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Atmospheric transport of environmental pollutants to Lake Mjøsa

Rapport
1059/2009

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Preface

The purpose of this study has been to gain a broader insight on the sources that control present levels of selected environmental contaminants in Lake Mjøsa. The study was performed by the Norwegian Institute for Air Research (NILU), with the help of Eirik Fjeld of the Norwegian Institute for Water Research (NIVA).

We would like to thank the Norwegian Pollution Control Authority (SFT) for funding this project.

We would also like to thank the people who have assisted with the sample collection, and the employees who were involved with this work at the Norwegian Crop Research Institute in Kise (Bioforsk).

I would like to thank Jon L. Fuglestad, who was responsible for this study at the Norwegian Pollution Control Authority.

Kjeller, 6. November 2009.

Martin Schlabach
Senior scientist, NILU

Contents

1. English summary

This report describes the results of a study aiming to identify and quantify the major sources that control levels of selected contaminants in Lake Mjøsa. The project focused on sources and source regions to air, airborne transport and atmospheric deposition of four of environmental contaminants: polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDDs), and mercury (Hg). Building on earlier results, the following activities have been conducted from summer 2006 to summer 2009: Active air measurements of selected POPs at a site representative for the region (Kise), passive air measurements of selected POPs around the lake and at suspected hot-spots, and Hg-measurements and field campaigns. Based on these and earlier measurements air transport modeling and mass balance calculations were performed.

PCB

The atmospheric PCB levels for the Mjøs region, measured at Kise, reflects typical Norwegian background levels as also seen at the Birkenes observatory in Aust-Agder. The average concentration of ΣPCB_7 in air for the whole period was 5.87 pg/m^3 (min – max: 2.47 – 16.6 pg/m^3). The measured concentrations show some year-to-year variation. However, no long-term time trend can be identified on the basis of data presented herein.

The Mjøs region as a whole does not seem to act as a major source of PCB emission to air. However, two passive sampling sites close to Gjøvik (“Oppland metal” and “Dalborgmarka”) show elevated PCB concentrations and indicate that there are one or more active sources of PCB emissions to the atmosphere in this area. At present, the small number of samples excludes the possibility to unequivocally identify the specific source(s) responsible for the high concentrations recorded. Furthermore, it is not possible to quantify the emission flux into air on the basis of the data presented herein. It may therefore be desirable to carry out follow up studies for the purpose of (*i*) identifying the specific activities responsible for these emissions, and (*ii*) to estimate the total flux of these sources to assess its potential significance with respect to the contaminant mass balance in Lake Mjøsa.

The results from this study and from earlier studies were used to build an improved mass balance model for PCBs for Lake Mjøsa. The model results suggest fresh water inflow (i.e. mainly rivers) is dominating inflow of ΣPCB_7 to the lake (~53%), followed by atmospheric deposition (~32%) and STPs (~15%). It is therefore recommended that further studies should be directed towards (*i*) an improved characterisation of inflows from the more contaminated rivers and (*ii*) identification of the possible sources (e.g. atmospheric deposition, local emissions direct to the water, and re-suspension from river sediments) that are responsible for the elevated concentrations observed in rivers. In total, about 0.6 kg ΣPCB_7 is estimated to enter the lake in 2007. However, the annual loss of ΣPCB_7 is calculated to be about twice this value (~1.2 kg), indicating that the contaminant burden is gradually being reduced. The major loss processes of ΣPCB_7 during 2007 are estimated to be degradation in sediment (44%) and sediment burial (42%). Altogether, the results suggest that the pool of ΣPCB_7 in Lake Mjøsa during 2007 amounts to about 20 kg, most of which is stored in sediments.

Although, any future attempts to further reduce the input of PCBs to Lake Mjøsa via STPs, river and air will contribute to further reduce the levels in the lake as well as in fish, the effect of any such measures may be limited in the short-term because of the long residence time of these persistent chemicals within the lake.

PBDE

The atmospheric PBDE load measured at Kise from 2006 to 2009 (Average $\Sigma PBDE_5$: 0.88 pg/m^3; min – max: 0.19 – 4.28 pg/m^3) reflects most likely a "typical" Norwegian background level as also seen at the Birkenes observatory in Aust-Agder. From 2004 to 2009 there may have been a downward time-trend at Kise. However, as the 2004/5 measurements were discontinuous but the new measurements were continuous, the average for 2004/5 may be overestimated due to some single extreme values during late autumn 2004.

