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National moss survey 2015

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Atmosfærisk nedfall av organiske miljøgifter over Norge. Landsomfattende moseundersøkelse 2015
Atmospheric deposition of organic contaminants in Norway: National moss survey 2015

Summary – sammendrag

For the second Norwegian Moss survey on organic contaminants 20 samples were collected on the Norwegian mainland in rural areas presumably little affected by local point sources of pollutants. PeCB, HCB, PCB, HCH, DDT, PBDE, DBDPE, HBCD, PFAS, and PAH were determined. There is a general trend of decreasing contamination from 2010 to 2015 for the POPs included in the survey. A trend of decreasing contamination with increasing latitude shown in the 2010 moss data is confirmed in the results from 2015. The results for PCB indicate release from local sources in the Oslo area.

Til den andre norske moseundersøkelsen med tanke på organiske miljøgifter, ble det samlet inn 20 prøver på det norske fastlandet, fortrinnsvis i området som er lite påvirket av lokale kilder til forurensning. PeCB, HCB, PCB, HCH, DDT, PBDE, DBDPE, HBCD, PFAS og PAH er bestemt. Den generelle trenden viser en nedgang i kontamineringen fra 2010 til 2015 for de POPene som er inkludert i undersøkelsen. En trend som viser minkende forurensning ved stigende lengdegrad vist i 2010 mosedata, blir bekreftet i 2015-resultatene.

PCB resultatene indikerer utslipp fra en lokal kilde i Oslo-området.

4 emneord	4 subject words
POP, PAH, mose, atmosfærisk deposisjon	POP, PAH, moss, atmospheric deposition

Front page photo

Ingjerd Sunde Krogseth

Content

Summary

On behalf of the Norwegian Environment Agency, NILU together with NTNU completed the second Norwegian Moss survey focused on the deposition of organic contaminants.

In total, 20 samples were collected on the Norwegian mainland. The majority of the sampling sites are located in rural areas and presumably little affected by local point sources of pollutants. State-of-the-art analytical methods were used to measure PeCB, HCB, PCB, HCH, DDT, PBDE, DBDPE, HBCD, PFAS, and PAH.

There is a general trend of decreasing contamination from 2010 to 2015 in the groups of POPs included in the survey, and the trend of decreasing contamination with increasing latitude shown in the 2010 moss data, as well as in previous studies using other sampling media, is confirmed in the results from 2015. The results for PCB indicate emissions from local sources in the Oslo area.

In general, data from the 2015 moss survey confirm that sampling and analysis of moss, as described in the 2010 report, is a useful way of detecting levels and assessing temporal trends of deposition of POPs in the terrestrial environment. It is therefore recommended to continue this survey in future monitoring.

Sammendrag

På oppdrag av Miljødirektoratet utførte NILU, i samarbeid med NTNU, den andre undersøkelsen av avsetning av organiske miljøgifter på mose.

Det ble tatt 20 prøver fordelt over hele Norge. De fleste prøver ble tatt i bakgrunnsområder som antas å være lite påvirket at lokale punktkilder. Moderne og tilpassete analysemetoder ble brukt for å måle PeCB, HCB, PCB, HCH, DDT, PBDE, DBDPE, HBCD, PFAS og PAH.

For de fleste stoffer viser prøvene tatt i 2015 generelt lavere konsentrasjoner sammenlignet med moseprøver tatt i 2010. Videre bekreftes den tidligere observerte trenden med avtakende konsentrasjon med stigende nordlig bredde. PCB-resultater viser vedvarende utslipp fra lokale kilder i Oslo-området.

Den nye studien viser at overvåkning av atmosfærisk avsetning av organiske miljøgifter ved hjelp av prøvetaking og analyse av mose, gir verdifull informasjon om romlig fordeling og utvikling over tid. Det gis derfor en klar anbefaling om å fortsette med denne overvåkningen også i framtiden.

1. Introduction

Since the 1970s, it has been evident that samples of terrestrial mosses may be used for the monitoring of atmospheric deposition of pollutants such as heavy metals. Based on experience from the Nordic countries a network for moss sampling and analysis with respect to key heavy metals, covering a large part of Europe, has been established where coordinated surveys are carried out every five years (Harmens et al., 2015b, Harmens et al., 2015a, Harmens et al., 2010, Harmens et al., 2004). In Norway nationwide atmospheric deposition surveys for trace metals based on sampling on the terrestrial moss Hylocomium splendens have been conducted at regular intervals since 1977 (Steinnes et al., 2011), and in recent years these data have constituted part of the joint European moss survey. Quantitative relations between concentration in moss and bulk atmospheric deposition in Norway has been well documented for most heavy metals of key interest (Berg and Steinnes, 1997, Berg et al., 1995).

Within the European network the question has been raised whether moss samples might be used for mapping of other pollutants such as nitrogen compounds and persistent organic pollutants (POPs) (Harmens et al., 2011). Along with the contribution from Norway to the 2010 European moss survey it was decided to carry out a pilot study on the feasibility of moss sampling for assessing geographical differences in deposition of a number of commonly studied POPs. This idea is far from new: already around 1980 some investigators reported data for PAH (Thomas and Herrmann, 1980) and chlorinated compounds (Carlberg et al., 1983, Thomas and Herrmann, 1980) in moss/lichen samples. These early studies have been followed by other publications on PAH (Dolegowska and Migaszewski, 2011, Foan et al., 2015, Foan et al., 2010, Gerdol et al., 2002, Liu et al., 2005, Migaszewski et al., 2009, Otvos et al., 2004, Skert et al., 2010, Thomas et al., 2005, Thomas, 1986, Thomas et al., 1984) PCB and other chlorinated compounds (Grimalt et al., 2004, Knulst et al., 1995, Larsen et al., 1985, Lead et al., 1996, Oehme et al., 1985, Thomas et al., 1984, Thomas et al., 1985) , as well as brominated flame retardants (Mariussen et al., 2008) in mosses. The literature on terrestrial mosses as biomonitors of atmospheric POPs was recently reviewed by Harmens et al. (Harmens et al., 2013) with emphasis on PAHs. The main conclusion was that mosses appear to be suitable organisms to monitor spatial patterns and temporal trends. Furthermore, the "ICP Vegetation Working Group on Effects of the Convention on Long-range Transboundary Air Pollution" that more countries determine POPs concentrations in mosses as part of the European moss survey, in order to establish spatial trends in mosses across Europe (Harmens et al., 2011).

2. Experimental

2.1 Sampling and sample transport

Moss samples were collected during the period May – August 2015 at 20 sites distributed all over the mainland of Norway. The network was the same as used in previous studies of brominated flame retardants (Mariussen et al., 2008) and the National Moss Survey 2010 (Steinnes and Schlabach, 2012). Coordinates at each site were recorded by GPS. A map showing the 2015 sampling locations is presented in Figure 1, and their geographical coordinates are listed in Table 1.

For selection of the sampling sites, sampling, and sample storage the recommendations given in the manual of ICP Vegetation (Frontasyeva and Harmens, 2014) were followed. The majority of the sampling sites are located in rural areas and presumably little affected by local point sources of pollutants. Site 7 is an exception, as it is located only 5 km from the centre of the capital Oslo. Sampling sites were located at least 300 m from main roads and densely populated areas, and at least 100 m from any local road, single house, or agricultural field. If possible, moss sampling under the crown projection of trees was avoided.

The samples were collected using bare hands, pre-cleaned with wet Sphagnum moss from the same site. A total of three litres of Hylocomium splendens moss was collected at each site covering an area of roughly 50 m x 50 m comprising between 5 and 10 sub-samples. The total living part of each moss plant was collected, most often covering the last 3-5 years´ growth. The samples were directly put into pre-cleaned glass jars (3 L) which were covered with a layer of aluminium foil and a screw lid. In field and during transport the samples were stored in freezing bags together with some ice packs. In the laboratory the jars containing the samples were stored at -20° C until analysis.

