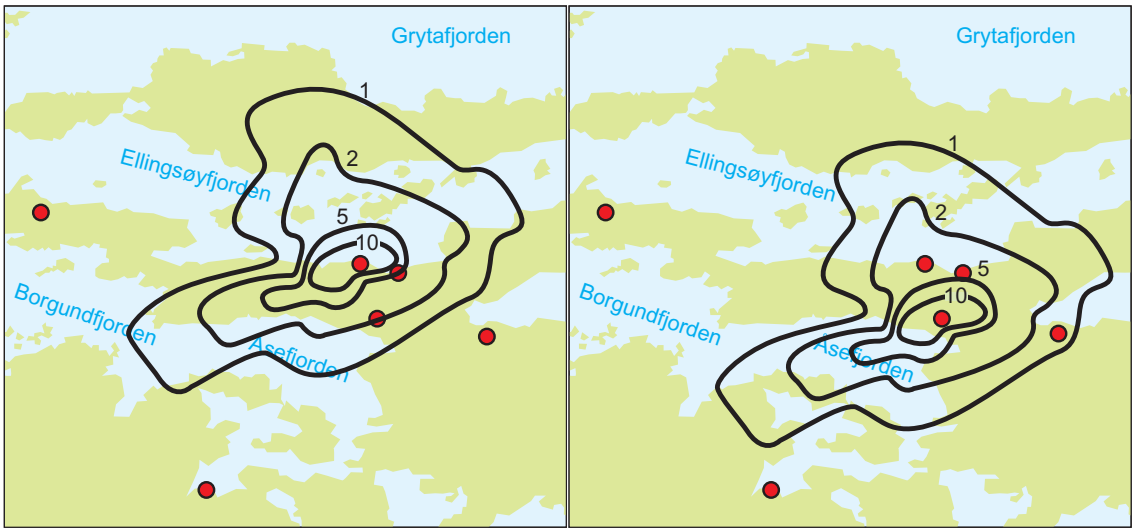
DEPOSITION OF AIRBORNE BFR AROUND THE CITY OF ÅLESUND, NORWAY

Schlabach M, Gjerstad KI
Norwegian Institute for Air Research (NILU), Kjeller, Norway.

Introduction
Previously, high concentrations of brominated flame retardants (BFR), especially hexabromocyclododecane (HBCD) and polybrominated diphenylether (PBDE), have been found in sediments and mussels in Åsefjorden by Ålesund[1,2]. The company Brødrene Sunde use HBCD in their production of Sundolitt (a polystyrene polymer) and the magnitude of emissions from Brødrene Sunde over the years could cause the high concentration of HBCD. Until now it has not been possible to identify any significant emission sources of PBDE in the area. This study seeks to determine whether PBDE are transported to Åsefjorden through air.

This study will examine if emissions of PBDE and HBCD to air might have contributed to BFR pollution in Åsefjorden, and if it might be caused by the deposition of emissions to air from Tafjord waste incinerator.

Materials and Methods
Calculations have been carried out using the Gaussian dispersion- and deposition model CONDEP[3]. There is no actual emission data, therefore the magnitude of emissions employed are nominal. To allow evaluation of the calculations, the relative depositions are estimated for two locations of the emission source: (1) Tafjord waste incinerator and (2) the factory of Brødrene Sunde.



Instead of taking air samples we chose to utilise samples of soil and moss. This decision was motivated by the need to perform this study within a short time period and with quite limited budget. For both sample types the only source (if you can exclude direct contamination) of BFR are due to deposition from the air. Soil will represent a deposition integrated over several years, whilst samples of moss represent deposition the last three years[4].

The samples were collected at sites where low, medium, and high deposition was expected from Tafjord waste incinerator. Eight samples of moss and three samples of soil were collected.