The passive air samples clearly prove that there is a very strong local source of PBDEs located in Lillehammer as late as in 2008, even after one known point source had to stop using PBDEs. PBDEs were also found to be elevated at the two Gjøvik sites "Oppland metal" and "Dalborgmarka", but not as significantly as in the Lillehammer area.

In general, decreasing levels of PBDE are now observed for most environmental samples from the region over the latest five-six years. This suggests that the input of PBDEs to the lake have been reduced in response to control strategies and remediation measures directed towards the point source at Lillehammer. International control strategies may have further contributed to reduce long-range atmospheric transport of PBDEs to Kise, although the relative importance of historical and contemporary atmospheric inputs to the contaminant loads within the lake has not been evaluated.

PBDEs are, as PCBs, regarded as persistent organic pollutants. Degradation is slow and any long-lived contaminants are likely to experience a long residence time in the lake, simply because of the long residence time of water in Lake Mjøsa. It is therefore expected that it will take several years until normal background levels will be reached.

HBCDD

The measured levels of HBCDD were in general close to the limit of detection (Average ΣHBCDD: 0.49 pg/m^3; min – max: 0 – 5.2 pg/m^3). The concentrations measured in air samples from Kise seem to be lower than in samples from Birkenes. Hence, background atmospheric levels in the area seem to be low. The passive air samples are close to the limit of detection as well. Only three passive air samples from Gjøvik were found to be slightly elevated above detection limit ("Mustad", Oppland metall" and "Dalborgmarka"), indicating the presence of one or more local sources in this area. However, other environmental data points towards elevated levels in the northernmost part of the lake (Fjeld et al., 2006), suggesting that one or more local sources of HBCDD are/have been active in this region.

As both the active and passive air measurements presented herein, as well as the river water measurements presented earlier, were close to the detection limit, the determined average concentrations and inflows remain quite uncertain. Detailed data for air from the northernmost part are furthermore lacking. Hence, no attempt has been made to estimate a mass balance for

HBCDD in Lake Mjøsa. Given the elevated levels recorded in the northernmost part of the lake and the relatively low levels in background air (Kise), further studies should be directed towards a better characterization of contemporary sources, fluxes and pathways of HBCDD in the more contaminated parts of the lake. For example, a passive air sampling strategy around Lillehammer may be desirable to track potential active sources of HBCDD to air, which in turn could be compared and contrasted against levels recorded elsewhere (Gjøvik, Kise).

Hg

The aim of the presented study was to assess to what extent long range transport contribute to the mercury loadings to Lake Mjøsa. For this investigation monitoring of atmospheric concentrations of elemental mercury and mercury species in wet and dry deposition was performed, in addition to water-to-air gas exchange.

The average concentration of elemental mercury in air at Kise during the study period was 1.61 ± 0.19 ng/m^3, being comparable to the northern hemispheric background mean. Episodes with high concentrations of atmospheric mercury were observed year round, mainly associated with transport of polluted air from Europe. The annual average of total mercury deposition was 7.37 µg/m2 * year. This corresponds to 2.9 kg of mercury deposited to Lake Mjøsa pr year. Bioavailable methylmercury constitutes 2% of the wet deposition. Dry deposition accounts for approximately 11% of the total deposition to Lake Mjøsa, indicating that the majority of deposited mercury to Lake Mjøsa is of long-range origin. Approximately 20% of the total Hg deposition to Lake Mjøsa is lost to the atmosphere through evasion from the water surface due to reduction reactions in the water column.

The main contributor of Hg to the water seems to be the inflow from rivers and the sediment-water exchange which account for up to 35 kg/year (inflow 5-35 kg/y and sediment-water 0-35 kg/y). However, the river water concentrations and the sediment-water exchange have never been determined by field measurements.

From 2005 to 2008 the mercury contamination of trout in Mjøsa has increased with about 50 %. The atmospheric measurements do not show any significant time-trend which could explain the observed trend in trout.