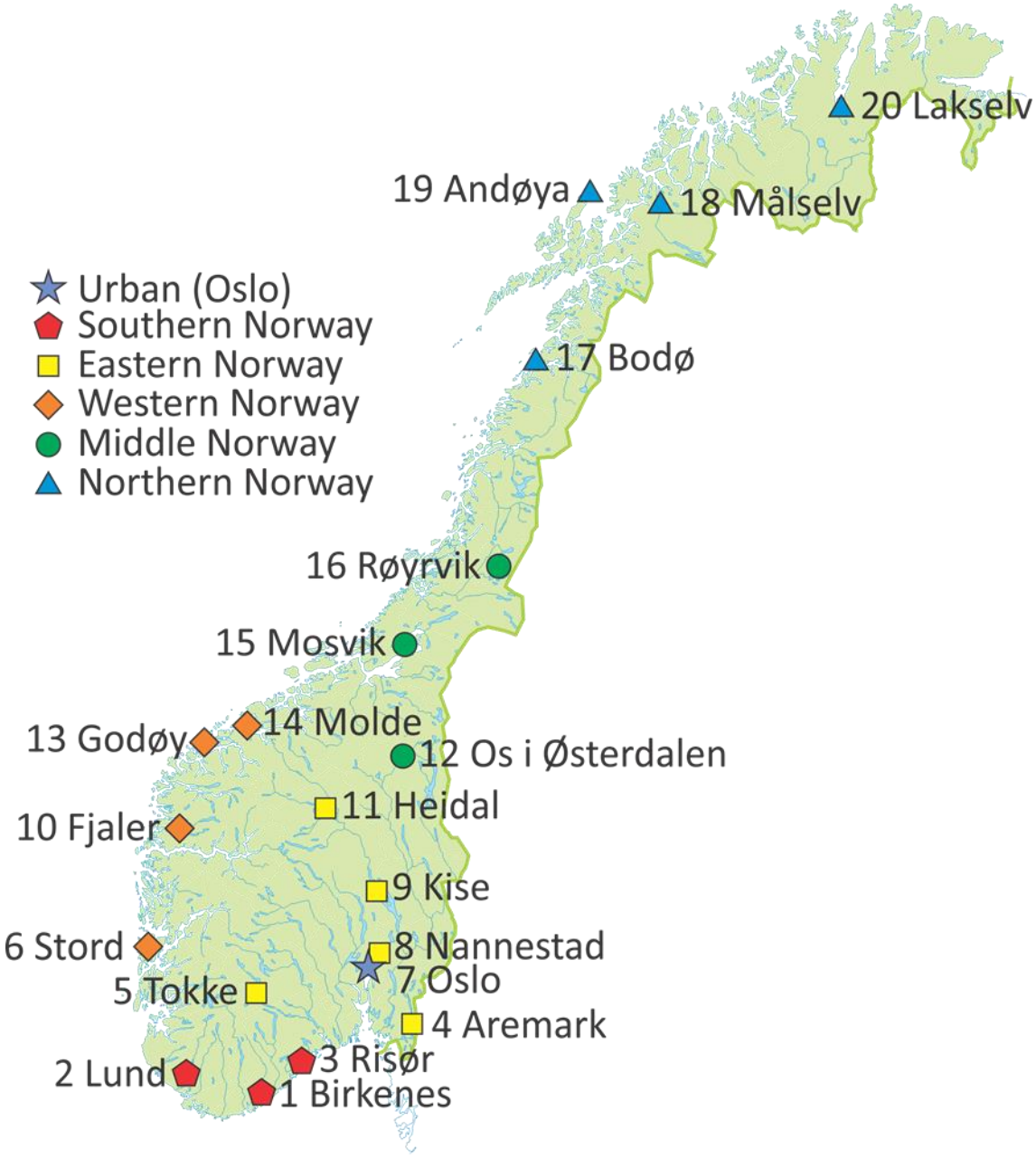

Figure 1: Map showing all moss sampling sites used in the POP study.

Table 1: Moss sampling sites used for the POP study

	Site	Area	Latitude [° N]	Longitude [° E]	RPD* [C 25km]	Mean annual Temperature [° C]	Mean annual Precipitation [mm]
1	Birkenes	SN	58.3878°	8.2499°	2.8E-04	6.5	1381
2	Lund	SN	58.5370°	6.3772°	2.1E-04	5.9	2250
3	Risør	SN	58.7597°	9.2101°	2.6E-04	6.9	1166
4	Aremark	EN	59.2292°	11.7326°	3.7E-04	5.0	859
5	Tokke	EN	59.4897°	7.9523°	1.8E-04	3.8	1035
6	Stord	WN	59.8805°	5.3430°	2.7E-04	6.6	1978
7	Oslo/Maridalen	urban	59.9790°	10.7517°	9.7E-04	4.9	915
8	Nannestad	EN	60.2517°	11.1144°	8.6E-04	3.6	823
9	Kise	EN	60.7822°	10.7957°	3.5E-04	3.3	585
10	Fjaler	WN	61.2485°	5.4088°	1.4E-04	6.7	3131
11	Heidal	EN	61.7799°	9.2448°	1.2E-04	0.5	452
12	Os i Østerdalen	MN	62.3654°	11.4799°	9.3E-05	-1.9	487
13	Godøy	WN	62.4763°	6.0172°	1.5E-04	6.4	1405
14	Molde	WN	62.7333°	7.0170°	1.5E-04	5.8	1590
15	Mosvik	MN	63.8019°	10.5931°	2.1E-04	4.5	1856
16	Røyrvik	MN	64.8892°	13.9310°	3.1E-05	-0.2	873
17	Bodø	NN	67.3908°	14.6523°	5.8E-05	3.1	1565
18	Målselv	NN	69.0106°	18.9833°	5.3E-05	0.3	725
19	Andøya	NN	69.2887°	16.0421°	3.8E-05	3.8	1007
20	Lakselv	NN	69.8295°	25.1698°	1.8E-05	-1.1	434

*: Relative population density (RDP) values were calculated for each sampling site with census data given in a 1 km x 1 km grid and for a radius of 25 km as described by Schuster et al. 2011 (Schuster et al., 2011). RPD ranges from 1.8E-05 for the most rural site Lakselv to 9.7E-04 at the most densely populated site in Oslo/Maridalen.

2.2 Analysis

Table 2 provides a detailed list of the compounds and compound groups determined in the moss samples

Table 2: Analytes included in this study

Parameter	Single compounds	Comment
PCB	PCB-28, -52, -101, -118, -138, -153, -180 (plus -18, -31, -33, -37, -47, -66, -74, -99, -105, -114, -122, -123, -128, -141, -149, -156, -157, -167, -170, -183, -187, -189, -194, -206, -209)	
PBDE	BDE-47, 99, 100, 153, 154, 183, 196, 206 og 209	
PAH	Naphtalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Benzo(b)fluoranthenes, Benzo(k)fluoranthenes, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenzo(ah)anthracene, and Benzo(ghi)perylene.	
Other organochlorine compounds	α-HCH,γ-HCH, HCB, p,p'-DDE, p,p'-DDD, p,p'-DDT, o,p'-DDE, o,p'-DDD, o,p'-DDT	Only p,p'-DDE were regularly detected above LoD[1]
PFC	PFOS, PFOA, PFNA, PFDcA (c10), PFUnA(c11), PFDoA (c12), PFTrA (c13), PFBS og PFHxS	All compounds were below LoD[1]
Other brominated flame retardants	Decabromodiphenyl ethane (DBDPE)	All compounds were below LoD[1]
Chloroparaffins	SCCP (C10-C13) and MCCP (C14-C17)	All compounds were below LoD[1]

2.2.1 Sample storage and sample preparation

Until start of sample preparation, clean-up, and quantitative analysis the samples were stored in a freezer at a temperature below -20° C. Prior to extraction the moss samples were unpacked and dried at room temperature (20 – 25° C) in a fume hood localized in a special clean laboratory environment (class 100000 part/m^3/ft).

2.2.2 Extraction

In order to monitor recovery rates for the extraction and clean-up procedures, mixtures containing internal standards were added to the moss samples prior to extraction and clean-up (see below). For determination of the chlorinated and brominated compounds and for PAHs the moss samples were Soxhlet extracted for 8-10 hours in approximately 250 mL of n-hexane. Extracts were concentrated to about 0.5 mL on a TurboVap 500 System (Zymark, Hopkinton, MA, USA), and transferred to a graduated cylinder. Further sample treatment was done separately and the extracts were therefore divided into two identical aliquots. For determination of the polyfluorinated compounds the samples were homogenized with an Ultra-Turrax. 1-g samples were extracted three times with methanol by sonication in an ultrasonic bath and concentrated to circa 1 mL.

2.2.3 Clean-up

For determination of PCB, HCH, DDT, HCB, PBDE, DBDPE, SCCP, and MCCP one aliquot of the hexane extract was transferred to a centrifuge tube, adjusted to 2 mL, and treated with 2 mL concentrated sulfuric acid for mixing by vigorous whirling on a whirl mixer. During this treatment the extract color turns to dark yellow. The treatment was repeated until no more color change was visible (2-3 times). The extract was then transferred to an evaporation unit and reduced to 0.5 mL for further clean-up by fractionation with a silica column (15 mm in diameter and 200 mm in length). The column consists of 4 g of activated silica (Silica gel 60 Merck nr. 7734 0.063 – 0.200 mm pretreated 8 h at 550°C) topped with 1 cm anhydrous sodium sulfate (pretreated 12 h at 600°C). The column was prewashed with 30 mL n- hexane. The samples were eluted with 30 mL n-hexane/10 % diethyl ether. Extracts were reduced to 0.5 mL by evaporation and solvent exchanged into iso-octane and transferred to a small vial with a screw-cap.

For determination of PAHs the second aliquot of the hexane extract was solvent exchanged to cyclohexane. The bulk of the sample matrix was removed using a modified version of a liquid/liquid partitioning described by Grimmer and Böhnke (Grimmer and Böhnke, 1972) followed by a clean-up on a silica liquid chromatography column. Finally, the extract was reduced to 0.5 mL by evaporation and transferred to a small vial with a screw-cap.

For the determination of PFAS the samples were extracted with acetonitrile and treated with emulsive clean-up prior to analyses with UPLC/MS/MS in ESI(-) mode.

Before the instrumental analyses all extracts were further reduced to approximately 50 µL by a gentle stream of nitrogen.

2.2.4 Instrumental analyses

In order to monitor recovery rates for the extraction and clean-up procedures, a mixture of internal standards was added to the samples prior to extraction and clean-up. This standard mixture consisted of a range of 13C – labeled polychlorinated biphenyls (PCB) congeners (13C PCB-28, 52, 101, 105, 114, 118, 123, 138, 153, 156, 157, 167, 180, 189, and 209) and organochlorine pesticides (OCPs) (13C α, ß, γ- hexachlorocyclohexane (HCH), 13C-hexachlorobenzene (HCB), 13C p,p'- dichlorodiphenyldichloroethylene (DDE), 13C p,p'-dichlorobiphenyldichloroethane (DDT), 13C PBDE-28, 47, 99, 153, 183, and 209). For the PAHs, a mixture of deuterium labeled polyaromatic hydrocarbons (PAH) congeners (2-methylnaphtalene- d10, acenaphtene- d10, anthracene- d10, pyrene- d10, benz(a)anthracene- d12, benz(e)pyrene- d12, benz(ghi)perylene- d12), was added. All standards were purchased from LGC, formerly Promochem AB (Borås, Sweden). In order to quantify the recovery of the internal standards, a recovery standard consisting of deuterated PAHs (biphenyl-d10, fluorantene-d10 and perylene-d12) was added to the PAH extracts, while 1,2,3,4-tetrachloronaphtalene) was added to the acid resistant extracts. The recovery of the added labelled standards was determined for each sample.