Extraction and clean up
All the samples were spiked with internal standards (^{13}C-PBDEs and ^{2}D-HBCDs) prior to the sample preparation. Soil and moss samples were dried and then Soxhlet extracted acetone/hexane. The samples were treated with concentrated sulphuric acid and further cleaned on a 4 g silica column with n-hexane/diethyl ether (9/1). The polybrominated diphenyl ethers (PBDE) were analyzed with GC/HRMS (PBDE #: 28, 47, 66, 49+71, 77, 85, 99, 100, 119 138, 153, 154, 183, 196, 206, and 209). α-, β-, and γ-Hexabromocyclododecanes (HBCD) were analyzed with LC/MS[4,5].

Results and Discussion
Results are given in table 1 and figure 1 and 2.

Table 1: Concentrations of the most prominent PBDE congeners, the sum of all detected PBDEs, α-, β-, and γ-HBCD and the sum of all detected HBCD-isomers given in ng/g dry weight (d.w.)

	BDE-47	BDE-99	BDE-100	BDE-153	BDE-154	BDE-209	Sum BDE without 209	Sum BDE with. 209	α-HBCD	β-HBCD	γ– HBCD	Sum HBCD
Soil												
Godøy	0,02	0,01	< 0,01	<0,05	<0,05	0,32	0,03	0,35	0,03	0,01	0,01	0,04
Spjelkavik	0,02	0,01	< 0,01	<0,05	<0,05	0,17	0,03	0,19	0,50	0,06	3,41	3,97
Breivik	0,05	0,03	0,01	<0,05	<0,05	4,34	0,10	4,44	0,31	0,02	1,61	1,94
Moss												
Godøy	0,06	0,07	0,01	<0,05	<0,05	1,82	0,14	1,97	0,27	0,17	0,41	0,86
Sukkertoppen	0,36	0,63	0,16	<0,05	0,08	6,29	1,39	7,69	1,12	0,07	9,22	10,4
Aksla	0,07	0,07	0,02	<0,05	<0,05	1,24	0,15	1,39	1,23	0,03	10,7	12,0
Mauseidvåg	0,07	0,08	0,02	<0,05	<0,05	1,17	0,18	1,35	0,76	0,06	6,20	7,02
Spjelkavik	0,20	0,18	0,05	<0,05	<0,05	8,64	0,63	9,26	19,5	0,53	97,5	118
Breivik	0,16	0,21	0,05	<0,05	<0,05	2,61	0,43	3,04	2,03	< 0,05	17,4	19,4
Vass-stranda	0,27	0,23	0,06	0,01	0,03	2,31	0,74	3,04	2,53	0,16	17,8	20,5
Skinnstareset	0,03	0,03	0,01	<0,05	<0,05	0,43	0,08	0,50	0,47	0,05	5,14	5,66

Concentrations of PBDE in soil samples at Godøy and Spjelkavik are comparable, 0,20 – 0,35 ng/g t.v., while the level at Breivik is 10 – 20 times higher, 4,4 ng/g t.v. Mostly BDE-209 (DecaBDE) contributes to this increase. These results indicate that there has been significant emission of PBDE in the surroundings the last twenty years. According to the calculations one could expect twice as high deposition at Breivik as at Spjelkavik if Tafjord waste incinerator is the emission source.

The results from the moss samples taken from sites surrounding Åsefjorden show that concentration of PBDE does not deviate from Norwegian background level. Level of PBDE in moss is low and there is no correlation between geographical variation of samples and the model calculation. This indicates that there has not been any significant emission of PBDE to air from any source next to Åsefjorden the last three years.