2. Norsk sammendrag

Denne rapporten beskriver en studie av de antatt viktigste kildene til utvalgte miljøgifter i Mjøsa. Prosjektet fokuserer på kilder og kilderegioner for utslipp til luft, lufttransport og avsetning av fire miljøgifter: polyklorerte bifenyler (PCB), polybromerte difenyletere (PBDE), heksabromsyklododekan (HBCDD) og kvikksølv (Hg). Med utgangspunkt i tidligere resultater ble følgende aktiviteter gjennomført i tidsrommet sommer 2006 til sommer 2009: aktiv luftprøvetaking av utvalgte persistente organiske forurensninger (POPer), passiv luftprøvetaking av utvalgte POPer og kvikksølvmålinger. Disse og tidligere resultater dannet basis for lufttransportmodellering og studier av massebalanse for miljøgiftene i innsjøen.

PCB

PCB konsentrasjoner målt i luft i Mjøsregionen ved Kise tilsvarer generelt det typiske bakgrunnsnivået som man også har sett ved Birkenes observatoriet i Aust-Agder. Gjennomsnittskonsentrasjonen for ΣPCB_7 tatt med aktiv luftprøvetaker er 5.87 pg/m^3 (min – maks: 2.47 – 16.6 pg/m^3) for hele perioden 2006 til 2009. Resultatene svinger noe fra år til år, men i disse resultater er ingen tidstrend synlig.

Med unntak av et område ved Gjøvik er det lite sannsynlig at Mjøsregionen utgjør en betydelig kilde for PCB-utslipp til luft. To passive luftprøver tatt nær Gjøvik har imidlertid forhøyete PCB verdier og viser at det finns en eller flere aktive kilder av PCB-utslipp til luft i dette område. På grunn av et veldig begrenset antall prøver er det foreløpig vanskelig å identifisere kildene entydig. Videre tillater de tilgjengelige data heller ikke å kvantifisere utslippsmengden til luft. Det kan derfor være ønskelig å starte en oppfølgingsstudie (i) for å identifisere de forskjellige aktiviteter som er ansvarlig for disse utslipp og (ii) for å estimere den totale mengden disse kilder bidrar med til massebalansen for PCB i Mjøsa.

Resultatene fra denne og tidligere målinger ble brukt for å bygge en oppdatert massebalansemodell for PCB i Mjøsa. Modellresultater antyder at innløp av ferskvann, i all hovedsak fra elver, utgjør hovedmengden av PCB tilførsler (53 %). Atmosfærisk deposisjon utgjør 32 % og utløp fra renseanleggene utgjør 15 %. Det anbefales derfor at tilførslene via de mer belastete elver undersøkes nærmere med tanke på å identifisere årsaken og kilder for denne forurensningen (atmosfærisk deposisjon, lokale utslipp direkte til vann og resuspensjon fra forurensete sedimenter). Totalt beregnes det en tilførsel av omtrent 0.6 kg ΣPCB_7 til Mjøsa i 2007. Man regner med at det årlige tapet er om lag dobbelt så stort (~1.2 kg) der nedbrytning i sediment (44 %) og begraving i dypere sedimentlag (42 %) bidrar mest til tapet. Dette innebærer at nivåene av PCB i Mjøsa gradvis reduseres over tid. For 2007 anslås totalmengden på omtrent 20 kg ΣPCB_7 for hele Mjøsa der mesteparten hovedsakelig er lagret i sedimentene.

Selv om framtidige reduksjoner i tilførsler av PCB via renseanlegg, elver og luft vil bidra til å redusere PCB-nivået i innsjøen og i tillegg i fisk, vil virkningen av slike tiltak være temmelig begrenset på kort sikt. Dette skyldes den langsomme nedbrytningen og den lange oppholdstiden av slike stoffer i miljøet.

PBDE

Konsentrasjoner av PBDE målt i luft i Mjøsregionen ved Kise representerer det vanlige bakgrunnsnivået som man også finner ved Birkenes observatoriet i Aust-Agder. Gjennomsnittskonsentrasjonen for $\Sigma PBDE_5$ tatt med aktiv luftprøvetaker er 0.88 pg/m^3 (min – maks: 0.19 – 4.28 pg/m^3) for hele perioden 2006 til 2009. Fra 2004 til 2009 ser det ut som om nivåene har avtatt noe.