For all samples the recovery rates were accepted. As the concentrations of the analytes were calculated based on the measured internal standard signals, no adjustment according to recovery rates was applied.

Determinations of the PCB congeners, α-HCH, ß-HCH, γ-HCH, p,p'-DDE, p,p'-DDD, o,p'-DDT and p,p'-DDT, HCB were performed with GC/HRMS on an Agilent 6890N gas chromatograph coupled to a Waters AutoSpec mass spectrometer in electron impact (EI) mode.

The different PCB congeners were separated using a HT-8 (50 m×0.22 mm inner diameter (SGE)) fused silica capillary column. The GC was operating in splitless mode with helium as a carrier gas. 1 µL of sample extract was injected at an injector temperature on 280°C. In 2015, a blank contamination was found for PCBs. The source of this contamination was found to be a solvent 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. 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. After these corrections PCB levels and patterns were similar to those observed in previous years.

Separation of α-HCH, ß-HCH, γ-HCH, p,p'-DDE, p,p'-DDD, o,p'-DDT and p,p'-DDT compounds was done by use of a HP-1 (25 m×0.2 mm inner diameter (J&W Scientific)) fused silica column. 1 µL was injected by an autosampler on the split/splitless injection port in splitless mode with helium as a carrier gas (flow rate 1 mL/min).

Determination of PAHs was carried out by a GC/LRMS on an Agilent 6890N gas chromatograph coupled to an Agilent 5973 mass spectrometer in an electron impact (EI) mode. 1 µL was injected by an auto sampler on the split/splitless injection port in splitless mode with helium as a carrier gas (flow rate ~1 mL/min).

Determination of PFAS were performed by UPLC/MS/MS in ESI(-) mode.

2.3 Uncertainties

All monitoring of contaminants is to some extent subject to measurement uncertainties. All steps in the process may in theory contribute to the total uncertainty. This includes the study design, selection of sampling media, sampling sites, sampling frequency, time of sampling, performance of sampling, transport and storage of samples, chemical analysis, and data treatment. To quantitatively estimate the contribution of the different steps is an extremely difficult task. In the following the relevance of the different contributing factors is discussed in a qualitative way.

Study design
Deposition measurements intended to cover an entire country in a representative way are an extreme costly and complex task. Moss has therefore been used as a proxy for the rate of atmospheric deposition for many decades in the case of heavy metals. The use of moss for deposition measurement of organic contaminants started only recently and it is still an open question if it is possible to derive a quantitative relationship between moss concentrations and deposition rates. It has been shown in laboratory experiments that hydrated moss (Hylocomium splendens) takes up more HCH than completely desiccated moss (Kylin and Bouwman, 2012). If this is relevant under the humid Norwegian climate is not yet clear.

Moreover, the concentrations of the different analytes in moss samples may vary due to different local conditions, such as local sources and local differences in precipitation and deposition processes.
At least for PAHs there are a variety of different small local sources, e.g. forest fires, campfires, use of forestry machineries, etc., which are not easily identified and may have contributed to a local increase of the PAH exposure.

Sampling and sample handling
Factors influencing sampling uncertainty may be related to (1) representativeness of the subsamples, (2) contamination during sampling and storage, (3) loss of analytes due to evaporation from the sample container or adsorption to the sample containers, and (4) degradation during transport and storage.

The risk of contamination during sampling seems to be particularly high for compounds such as BDE-209 (DecaBDE), which may still be in use as flame retardants in articles of daily use (textiles, electronic equipment, vehicles etc.)

Chemical analysis
Uncertainty in the chemical analysis can be related to (1) loss during extraction and clean-up, (2) interference from other compounds, (3) trueness of analytical standards, (4) instrumental parameters, and (5) contamination. In contrast to the other uncertainties it is often possible to estimate and quantify these analytical factors. The normal approach is participation in a laboratory inter-calibration. The uncertainty is expected to be larger for compounds which are analysed infrequently than for compounds commonly analyzed. In total this means that analytical uncertainties for most of the compounds discussed in this report (PCB, chlorinated pesticides and PAHs) may be within the range of 20 to 40 %, and even higher for PBDEs and PFAS.

For all these groups of POPs we consider the analytical uncertainty as fit-for-purpose, that means adequate for an initial screening study. Use of these results for future time trend studies, however, may be limited by the considerable uncertainties in analytical data.

3. Results and Discussion

In the following the present results for DDE, and selected congeners of PCB, PBDE, and PAH are shown and compared with corresponding data from the 2010 survey. The complete results for determination of all compounds studied in the 20 moss samples are given in Appendix. PFAS, PeCB, HCB, the HCH-group and some compounds of the DDT-group were found to be below LoD in most of the samples, and results for these components are not shown. In the 2010 survey the LoD is based on the instrumental detection limit was included in the LoD. We now apply a more conservative procedure for estimation of LoD.

3.1 PCB

Concentrations of selected PCB congeners are shown in Figure 3 in comparison to corresponding values from the 2010 survey in Figure 2.

The general levels are around 70% of the 2010 values and the congener distribution is similar among the sites, confirming the general impression from other studies that long-range atmospheric transport is the dominant source of PCB to the environment in Norway. One remarkable difference is evident for the Oslo/Maridalen site where the congener ratio is different from that seen at the other sites and the sum of congeners is 5-10 times higher than at the other sites. This indicates a still active source releasing PCB to the air the Oslo area. The concentration levels measured in 2015 (PCB-4: 580 pg/g dw) also appear slightly higher compared to 2010 (PCB-4: 460 pg/g dw). However, this difference is not greater than the estimated measurement uncertainty and thus not showing a significant time trend. As far as we know the most recent PCB air measurements from Oslo are from 2002 and 2007, which showed a much higher average air concentration in Oslo, Sofienbergparken 2007 (PCB-7: 31.8 pg/m3) and Sjursøya 2002 (PCB-7: 54 pg/m3) compared to a background site such as Birkenes, 2007 (PCB-7: 4.55 pg/m3) (Schlabach, 2008; Aas et al., 2012).

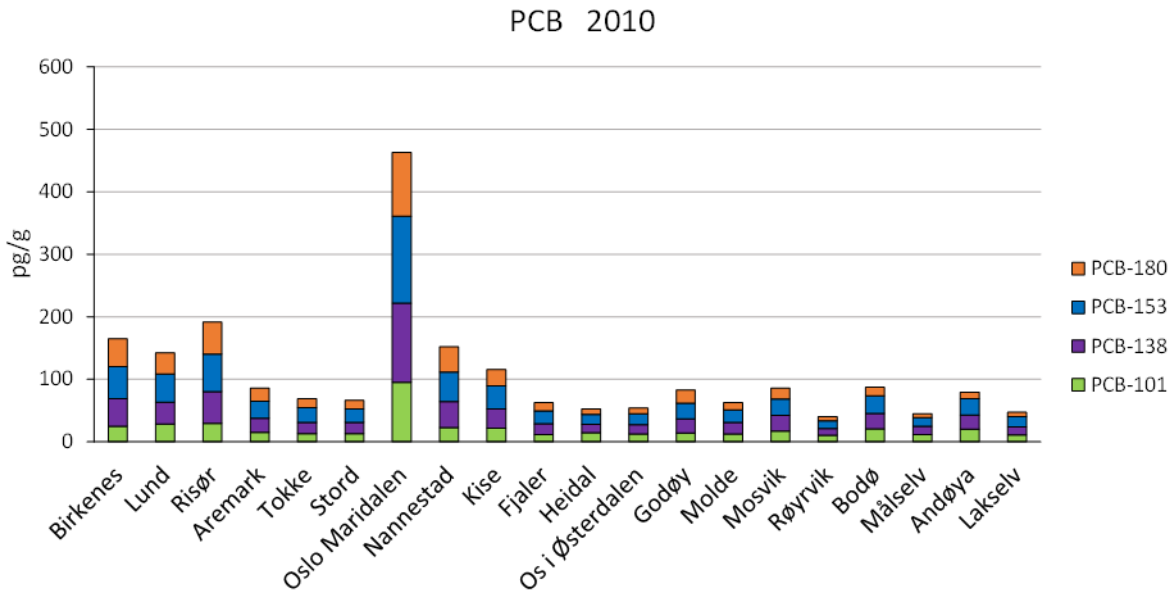

Figure 2: Distribution of selected PCB congeners from the 2010 study.