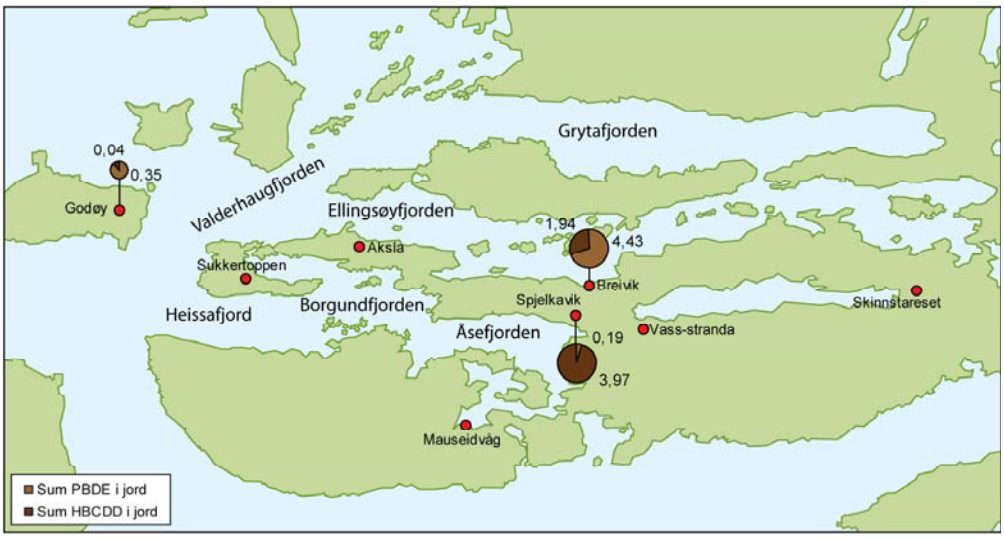


Figure 1: Concentrations of ΣPBDE and ΣHBCD of soil samples for all sampling sites given in ng/g d.w.

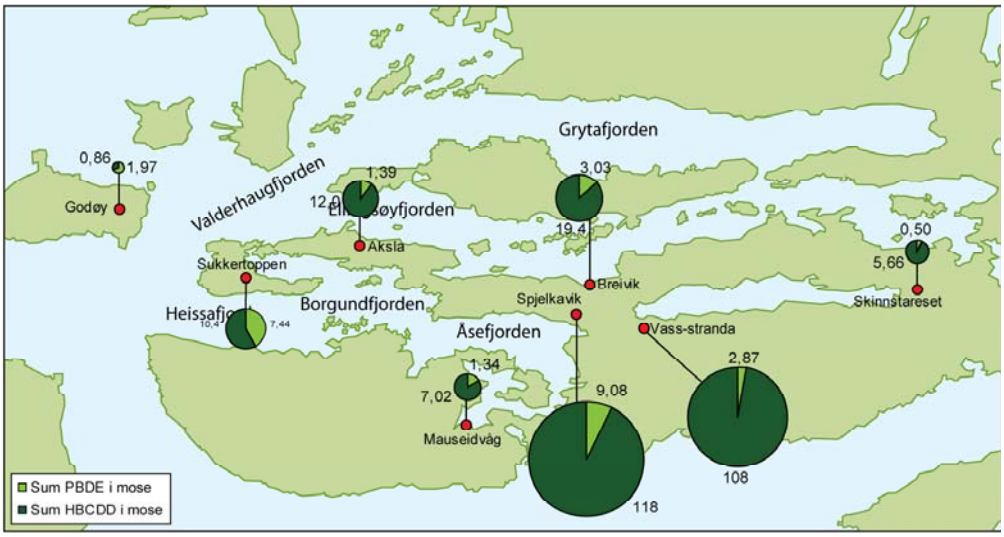


Figure 2: Concentrations of ΣPBDE and ΣHBCD of moss samples for all sampling sites given in ng/g d.w.

One soil sample (Breivik) indicates that there has probably been higher emission of PBDE previously, especially BDE-209 (DecaBDE). Comparison between samples and calculations indicates that Tafjord waste incinerator might be the emission source. BDE-209 is not the only high level component in sediments and mussels; technical penta-BDE (BDE-47, 85, 99, -100, -138, -153 and -154) also shows high levels. Hence, emission to air followed by deposition to water surface is not a significant source to PBDE-pollution of the marine environment in Åsefjorden. Therefore, we conclude that PBDE contamination in Åsefjorden is not caused by atmospheric transport.