De passive luftprøvene viser tydelig at det så sent som i 2008 fortsatt fantes en veldig stor lokal kilde av PBDE i Lillehammer, selv om en stor lokal kilde måtte avvikle bruken av PBDE allerede i 2003. PBDE var også noe forhøyet ved to steder i nærheten av Gjøvik.

I de siste fem-seks år viser de fleste miljøprøvene fra Mjøsregionen nedadgående konsentrasjoner av PBDE. Dette skyldes trolig en generell reduksjon av tilførsler av PBDE til Mjøsa på grunn av PBDE-forbudt og gjennomførte rensetiltak som ble i verk satt. Videre kan også internasjonale kontrolltiltak ha redusert tilførsler via atmosfærisk langtransport, selv om den relative betydningen av både historiske og aktuelle atmosfæriske tilførsler ikke kunne anslås nærmere.

På samme måte som PCB, kan PBDE karakteriseres som vanskelig å bryte ned. Framtidige reduksjoner i tilførsler av PBDE via renseanlegg, elver og luft vil bidra til å redusere PBDE-nivået i innsjøen og i tillegg i fisk, selv om virkningen av slike tiltak vil være begrenset på kort sikt. Dette skyldes den langsomme nedbrytningen og den lange oppholdstiden av slike stoffer i miljøet og man forventer at det vil ta mange år før man oppnår et mer normalt bakgrunnsnivå.

HBCDD

De målte verdier av HBCDD var generelt nær deteksjonsgrensen (Gjennomsnitt: ΣHBCDD: 0.49 pg/m^3; min – maks: 0 – 5.2 pg/m^3). Konsentrasjoner i prøvene tatt ved Kise var noe lavere enn i prøver fra Birkenes. Også de passive luftprøver viste verdier veldig nær eller under deteksjonsgrensen. Kun tre steder i og i nærheten av Gjøvik viste noe forhøyete verdier som indikerer en eller flere lokale kilder i området. Andre miljøprøver tyder på at man har en eller flere kilder av HBCDD i den nordlige delen av Mjøsa.

Siden både de aktive og passive luftprøvene, og også målinger i elvevann, er tett opp mot eller under deteksjonsgrensen, blir de beregnete gjennomsnittskonsentrasjoner og tilførselsmengder svært usikkert. Detaljerte data for luft fra den nordlige delen av Mjøsa mangler. Man har derfor ikke kunnet prøve å estimere massebalansen av HBCDD for Mjøsa. Med utgangspunkt i de forhøyete konsentrasjoner av HBCDD i miljøprøvene fra nordenden av Mjøsa og de lave luftkonsentrasjoner målt ved bakgrunnsstasjonen ved Kise, anbefales det at man innleder en studie som karakteriserer de aktive kildene samt mengden og transport av HBCDD i denne regionen. En kampagne med passive luftprøvetakere rundt Lillehammer kan bidra til å kartlegge aktive kilder av HBCDD-utslipp til luft og resultatene kan sammenlignes med nivåer målt i andre regioner (Gjøvik og Kise).

Hg

Formålet med studien var å undersøke i hvilken grad nedfall av langtransportert kvikksølv bidrar til forurensingsproblematikken i Mjøsa. Til dette ble det overvåket konsentrasjoner av elementært kvikksølv i luft, det ble foretatt målinger av våt og tørr avsetting av ulike kvikksølvformer samt at gassutveksling mellom vann og luft ble målt.

Den gjennomsnittlige konsentrasjonen av kvikksølv i luft gjennom hele studieperioden var 1.61 ± 0.19 ng/m^3. Dette er sammenliknbart med gjennomsnittskonsentrasjonen for bakgrunnsområder på den nordlige halvkule. Episoder med høye konsentrasjoner av kvikksølv i luft ble observert hele året, og dette var i hovedsak i sammenheng med transport at forurenset luft fra Europa. Den årlige gjennomsnittlige mengden av kvikksølv som avsettes i Mjøs-regionen er 7.37 µg/m2 * år. Dette tilsvarer 2.9 kg avsatt kvikksølv på Mjøsa pr år. Av den totale våtavsettingen består 2% av methylkvikksølv. Tørravsetting bidrar med ca 11% av den totale avsettingen til Mjøsa, noe som tilsier at mesteparten av avsatt kvikksølv på Mjøsa er langtransportert. Ca 20% av avsatt kvikksølv til Mjøsa mistes til atmosfæren pga avdamping fra vannoverflaten som følge av reduksjons-reaksjoner i vannsøyla.