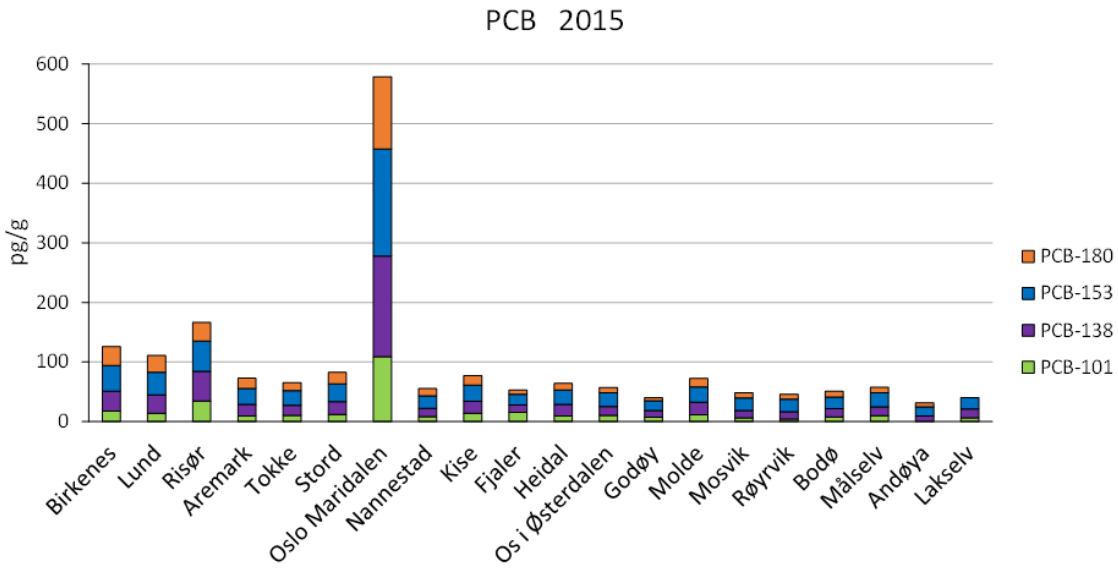

Figure 3: Distribution of selected PCB congeners from the 2015 study.

3.2 DDE

The only compound of the DDT-group which could be detected above LoD in all samples is p,p'-DDE. The distribution of p,p'DDE is shown in Figure 5 in comparison to corresponding values from the 2010 survey in Figure 4. The result for DDE show that previous contamination from DDT and its daughter products is still declining. Like in 2010 the DDE level at Kise is considerably higher than elsewhere. Also other studies showed a higher DDE/DDT contamination in and around Lake Mjøsa and a waste disposal site about 3 – 4 km east of the Kise moss sampling site was identified as an important source of DDT leakage to Lake Mjøsa (Norwegian Environment Agency, 2008). This disposal site was cleaned-up in 2009, but might still contribute to a locally high DDE air concentration. Another source of DDE might be the Kise Agricultural Research station.

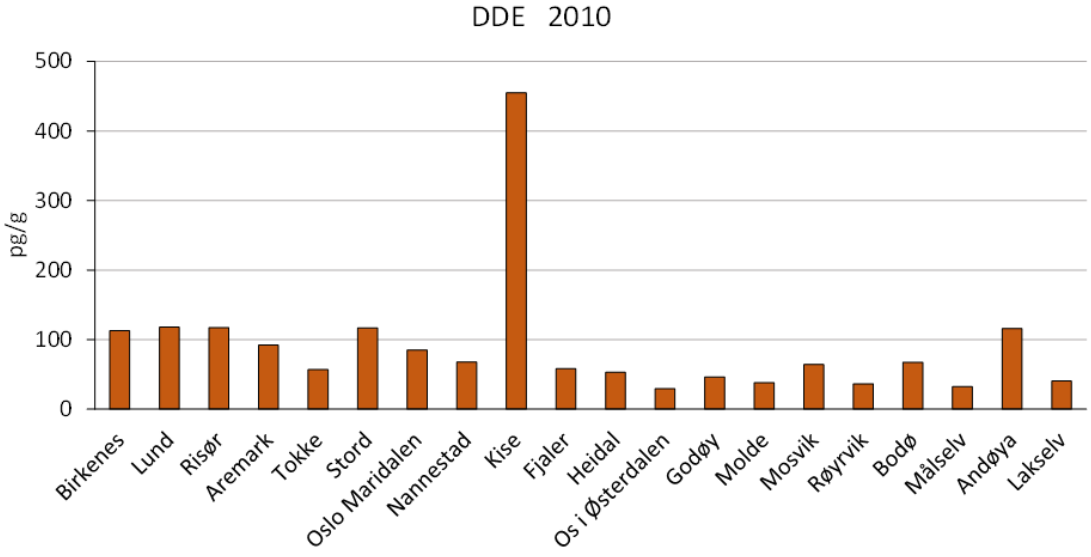

Figure 4: Distribution of p,p'-DDE from the 2010 study.

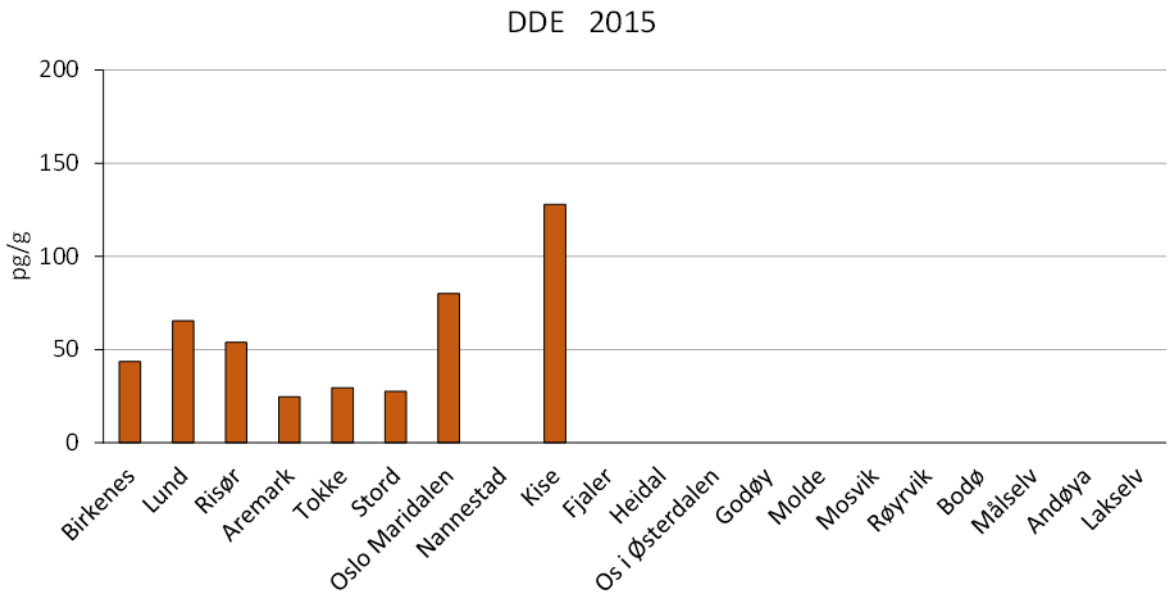

Figure 5: Distribution of p,p'-DDE from the 2015 study.

3.3 PBDE

Concentrations of selected PBDE congeners are shown in Figure 7 and Figure 9 (with and without BDE-209) in comparison to corresponding values from the 2010 survey in Figure 6 and Figure 8, respectively.

Both in 2010 and 2015 the BDE-209 is the dominating congener. For most sites the total PBDE value remains stable or lower in 2015 compared to 2010, but Oslo Maridalen and Kise show a higher total PBDE concentration in 2015. However, as explained in Chapter 2.3 Uncertainties, the measurement of BDE-209 is exposed to a much higher measurement uncertainty, mainly related to the risk of contamination, and a conclusion on the time trend remains open until more results are available.

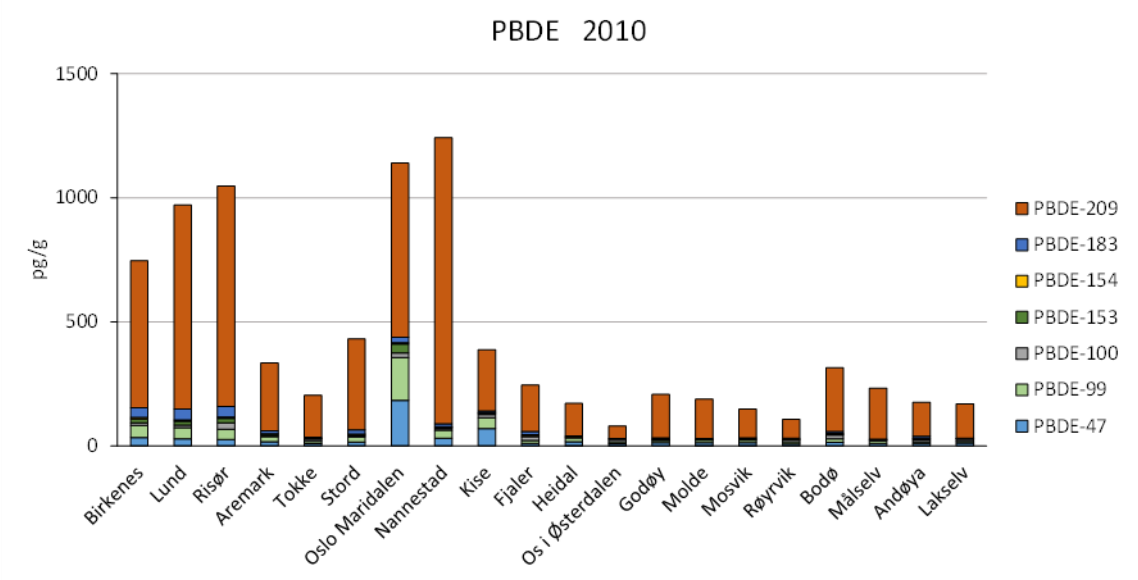

Figure 6: Distribution of selected PBDE congeners (including BDE-209) from the 2010 study.

