014	0.009	0.003	0.011	0.008

Table A.2.13, cont.

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
PCB-180	0.02	0.01	0.01	0.01	0.01	0.03	0.04	0.03	0.04	0.02	0.01	0.03	0.022
PCB-183	0.008	0.006	0.004	0.006	0.005	0.009	0.011	0.008	0.015	0.007	0.003	0.016	0.008
PCB-187	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.01	0.05	0.023
PCB-189	0.001	0.002	0.003	0.002	0.001	0.005	0.004	0.001	0.001	0.001	0.001	0.001	0.002
PCB-194	0.001	0.002	0.002	0.002	0.001	0.003	0.003	0.002	0.002	0.001	0.001	0.003	0.002
PCB-206	0.002	0.002	0.003	0.003	0.001	0.004	0.003	0.001	0.001	0.001	0.002	0.001	0.002
PCB-209	0.003	0.005	0.003	0.005	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
sum Trichlor	7.21	8.61	7.81	9.01	15.24	8.79	12.04	12.65	4.43	6.85	9.08	6.13	8.882
sum Tetrachlor	1.51	2.11	2.75	2.83	3.07	2.01	2.88	2.99	1.59	1.89	2.82	2.53	2.404
sum pentachlor	0.58	0.66	0.86	1.04	0.47	0.40	0.59	0.59	0.66	0.44	0.49	0.97	0.649
sum hexachlor	0.38	0.37	0.34	0.43	0.27	0.51	0.58	0.51	0.88	0.47	0.19	2.53	0.652
sum heptachlor	0.06	0.04	0.03	0.03	0.04	0.07	0.09	0.09	0.15	0.08	0.04	0.14	0.076
sum PCB-7	2.66	2.81	2.42	2.88	4.10	2.55	3.27	3.54	1.98	2.12	2.49	2.41	2.75
sum PCB	9.73	11.80	12.20	13.36	19.09	11.80	17.12	16.83	7.71	9.75	12.61	12.31	12.70

Table A.2.14: Monthly and annual mean concentrations (pg/m^3) for PBDEs and TBA in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
BDE-28	0.006	0.009	0.007	0.013	0.007	0.012	0.039	0.042	0.013	0.005	0.025	0.006	0.016
BDE-47	0.06	0.14	0.19	0.49	0.22	0.27	1.19	0.07	0.25	0.08	1.81	0.07	0.40
BDE-49	0.005	0.008	0.010	0.018	0.008	0.010	0.027	0.004	0.007	0.006	0.037	0.006	0.012
BDE-66	0.005	0.006	0.006	0.010	0.006	0.007	0.014	0.006	0.006	0.004	0.014	0.004	0.007
BDE-71	0.032	0.008	0.019	0.006	0.006	0.006	0.003	0.001	0.006	0.006	0.0067	0.006	0.009
BDE-77	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001
BDE-85	0.002	0.003	0.002	0.002	0.002	0.003	0.011	0.013	0.004	0.002	0.002	0.002	0.004
BDE-99	0.01	0.03	0.02	0.03	0.02	0.02	0.08	0.01	0.02	0.02	0.05	0.02	0.026
BDE-100	0.009	0.012	0.011	0.018	0.010	0.012	0.036	0.002	0.010	0.009	0.039	0.009	0.015
BDE-119	0.002	0.003	0.007	0.020	0.002	0.003	0.005	0.006	0.003	0.002	0.002	0.002	0.005
BDE-138	0.007	0.009	0.006	0.006	0.007	0.007	0.005	0.005	0.007	0.006	0.006	0.006	0.006
BDE-153	0.005	0.006	0.005	0.005	0.005	0.005	0.004	0.003	0.005	0.005	0.005	0.005	0.005
BDE-154	0.003	0.005	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.004
BDE-183	0.004	0.006	0.004	0.004	0.004	0.006	0.016	0.019	0.007	0.004	0.004	0.005	0.007
BDE-196	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.020
BDE-206	0.02	0.17	0.02	0.02	0.02	0.07	0.24	0.30	0.07	0.02	0.04	0.03	0.093
BDE-209	0.43	2.40	0.40	0.32	0.32	0.66	0.25	0.08	0.28	0.36	1.04	0.57	0.538
Sum BDE	0.63	2.85	0.72	0.98	0.66	1.12	1.94	0.58	0.70	0.55	3.10	0.76	1.164
TBA	5.15	3.40	2.53	1.79	2.96	5.34	7.04	6.53	8.07	11.33	15.34	15.92	6.68