The HBCD concentrations in soil samples are respectively 4 ng/g at Spjelkavik, 2 ng/g at Breivik and less than 0,1 ng/g at Godøy. These results indicate that there has beensignificant emission of HBCD in the surroundings the last twenty years. According to the variation of soil samples and the deposition calculation it is not likely that there is any emission of HBCD from Tafjord waste incinerator. The samples fits on the other hand well with the calculations if Brødrene Sunde Factory is assumed to be emission source.

The HBCD results from the moss samples surrounding Åsefjorden show that the sample from Godøy is the only one that is comparable to Norwegian background. The other samples are far above. Highest levels are from Vass-stranda and Spjelkavik, more than 100 ng/g t.v. Sukkertoppen, Aksla, Skinnstareset and Breivik show samples about 10 ng/g t.v., also significant higher than background level. This indicates that there is some significant emission source of HBCD close to Åsefjorden today. According to comparison between the moss samples and the calculations it is not probable that there is any HBCD emission at Tafjord waste incinerator. The samples correspond better to the calculations when the Brødrene Sunde Factory is assumed to be the emission source.

Samples of both moss and soil close to Åsefjorden contain higher concentration of HBCD than the background samples. This clearly indicate that there is emission of HBCD to air somewhere close to Åsefjorden. Since samples of both moss and soil contain significantly lower concentration at Breivik than at Spjelkavik, Tafjord waste incinerator is probably not the source of HBCD. If Tafjord was the source, we could expect twice as high level at Breivik as at Spjelkavik. The samples do not show this. The samples correspond better to the calculations where the emission source is located at the Brødrene Sunde Factory. It is therefore most likely that an emission source of HBCD to air is located somewhere close to the Brødrene Sunde Factory. Compared to samples from factories in Europe, concentration in soil next to Åsefjorden is low. It is not possible to conclude whether emission to air followed by deposition to water surface is a significant contribution to HBCD contamination in Åsefjorden.

Acknowledgements
The survey was done on behalf of the Norwegian Pollution Control Authority (SFT).

References

1. Fjeld E, Schlabach M, Berge JA, Green N, Eggen T, Snilsberg P, Vogelsang C, Rognerud S, Kjellberg G, Enge EK, Dye C, Borgen A og Gundersen H (2005) Kartlegging av utvalgte nye organiske miljøgifter 2004 : bromerte flammehemmere, perfluoralkylstoffer, irgarol, diuron, BHT og dicofol. Oslo (NIVA Rapport 5011-2005) (Statlig program for forurensningsovervåking. Rapport 927/2005) (TA-2096/2005). (Norwegian with English abstract).
2. Berge JA, Schlabach M, Fagerhaug A, Rønneberg JE, (2006), Kartlegging av utvalgte miljøgifter i Åsefjorden og omkringliggende områder. Bromerte flammehemmere, klororganiske forbindelser, kvikksølv og tribromanisol. Oslo (NIVA Rapport 5132/2006) (Statlig program for forurensningsovervåking. Rapport 946/2006) (TA-2146/2006). (Norwegian with English abstract).
3. Bøhler T (1987) Users guide for the Gaussian type dispersion models CONCX and CONDEP. Lillestrøm (NILU TR 8/87).
4. Mariussen E, Steinnes E, Gundersen H, Borgen A and Schlabach M (2005) Analysis of polybrominated diphenyl ethers in moss (Hylocomium splendens) from the Norwegian environment. Organohal. Comp., 67, 591-593.
5. Schlabach M, Mariussen E, Borgen A, Dye C, Enge EK, Steinnes E, Green N og Mohn H (2002) Kartlegging av bromerte flammehemmere og klorerte parafiner. Kjeller (NILU OR 62/2002) (Statlig program for forurensningsovervåking. Rapport 866/02) (TA-1924-2002).