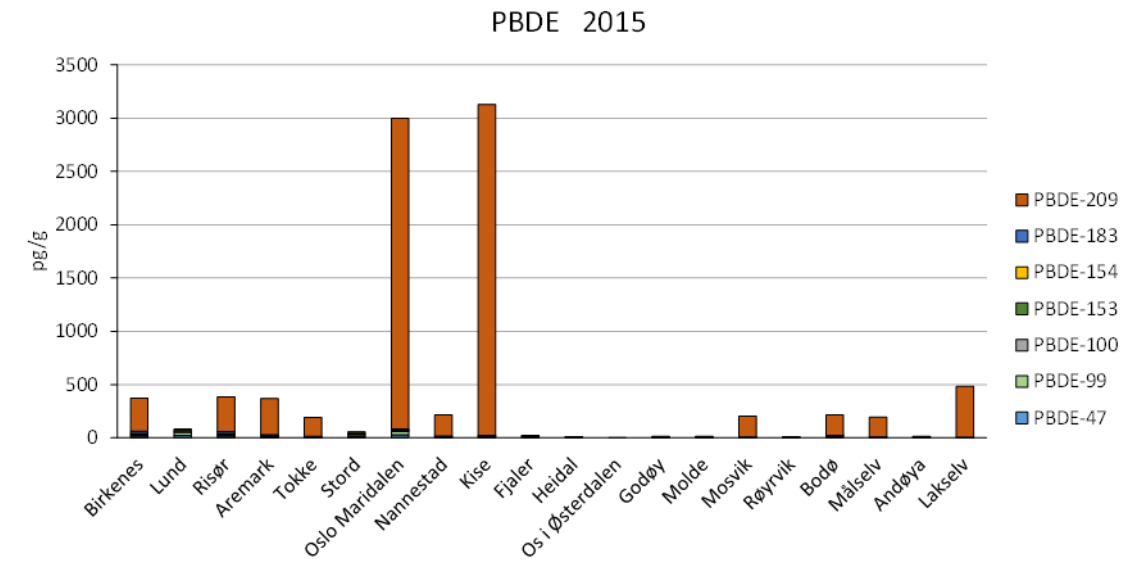

Figure 7: Distribution of selected PBDE congeners (including BDE-209) from the 2015 study.

Without BDE-209 the picture is changing and the 2015 study shows lower PBDE concentrations in general compared to 2010, with a somewhat higher level in the south than in the more northerly parts of the country, and Oslo Maridalen as a local hotspot.

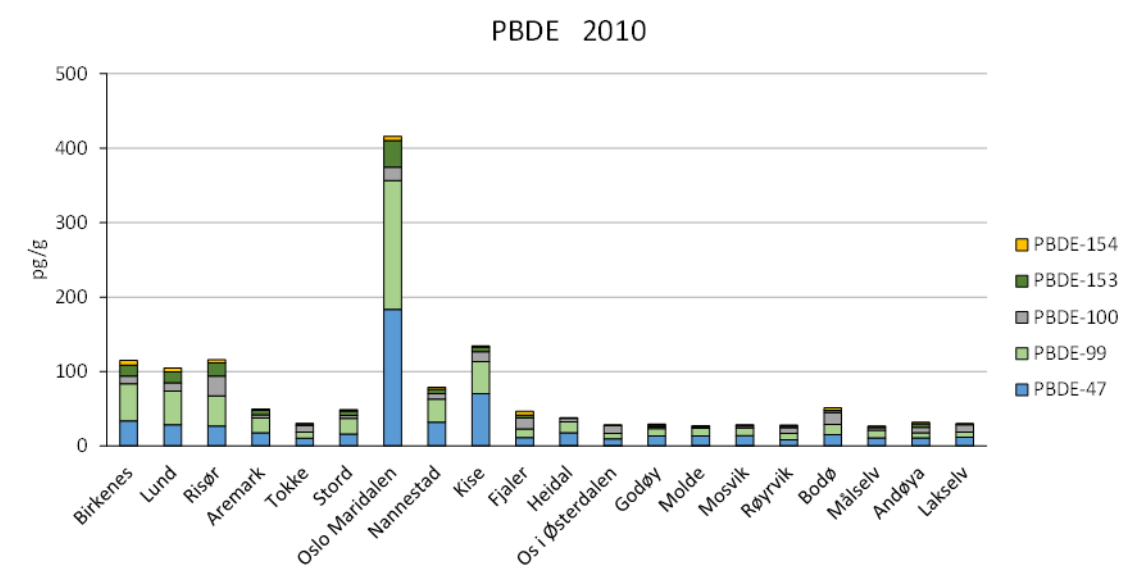

Figure 8: Distribution of selected PBDE congeners (without BDE-209) from the 2010 study.

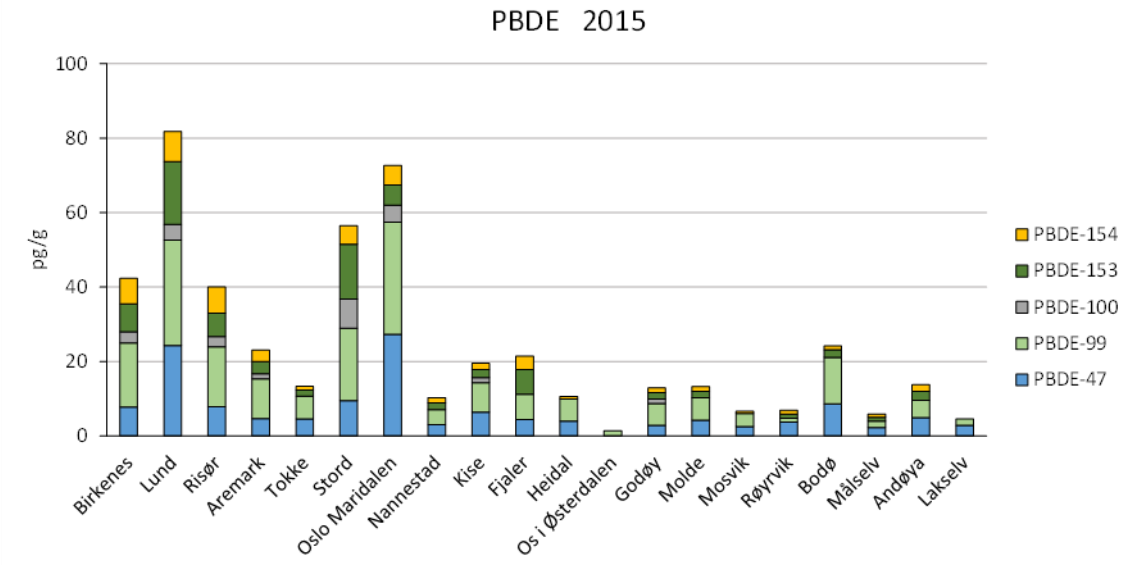

Figure 9: Distribution of selected PBDE congeners (without BDE-209) from the 2015 study.

3.4 PAH

The data for PAH also show a generally declining trend, with a somewhat higher level in the south than in the more northerly parts of the country. In general the PAH monitoring using moss samples may be sensitive to possible use of open fires in sampling areas. It is suspected that influence from such events may have contributed to the relatively high values observed in samples from Lakselv 2010 and correspondingly for Oslo Maridalen and Godøy in 2015. The results for Birkenes in 2015 are difficult to understand.

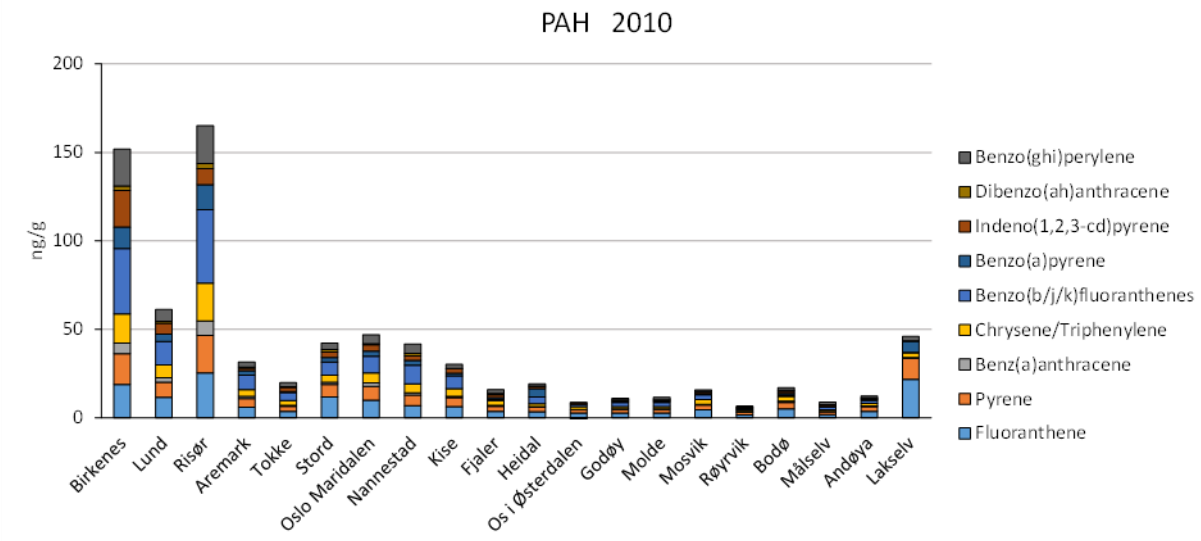

Figure 10: Distribution of selected PAH compounds from the 2010 study.