Table A.2.15: Monthly and annual mean concentrations (pg/m^3) for HBCDs in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
α-HBCD	<0.03	<0.03	<0.02	<0.03	<0.01	0.03	*0.02*	0.02	0.08	0.18	*0.07*	<0.05	*0.05*
β-HBCD	<0.04	0.00	<0.05	<0.04	<0.03	<0.02	<0.02	<0.02	<0.02	<0.04	<0.05	<0.13	*0.04*
γ-HBCD	<0.04	<0.04	<0.02	0.03	<0.02	<0.01	<0.01	0.05	0.02	0.03	*0.03*	<0.06	*0.03*
Sum HBCD	<0.11	*0.07*	<0.09	*0.10*	<0.06	*0.06*	*0.05*	*0.09*	*0.12*	*0.25*	*0.15*	<0.24	*0.11*

Table A.2.16: Monthly and annual mean concentrations (ng/m^3) for PAHs in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Naphthalene	1.112	1.650	0.935	0.611	1.621	0.945	0.683	0.229	0.477	0.321	0.751	1.021	0.868
2-Methylnaphthalene	0.188	0.264	0.122	0.073	0.113	0.082	0.085	0.045	0.038	0.053	0.177	0.243	0.121
1-Methylnaphthalene	0.168	0.268	0.081	0.039	0.046	0.031	0.037	0.022	0.018	0.031	0.133	0.209	0.088
Biphenyl	1.099	0.970	0.658	0.165	0.036	0.021	0.020	0.017	0.023	0.091	0.492	0.796	0.335
Acenaphthylene	0.005	0.009	0.007	0.003	0.004	0.003	0.004	0.002	0.004	0.002	0.002	0.002	0.004
Acenaphthene	0.013	0.007	0.008	0.008	0.005	0.003	0.008	0.004	0.005	0.002	0.017	0.010	0.007
Dibenzofuran	1.603	1.286	0.919	0.304	0.043	0.029	0.033	0.041	0.057	0.125	0.651	1.034	0.466
Fluorene	0.746	0.489	0.193	0.047	0.018	0.014	0.018	0.019	0.021	0.038	0.295	0.537	0.185
Dibenzothiophene	0.004	0.005	0.003	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.005	0.005	0.003
Phenanthrene	0.109	0.148	0.044	0.025	0.014	0.019	0.027	0.020	0.022	0.017	0.114	0.090	0.052
Anthracene	0.002	0.003	0.003	0.002	0.002	0.002	0.003	0.002	0.004	0.002	0.001	0.002	0.002
3-Methylphenanthrene	0.007	0.012	0.004	0.004	0.003	0.004	0.005	0.003	0.005	0.004	0.006	0.004	0.005
2-Methylphenanthrene	0.008	0.012	0.004	0.004	0.002	0.005	0.006	0.004	0.005	0.004	0.007	0.006	0.006
2-Methylanthracene	0.002	0.003	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002	0.002
9-Methylphenanthrene	0.004	0.008	0.004	0.003	0.002	0.003	0.004	0.003	0.004	0.003	0.003	0.002	0.004
1-Methylphenanthrene	0.006	0.009	0.004	0.004	0.002	0.003	0.004	0.003	0.004	0.003	0.004	0.003	0.004
Fluoranthene	0.075	0.073	0.018	0.015	0.005	0.005	0.006	0.005	0.005	0.006	0.039	0.044	0.023
Pyrene	0.033	0.036	0.007	0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.011	0.015	0.011
Benzo(a)fluorene	0.004	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002
Retene	0.006	0.005	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.004	0.003
Benzo(b)fluorene	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Benzo(ghi)fluoranthene	NaN	NaN	NaN	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cyclopenta(cd)pyrene	0.001	NaN	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Benz(a)anthracene	0.007	0.007	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.002
Chrysene	0.024	0.025	0.004	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.004	0.007	0.006

Table A.2.16, cont.