Massebalansemodellen viser at hovedmengden av kvikksølv til Mjøsa (35 kg/år) kommer fra elvene (5 - 35 kg/år) og gjennom overgang fra sedimenter til vann (0 – 35 kg/år). Dette er imidlertid aldri blitt målt i felt.

Fra 2005 til 2008 økte Hg-nivået i ørret i Mjøsa med omtrent 50 %. Resultatene fra luftmålinger i denne undersøkelsen viser ingen tidstrend og kan ikke forklare økningen i ørretnivået.

3. Introduction

Lake Mjøsa is the largest lake in Norway, with a surface area of 365 km^2. Some 200,000 people live within Lake Mjøsa's drainage basin, and about 150,000 of these people live in the cities of Hamar, Lillehammer and Gjøvik, and in towns of varying sizes. Past pollution of Lake Mjøsa in the 1960s and 1970s led to major changes to the lake, including frequent flourishing of algae. However, local measures that were part of the “Lake Mjøsa action plan” in the 1970s and 1980s have yielded results, and led to a substantial improvement of the water quality. During the last few years, awareness has increased of a number of problem compounds (environmental contaminants), creating new cause for concern. Dietary advice has been introduced to minimize the risk associated with consuming certain species of fish. However, an evaluation of sensible control strategies to reduce the burden on the environment, requires an understanding of quantitative relationships between sources and levels of contaminants in Lake Mjøsa (source–receptor relationship). This report describes the results of a follow-up study to reveal some of the sources that control levels of selected contaminants in Lake Mjøsa. The project focused on four of these environmental contaminants: polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDDs), and mercury (Hg).

Building on the results of the pre-study the following activities have been conducted from summer 2006 to summer 2009:

1. Active air measurements of selected POPs at Kise
2. Multi-media fate modeling for PCBs
3. Passive air measurements of selected POPs:
    a. Lillehammer (2006)
    b. other cities in the Mjøs region (2008).
4. Hg-measurements and field campaigns
5. Air transport modeling for Hg measurements
6. Hg mass balance

4. Materials and methods

4.1 Active air sampling of selected POPs

An active air sampler was used from summer 2006 to summer 2009 to measure organic contaminants in air. The station was established after consulting meteorological experts regarding the representativeness of the Lake Mjøsa region as a whole. The station was located at the Norwegian Crop Research Institute in Kise circa 100 m away from Lake Mjøsa (130 m a.s.l., 32 EU89- UTM sone 32: 6738895, 598338 or 84 EU89 Decimal grads: 60.7733N, 10.8054E). The area around the station is a typical agricultural area. Until closure in summer 2008 about 5 to 10 persons were employed at the Kise department of the Norwegian Crop Research Institute, mainly working with farming (berries and wheat), agricultural research activities, paperwork, and machine maintenance. After closure of the Kise department in summer 2008, the activities around the sampling station is reduced to conventional farming.

The active air sampler (Digitel DHA-80 with a manual PUF cartridge changer, Hegnau, Switzerland) consists of a pump where air passes through a filter (Glass fibre filter Gelman type A/E, 140 mm diameter) followed by two PUF adsorbents (70 mm diameter, 40 mm thickness, density 25 kg/m3, toluene-dissocyanat-polyoxypropylentriole-copolymer, Sunde, Fetsund, Norway). The filter will mainly capture organic contaminants that are bound to particles in the air, while the adsorbent mainly captures contaminants in the gas phase. In the pre-study campaign samples were taken during two-days once a week. With a two days sampling period it may be possible to identify specific episodes with elevated levels. In this study, however, the attempt was to sample continuously and each of the samples represents the air concentration averaged over a two-weeks period. This approach is suitable for an improved characterisation of the typical atmospheric burden. The sampling flow rate was set to 86 L/min. With a sampling time of 14 days, this gives a total sample amount of ca. 1700 m^3. The samples are labelled by year and week number (for example: 2006-26) indicating the start of the sampling period. Due to problems with the air sampler and transportation sampling was interrupted several times especially in the beginning of the campaign. The true air concentration during these periods remain unknown and these gapes may increase the uncertainty of the average air concentrations determined. 57 samples were collected and analyzed at the Norwegian Institute for Air Research (NILU) in Kjeller. The analytical methods are described earlier (Manø et al., 2008b).