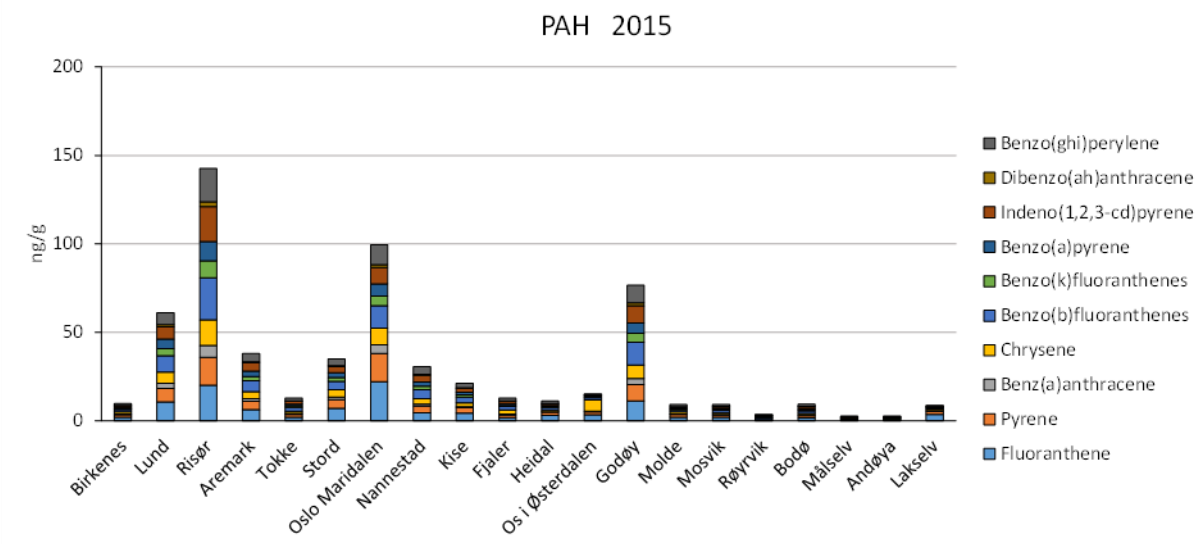

Figure 11: Distribution of selected PAH compounds from the 2015 study.

4. Conclusion

In general, data from the 2015 moss survey confirms that sampling and analysis of moss, as described in the 2010 report, is a useful way of detecting levels and assessing spatial trends of deposition of POPs in the terrestrial environment. The most striking trend observed is the decrease of PCB-concentration with increasing latitude. This trend was shown in the 2010 moss data, as well as in previous studies using other sampling media, and is confirmed in the results from 2015. In addition, the results for PCB indicate emissions from local sources in the Oslo area.

It is very likely that moss surveys will also be useful to identify temporal trends, and there seems to be a general trend of decreasing contamination from 2010 to 2015 in the groups of POPs included in the survey. However, with only two points on the time scale and with a measurement uncertainty in the same range or higher than the expected decrease of contamination level, it is not possible to draw a final conclusion yet.

Only very few studies have directly related the concentrations in mosses with measured atmospheric concentrations in deposition or deposition fluxes. It was not the goal of this report to attempt to correlate POP-concentrations in air and moss. However, the results from this study together with results from other countries where moss and air were sampled at identical sites, are important pieces of information for a better and probably quantitative understanding of the deposition mechanisms of POPs from air to moss.

The moss survey provides knowledge about the general temporal and spatial trends of POPs-contamination in Norway that is difficult to achieve by other means without substantially increased cost. It is therefore recommended to continue this survey in future monitoring.

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Appendix

POP concentration in moss 2015 given in pg/g d.w.								
	Site	PeCB	HCB	PCB-18	PCB-28	PCB-31	PCB-33	PCB-37
1	Birkenes	<43	**256**	<11	< 33	<23	< 18	<17
2	Lund	<43	< 179	<11	< 33	<23	< 18	<17
3	Risør	<43	**188**	<11	< 33	<23	< 18	<17
4	Aremark	<43	< 179	<11	< 33	<23	< 18	<17
5	Tokke	<43	< 179	<11	< 33	<23	< 18	<17
6	Stord	<43	< 179	<11	< 33	<23	< 18	<17
7	Oslo/Maridalen	<43	< 179	5,78	< 33	12,12	< 18	<17
8	Nannestad	<43	< 179	<11	< 33	<23	< 18	<17
9	Kise	<43	< 179	<11	< 33	<23	< 18	<17
10	Fjaler	<43	< 179	<11	< 33	<23	< 18	<17
11	Heidal	<43	< 179	<11	< 33	<23	< 18	<17
12	Os i Østerdalen	<43	< 179	<11	< 33	<23	< 18	<17
13	Godøy	<43	< 179	<11	< 33	<23	< 18	<17
14	Molde	<43	< 179	<11	< 33	<23	< 18	<17
15	Mosvik	<43	< 179	<11	< 33	<23	< 18	<17
16	Røyrvik	<43	< 179	<11	< 33	<23	< 18	<17
17	Bodø	<43	< 179	<11	< 33	<23	< 18	<17
18	Målselv	<43	141	<11	< 33	<23	< 18	<17
19	Andøya	<43	< 179	<11	< 33	<23	< 18	<17
20	Lakselv	<43	**201**	<11	< 33	<23	< 18	<17

POP concentration in moss 2015 given in pg/g d.w.

	Site	PCB-52	PCB-66	PCB-74	PCB-99	PCB-101	PCB-105	PCB-114
1	Birkenes	< 15	5,16	< 5,8	19,6	17,9	6,30	< 0,24
2	Lund	< 15	4,05	< 5,8	18,5	13,8	5,27	< 0,24
3	Risør	11,4	8,00	3,48	23,9	34,3	11,7	< 0,24
4	Aremark	< 15	< 10	< 5,8	13,4	9,3	3,09	< 0,24
5	Tokke	< 15	< 10	< 5,8	15,3	10,5	2,70	0,13
6	Stord	< 15	4,65	< 5,8	15,8	11,8	3,16	< 0,24
7	Oslo/Maridalen	29,8	26,3	11,8	42,0	109	48,1	2,84
8	Nannestad	< 15	< 10	< 5,8	14,5	8,4	1,41	< 0,24
9	Kise	< 15	< 10	< 5,8	16,8	14,0	3,79	0,38
10	Fjaler	< 15	< 10	< 5,8	11,0	15,7	1,86	< 0,24
11	Heidal	< 15	6,81	2,55	12,7	9,6	3,76	< 0,24
12	Os i Østerdalen	< 15	< 10	< 5,8	11,2	10,1	2,54	< 0,24
13	Godøy	< 15	< 10	< 5,8	14,3	7,5	1,28	< 0,24
14	Molde	< 15	4,83	3,87	18,0	11,2	2,57	< 0,24
15	Mosvik	< 15	3,90	< 5,8	27,3	6,6	2,43	< 0,24
16	Røyrvik	< 15	< 10	< 5,8	23,1	4,0	< 2,0	< 0,24
17	Bodø	< 15	5,65	< 5,8	23,6	8,0	2,89	< 0,24
18	Målselv	< 15	< 10	< 5,8	33,0	9,8	4,25	< 0,24
19	Andøya	< 15	< 10	< 5,8	14,2	< 9,6	1,33	< 0,24
20	Lakselv	< 15	6,17	< 5,8	30,6	6,5	3,70	< 0,24

POP concentration in moss 2015 given in pg/g d.w.

	Site	PCB-118	PCB-122	PCB-123	PCB-128	PCB-138	PCB-141	PCB-149
1	Birkenes	15,0	< 0,21	0,53	8,36	33,0	6,69	25,8
2	Lund	12,5	< 0,21	< 0,60	6,58	31,0	5,61	25,0
3	Risør	27,6	1,31	< 0,60	10,1	49,8	8,35	32,0
4	Aremark	7,95	< 0,21	1,01	4,84	19,5	3,71	14,4
5	Tokke	7,57	< 0,21	0,44	4,52	16,9	3,21	14,4
6	Stord	7,61	< 0,21	< 0,60	< 0,83	22,0	3,93	17,3
7	Oslo/Maridalen	106	1,35	7,87	48,3	169	41,5	121
8	Nannestad	6,39	< 0,21	< 0,60	4,74	13,7	2,87	11,6
9	Kise	11,0	< 0,21	< 0,60	5,49	20,2	4,34	17,3
10	Fjaler	6,48	< 0,21	< 0,60	2,71	12,3	2,48	12,6
11	Heidal	7,38	< 0,21	< 0,60	3,85	19,6	4,39	18,3
12	Os i Østerdalen	7,89	< 0,21	0,62	3,40	15,2	3,59	13,7
13	Godøy	6,03	< 0,21	< 0,60	2,76	11,1	1,83	9,59
14	Molde	9,02	< 0,21	< 0,60	< 0,83	21,2	1,76	15,4
15	Mosvik	7,71	< 0,21	< 0,60	< 0,83	12,4	1,64	9,39
16	Røyrvik	5,42	< 0,21	< 0,60	< 0,83	12,3	< 1,41	3,46
17	Bodø	7,99	< 0,21	< 0,60	3,75	13,8	2,57	8,92
18	Målselv	9,07	< 0,21	< 0,60	< 0,83	14,7	< 1,41	9,96
19	Andøya	4,43	< 0,21	< 0,60	2,55	9,5	< 1,41	6,99
20	Lakselv	10,3	< 0,21	< 0,60	< 0,83	15,0	1,13	9,94

POP concentration in moss 2015 given in pg/g d.w.