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
Benzo(b)fluoranthene	0.028	0.022	0.006	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.007	0.006
Benzo(k)fluoranthene	0.010	0.009	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.003
Benzo(a)fluoranthene	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Benzo(e)pyrene	0.015	0.012	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.004	0.003
Benzo(a)pyrene	0.006	0.006	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002
Perylene	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Inden(123-cd)pyrene	0.012	0.012	0.003	0.003	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.004	0.003
Benzo(ghi)perylene	0.012	0.011	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.004
Anthanthrene	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Coronene	0.006	0.006	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.003
Dibenzo(ae)pyrene	0.004	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.001	0.001	0.002
Dibenzo(ai)pyrene	0.005	0.005	0.005	0.003	0.002	0.002	0.003	0.002	0.004	0.003	0.001	0.002	0.003
Dibenzo(ah)pyrene	0.005	0.005	0.006	0.003	0.003	0.002	0.003	0.002	0.004	0.003	0.001	0.002	0.003
Dibenzo(ah)anthracene	0.002	0.002	0.001	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Sum PAH	5.28	5.33	3.05	1.35	1.95	1.20	0.98	0.45	0.73	0.74	2.73	4.06	2.22
Sum PAH-16	2.20	2.51	1.24	0.74	1.68	1.00	0.76	0.29	0.55	0.40	1.24	1.75	1.18

Table A.2.17: Monthly and annual mean concentrations (pg/m^3) for PFAS in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
6:2 FTS	<0.02	<0.02	<0.02	<0.02	*0.02*	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
PFBS	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
PFDA	<0.03	<0.03	*0.03*	*0.04*	<0.03	<0.03	*0.04*	<0.03	<0.03	<0.03	<0.03	<0.03	*0.03*
PFDcS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PFHpA	*0.06*	<0.03	<0.03	0.06	<0.03	*0.04*	*0.04*	<0.03	<0.03	<0.03	<0.03	<0.03	*0.04*
PFHxA	*0.06*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.07*	*0.06*	<0.05	<0.05	<0.05	<0.05	*0.05*
PFHxS	<0.008	*0.012*	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
PFNA	*0.13*	<0.03	*0.07*	*0.04*	<0.03	<0.03	*0.04*	*0.04*	<0.03	<0.03	<0.03	<0.03	*0.04*
PFOA	0.22	0.13	0.14	0.13	0.12	0.10	0.15	0.06	*0.03*	0.07	0.10	0.08	0.11
PFOS	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
FOSA	*<0.03*	*<0.03*	*0.04*	*<0.03*	*<0.03*	*<0.03*	*0.06*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*<0.03*	*0.04*
PFUnDA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
sum PFAS	*0.67*	*0.45*	*0.50*	*0.47*	*0.44*	*0.42*	*0.52*	*0.40*	*0.34*	*0.38*	*0.41*	*0.39*	*0.45*

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 and annual mean concentrations (pg/m^3) for M/SCCPs in air at Zeppelin, 2015

Zeppelin	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2015
SCCP	117	231	305	363	1140	498	603	268	280	395	377	479	423
MCCP	75	*29*	24	242	112	20	*67*	20	*595*	80	83	161	133

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	0.15	0.04	0.01
Cd	0.002	0.0003	0.0006
Zn	0.27	1.37	0.79
Cu	0.11	0.42	0.13
Ni	0.67	0.15	0.04
Cr	0.23	0.24	0.02
Co	0.005	0.004	0.0005
As	0.01	0.006	0.002
Mn		1.19	0.04
V	0.005	0.006	0.0007

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 (-20ºC) 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-6th August) and one in early winter (23rd Nov-9th Dec) 2015. Each campaign contained seven 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 cyclohexane. The filters and the corresponding PUF plugs were extracted separately, but in the same solvent in order to unify the sample. The extract was then concentrated and cleaned by 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 quantification PFAS

The filters were spiked with 20 µL of internal standards (IS) containing ^{13}C-labelled PFAS congeners (0.5 ng/µL) and then extracted using sonication bath for 3x10 min in methanol. The extract was then concentrated and cleaned 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 PFASs was carried out using UHPLC/MS-MS with ESI in negative ion mode using full scan mass detection. In total, 12 PFASs 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 analyzed in the same way as and parallel with the real samples. The lab blanks were obtained by extracting pre-cleaned PUFs and filters in solvent and using the same clean-up and analytical procedures as real samples and field blanks.
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 (laboratory 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. Values below LOD were used as LOD/2 in further statistical treatment.

In 2015, a blank contamination was found for PCBs and individual PBDEs (47, 66 and 99). The source for this contamination was found to be a solvent (diethyl ether) being used for the extraction of the samples. All samples being extracted in the specific solvents were found to have elevated levels of the PCBs and individual PBDEs. As the levels of the individual congeners in the solvent blanks were consistent their contribution to the individual samples could be identified. The contaminated samples were consequently blank adjusted with the amount found in blanks. This corrections resulted in levels and patterns similar to previous years. A report has been done at NILU's lab and new procedures are introduced (test of all solvents) in order to prevent this to re-occur.

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

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

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

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