	Site	PCB-153	PCB-156	PCB-157	PCB-167	PCB-170	PCB-180	PCB-183
1	Birkenes	43,2	3,78	0,94	2,02	12,5	31,8	5,72
2	Lund	38,0	3,21	< 0,22	1,44	10,5	28,3	6,92
3	Risør	51,0	6,21	< 0,22	2,59	15,5	31,4	6,89
4	Aremark	27,2	1,79	0,46	< 0,24	6,64	17,0	3,67
5	Tokke	24,6	1,62	0,42	0,91	4,29	13,4	3,28
6	Stord	29,7	2,32	< 0,22	1,27	< 1,52	19,2	< 0,40
7	Oslo/Maridalen	180	23,6	4,54	9,24	49,3	121	25,1
8	Nannestad	21,2	1,54	0,33	0,79	4,61	12,1	2,83
9	Kise	27,1	1,86	0,41	1,04	5,32	15,9	3,44
10	Fjaler	17,7	1,02	< 0,22	0,47	2,61	7,33	2,10
11	Heidal	23,8	1,40	< 0,22	0,78	5,54	11,0	3,12
12	Os i Østerdalen	22,9	1,17	0,23	0,67	2,83	8,93	2,48
13	Godøy	16,3	0,93	0,43	0,71	2,72	5,54	2,35
14	Molde	26,1	1,22	< 0,22	0,72	< 1,52	14,0	4,49
15	Mosvik	21,1	< 0,42	< 0,22	< 0,24	4,48	8,52	2,78
16	Røyrvik	21,3	< 0,42	< 0,22	< 0,24	< 1,52	8,49	< 0,40
17	Bodø	19,4	1,61	< 0,22	< 0,24	< 1,52	9,86	< 0,40
18	Målselv	23,9	< 0,42	< 0,22	< 0,24	< 1,52	9,22	< 0,40
19	Andøya	15,0	0,95	< 0,22	0,41	1,38	7,17	1,61
20	Lakselv	18,9	< 0,42	< 0,22	< 0,24	< 1,52	< 1,17	< 0,40

POP concentration in moss 2015 given in pg/g d.w.

	Site	PCB-187	PCB-189	PCB-194	PCB-206	PCB-209	a-HCH	b-HCH
1	Birkenes	14,2	< 0,13	2,09	2,87	2,96	< 69	< 19
2	Lund	16,2	1,37	6,24	< 0,49	2,98	< 69	< 19
3	Risør	19,3	< 0,13	8,03	< 0,49	< 0,48	< 69	< 19
4	Aremark	1,18	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
5	Tokke	0,68	< 0,13	1,96	< 0,49	< 0,48	< 69	< 19
6	Stord	10,7	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
7	Oslo/Maridalen	8,18	2,65	4,85	6,18	3,33	< 69	< 19
8	Nannestad	6,53	0,38	0,20	< 0,49	1,69	< 69	< 19
9	Kise	1,06	0,37	0,52	< 0,49	1,28	< 69	< 19
10	Fjaler	0,75	< 0,13	< 0,11	< 0,49	1,77	< 69	< 19
11	Heidal	7,55	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
12	Os i Østerdalen	< 1,11	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
13	Godøy	5,34	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
14	Molde	6,83	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
15	Mosvik	6,21	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
16	Røyrvik	7,81	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
17	Bodø	< 1,11	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
18	Målselv	< 1,11	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
19	Andøya	0,44	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19
20	Lakselv	< 1,11	< 0,13	< 0,11	< 0,49	< 0,48	< 69	< 19

POP concentration in moss 2015 given in pg/g d.w.

	Site	g-HCH	o,p'-DDE	p,p'-DDE	o,p'-DDD	p,p'-DDD	o,p'-DDT	p,p'-DDT
1	Birkenes	< 65	< 33	43,6	< 30	< 39	< 100	< 150
2	Lund	< 65	< 33	65,4	< 30	< 39	< 100	< 150
3	Risør	< 65	< 33	53,9	< 30	< 39	< 100	< 150
4	Aremark	< 65	< 33	24,7	< 30	< 39	< 100	< 150
5	Tokke	< 65	< 33	29,5	< 30	< 39	< 100	< 150
6	Stord	< 65	< 33	27,6	< 30	< 39	< 100	< 150
7	Oslo/Maridalen	< 65	< 33	80,1	< 30	< 39	< 100	129
8	Nannestad	< 65	< 33	< 37	< 30	< 39	< 100	< 150
9	Kise	< 65	< 33	128	< 30	< 39	< 100	< 150
10	Fjaler	< 65	< 33	< 37	< 30	< 39	< 100	< 150
11	Heidal	< 65	< 33	< 37	< 30	< 39	< 100	< 150
12	Os i Østerdalen	< 65	< 33	< 37	< 30	< 39	< 100	< 150
13	Godøy	< 65	< 33	< 37	< 30	< 39	< 100	< 150
14	Molde	< 65	< 33	< 37	< 30	< 39	< 100	< 150
15	Mosvik	< 65	< 33	< 37	< 30	< 39	< 100	< 150
16	Røyrvik	< 65	< 33	< 37	< 30	< 39	< 100	< 150
17	Bodø	< 65	< 33	< 37	< 30	< 39	< 100	< 150
18	Målselv	< 65	< 33	< 37	< 30	< 39	< 100	< 150
19	Andøya	< 65	< 33	< 37	< 30	< 39	< 100	< 150
20	Lakselv	< 65	< 33	< 37	< 30	< 39	< 100	< 150

POP concentration in moss 2015 given in pg/g d.w.

	Site	PBDE-17	PBDE-28	PBDE-47	PBDE-49	PBDE-66	PBDE-71
1	Birkenes	< 0,97	< 0,94	7,74	< 2,2	< 2,5	< 2,2
2	Lund	< 0,97	< 0,94	24,3	< 2,2	< 2,5	< 2,2
3	Risør	< 0,97	< 0,94	7,88	< 2,2	< 2,5	< 2,2
4	Aremark	< 0,39	< 0,94	4,65	< 2,2	< 2,5	< 2,2
5	Tokke	< 0,97	< 0,94	4,61	< 2,2	< 2,5	< 2,2
6	Stord	< 0,97	< 0,94	9,53	< 2,2	< 2,5	< 2,2
7	Oslo/Maridalen	< 0,97	< 0,94	27,3	1,82	< 2,5	< 2,2
8	Nannestad	< 0,97	< 0,94	3,00	< 2,2	< 2,5	< 2,2
9	Kise	< 0,97	< 0,94	6,37	< 2,2	3,07	< 2,2
10	Fjaler	< 0,97	< 0,94	4,40	< 2,2	< 2,5	< 2,2
11	Heidal	< 0,97	< 0,94	4,00	< 2,2	< 2,5	< 2,2
12	Os i Østerdalen	< 0,97	< 0,94	< 4,4	< 2,2	< 2,5	< 2,2
13	Godøy	< 0,97	< 0,94	2,87	< 2,2	< 2,5	< 2,2
14	Molde	< 0,97	< 0,94	4,28	< 2,2	< 2,5	< 2,2
15	Mosvik	< 0,97	< 0,94	2,55	< 2,2	< 2,5	< 2,2
16	Røyrvik	< 0,97	< 0,94	3,72	< 2,2	< 2,5	< 2,2
17	Bodø	< 0,97	< 0,94	8,63	< 2,2	< 2,5	< 2,2
18	Målselv	< 0,97	< 0,94	2,26	< 2,2	< 2,5	< 2,2
19	Andøya	< 0,97	< 0,94	4,93	< 2,2	< 2,5	< 2,2
20	Lakselv	< 0,97	< 0,94	2,82	< 2,2	< 2,5	< 2,2

POP concentration in moss 2015 given in pg/g d.w.

	Site	PBDE-77	PBDE-85	PBDE-99	PBDE-100	PBDE-119	PBDE-126	PBDE-138
1	Birkenes	< 1,4	< 3,0	17,2	3,00	< 2,2	< 2,0	< 1,5
2	Lund	< 1,4	< 3,0	28,3	4,22	< 2,2	< 2,0	< 1,5
3	Risør	< 1,4	< 3,0	16,1	2,82	< 2,2	< 2,0	< 1,5
4	Aremark	< 1,4	< 3,0	10,7	1,40	< 2,2	< 2,0	< 1,5
5	Tokke	< 1,4	< 3,0	6,10	< 1,3	< 2,2	< 2,0	< 1,5
6	Stord	< 1,4	< 3,0	19,4	7,83	< 2,2	< 2,0	< 1,5
7	Oslo/Maridalen	< 1,4	< 3,0	30,1	4,60	< 2,2	< 2,0	< 1,5
8	Nannestad	< 1,4	< 3,0	4,05	< 1,3	< 2,2	< 2,0	< 1,5
9	Kise	< 1,4	< 3,0	8,00	1,29	< 2,2	< 2,0	< 1,5
10	Fjaler	< 1,4	< 3,0	6,85	< 1,3	< 2,2	< 2,0	< 1,5
11	Heidal	< 1,4	< 3,0	6,00	< 1,3	< 2,2	< 2,0	< 1,5
12	Os i Østerdalen	< 1,4	< 3,0	1,42	< 1,3	< 2,2	< 2,0	< 1,5
13	Godøy	< 1,4	< 3,0	5,85	1,20	< 2,2	< 2,0	< 1,5
14	Molde	< 1,4	< 3,0	5,95	< 1,3	< 2,2	< 2,0	< 1,5
15	Mosvik	< 1,4	< 3,0	3,49	< 1,3	< 2,2	< 2,0	< 1,5
16	Røyrvik	< 1,4	< 3,0	1,07	< 1,3	< 2,2	< 2,0	< 1,5
17	Bodø	< 1,4	< 3,0	12,5	< 1,3	< 2,2	< 2,0	< 1,5
18	Målselv	< 1,4	< 3,0	1,74	< 1,3	< 2,2	< 2,0	< 1,5
19	Andøya	< 1,4	< 3,0	4,64	< 1,3	< 2,2	< 2,0	< 1,5
20	Lakselv	< 1,4	< 3,0	1,80	< 1,3	< 2,2	< 2,0	< 1,5

POP concentration in moss 2015 given in pg/g d.w.

	Site	PBDE-153	PBDE-154	PBDE-156	PBDE-183	PBDE-184	PBDE-191	PBDE-196
1	Birkenes	7,50	6,85	< 3,1	20,0	3,21	< 2,3	23,2
2	Lund	16,9	8,06	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
3	Risør	6,25	7,02	< 3,1	21,0	4,06	< 2,3	16,2
4	Aremark	3,26	3,08	< 3,1	7,28	< 0,86	< 2,3	< 4,6
5	Tokke	1,64	1,04	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
6	Stord	14,7	5,01	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
7	Oslo/Maridalen	5,43	5,22	< 3,1	11,9	< 0,86	< 2,3	< 4,6
8	Nannestad	1,83	1,42	< 3,1	5,61	< 0,86	< 2,3	< 4,6
9	Kise	2,18	1,69	< 3,1	4,59	< 0,86	< 2,3	< 4,6
10	Fjaler	6,62	3,60	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
11	Heidal	<1,1	0,68	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
12	Os i Østerdalen	<1,1	<0,59	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
13	Godøy	1,72	1,29	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
14	Molde	1,72	1,31	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
15	Mosvik	<1,1	0,64	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
16	Røyrvik	1,12	1,12	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
17	Bodø	2,01	1,06	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
18	Målselv	1,07	0,86	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
19	Andøya	2,45	1,74	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6
20	Lakselv	<1,1	<0,59	< 3,1	< 1,1	< 0,86	< 2,3	< 4,6

POP concentration in moss 2015 given in pg/g d.w.

	Site	PBDE-197	PBDE-202	PBDE-206	PBDE-207	PBDE-209		
1	Birkenes	18,7	7,99	22,2	59,7	310		
2	Lund	< 3,0	< 3,1	< 16	< 11	< 210		
3	Risør	18,1	< 3,1	25,9	74,3	324		
4	Aremark	9,97	< 3,1	< 16	21,4	339		
5	Tokke	< 3,0	< 3,1	< 16	< 11	178		
6	Stord	< 3,0	< 3,1	< 16	< 11	< 210		
7	Oslo/Maridalen	< 3,0	< 3,1	70,8	77,4	2912		
8	Nannestad	< 3,0	< 3,1	< 16	16,1	199		
9	Kise	< 3,0	< 3,1	48,8	42,8	3103		
10	Fjaler	< 3,0	< 3,1	< 16	< 11	< 210		
11	Heidal	< 3,0	< 3,1	< 16	< 11	< 210		
12	Os i Østerdalen	< 3,0	< 3,1	< 16	< 11	< 210		
13	Godøy	< 3,0	< 3,1	< 16	< 11	< 210		
14	Molde	< 3,0	< 3,1	< 16	< 11	< 210		
15	Mosvik	< 3,0	< 3,1	< 16	< 11	198		
16	Røyrvik	< 3,0	< 3,1	< 16	< 11	< 210		
17	Bodø	< 3,0	< 3,1	< 16	< 11	191		
18	Målselv	< 3,0	< 3,1	< 16	< 11	188		
19	Andøya	< 3,0	< 3,1	< 16	< 11	< 210		
20	Lakselv	< 3,0	< 3,1	< 16	< 11	479		

PAH concentration in moss 2015 given in ng/g d.w.

	Site	Naphtalene	Acenaphthylene	Acenaph-thene	Fluorene	Phenan-threne	Anthracene
1	Birkenes	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
2	Lund	< 2,9	0,18	0,21	< 1,4	< 21	0,20
3	Risør	< 2,9	1,04	< 0,34	< 1,4	< 21	1,41
4	Aremark	< 2,9	0,14	< 0,34	< 1,4	< 21	< 0,24
5	Tokke	< 2,9	< 0,10	< 0,34	< 1,4	< 21	2,79
6	Stord	< 2,9	1,26	< 0,34	< 1,4	< 21	< 0,24
7	Oslo/Maridalen	< 2,9	0,39	0,23	< 1,4	< 21	0,32
8	Nannestad	< 2,9	0,61	< 0,34	< 1,4	< 21	2,67
9	Kise	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
10	Fjaler	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
11	Heidal	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
12	Os i Østerdalen	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
13	Godøy	< 2,9	0,24	< 0,34	< 1,4	< 21	< 0,24
14	Molde	< 2,9	0,81	< 0,34	< 1,4	< 21	3,46
15	Mosvik	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
16	Røyrvik	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
17	Bodø	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
18	Målselv	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
19	Andøya	< 2,9	< 0,10	< 0,34	< 1,4	< 21	3,33
20	Lakselv	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24

PAH concentration in moss 2015 given in ng/g d.w.

	Site	Naphtalene	Acenaphthylene	Acenaph-thene	Fluorene	Phenan-threne	Anthracene
1	Birkenes	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
2	Lund	< 2,9	0,18	0,21	< 1,4	< 21	0,20
3	Risør	< 2,9	1,04	< 0,34	< 1,4	< 21	1,41
4	Aremark	< 2,9	0,14	< 0,34	< 1,4	< 21	< 0,24
5	Tokke	< 2,9	< 0,10	< 0,34	< 1,4	< 21	2,79
6	Stord	< 2,9	1,26	< 0,34	< 1,4	< 21	< 0,24
7	Oslo/Maridalen	< 2,9	0,39	0,23	< 1,4	< 21	0,32
8	Nannestad	< 2,9	0,61	< 0,34	< 1,4	< 21	2,67
9	Kise	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
10	Fjaler	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
11	Heidal	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
12	Os i Østerdalen	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
13	Godøy	< 2,9	0,24	< 0,34	< 1,4	< 21	< 0,24
14	Molde	< 2,9	0,81	< 0,34	< 1,4	< 21	3,46
15	Mosvik	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
16	Røyrvik	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
17	Bodø	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
18	Målselv	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24
19	Andøya	< 2,9	< 0,10	< 0,34	< 1,4	< 21	3,33
20	Lakselv	< 2,9	< 0,10	< 0,34	< 1,4	< 21	< 0,24

PAH concentration in moss 2015 given in ng/g d.w.

	Site	Fluor-anthene	Pyrene	Benz(a) anthracene	Chrysene	Benzo(b) fluoranthenes	Benzo(k) fluoranthenes
1	Birkenes	2,09	1,40	0,36	1,17	1,45	0,52
2	Lund	10,7	7,71	2,81	6,40	9,23	4,02
3	Risør	20,1	15,9	6,67	14,4	23,9	9,57
4	Aremark	6,32	4,76	1,47	3,91	6,10	2,59
5	Tokke	2,03	1,63	0,47	1,25	2,17	0,87
6	Stord	7,06	4,92	1,52	4,14	4,78	2,05
7	Oslo/Maridalen	22,2	15,9	4,89	9,50	12,6	5,48
8	Nannestad	4,63	3,75	1,11	3,05	5,02	2,05
9	Kise	4,34	3,05	0,68	2,17	3,19	1,28
10	Fjaler	1,89	1,46	0,59	2,23	1,94	0,66
11	Heidal	3,07	1,82	0,31	1,02	1,32	0,53
12	Os i Østerdalen	3,44	1,73	0,27	6,43	1,14	0,53
13	Godøy	11,3	9,21	3,33	7,79	12,9	5,04
14	Molde	2,12	1,48	0,32	1,11	1,21	0,43
15	Mosvik	1,97	1,31	0,35	1,07	1,31	0,55
16	Røyrvik	< 2,2	< 0,91	0,18	0,48	0,88	0,32
17	Bodø	1,70	1,24	0,35	0,97	1,42	0,58
18	Målselv	< 2,2	0,49	0,10	0,40	0,49	0,18
19	Andøya	< 2,2	< 0,91	0,15	0,35	0,65	0,25
20	Lakselv	3,58	1,93	0,18	0,81	0,71	0,29

PAH concentration in moss 2015 given in ng/g d.w.

	Site	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene
1	Birkenes	0,68	0,85	0,13	1,12
2	Lund	5,40	6,84	1,18	6,87
3	Risør	10,8	19,9	2,69	18,8
4	Aremark	3,01	4,64	0,59	4,65
5	Tokke	1,11	1,53	0,16	1,70
6	Stord	2,79	3,31	0,58	3,90
7	Oslo/Maridalen	7,02	9,25	1,60	11,3
8	Nannestad	2,35	3,90	0,41	4,28
9	Kise	1,50	2,25	0,25	2,59
10	Fjaler	0,91	1,38	0,25	1,55
11	Heidal	0,72	0,90	0,09	1,41
12	Os i Østerdalen	0,47	0,55	0,05	0,62
13	Godøy	5,78	9,75	1,71	9,89
14	Molde	0,58	0,76	< 0,03	1,30
15	Mosvik	0,72	0,86	0,08	1,08
16	Røyrvik	0,48	0,62	0,07	0,64
17	Bodø	0,75	0,98	0,09	1,29
18	Målselv	0,20	0,30	< 0,03	0,46
19	Andøya	0,30	0,45	0,05	0,58
20	Lakselv	0,40	0,39	0,04	0,48

Limit of Detection (LoD) in moss for compounds not listed above LoD given in pg/g d.w.											
PFBS	PFHxS	PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTrA	DBDPE	SCCP	MCCP
12	12	40	50	50	50	50	50	50	20	60	20

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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.