4.2 Passive air sampling of selected POPs

A passive air sampler measures atmospheric levels, integrated over an extended period of time (weeks to years). Several different passive samplers have been described in the literature (Ockenden et al., 2001, Shoeib and Harner, 2002, Wania et al., 2003). They all have in common that they contain sampling material that has a significant affinity and capacity for organic contaminants in air. A sampler that uses polyurethane foam (PUF) as sampling material was chosen, which has been tested and evaluated in several studies (see e.g.(Shoeib and Harner, 2002, Jaward et al., 2004). It samples an air volume of a couple of cubic meters of air per day (Jaward et al., 2004). For contaminants that are found in both particular form and in a gaseous phase, passive samplers are known to mainly capture the gaseous fraction (Harner et al., 2004).

A PUF disk sampler typically contains a PUF foam disk placed between two stainless steel metal domes (Figure 1) in a so called “flying saucer” design (Wilford et al., 2004).

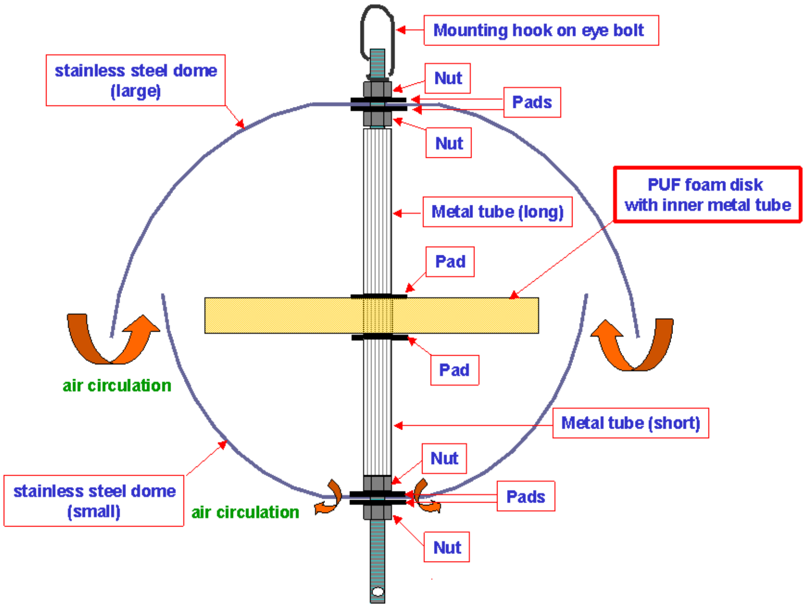


Figure 1: PUF-type passive sampler.

This design aims to protect the foam disk from precipitation, sunlight, wind speed effects and coarse particle deposition. Air flows through a gap between the two domes (Pozo et al., 2004). Different passive sampler housings have been tested, and a relatively recent study (Tuduri et al., 2006), shows that “the flying saucer” design dampens the wind speed effect adequately. The specific housing design used in this study with hollow metal tubes inside the sampler has the advantage that the width of the gap between the two domes is kept identical from site to site.

The primary goal of the use of several passive air samplers during this project was to evaluate the spatial variability of selected contaminants in the air around Lake Mjøsa. Significant spatial variation indicates variations in emissions of contaminants to air around Lake Mjøsa, while insignificant spatial variation indicates that the burden level is primarily due to atmospheric long-range transport, or that the contaminants in air are well mixed.

Passive samplers were deployed during two different campaigns:

1. From 19 July 2006 until 19 October 2006, in and around Lillehammer (9 stations).
2. From 9 July 2008 until 13 October 2008, in and around the other urban communities (21 stations).

The position of the sampling stations are shown in Figure 2 to Figure 6 and the coordinates are given in Table 1.

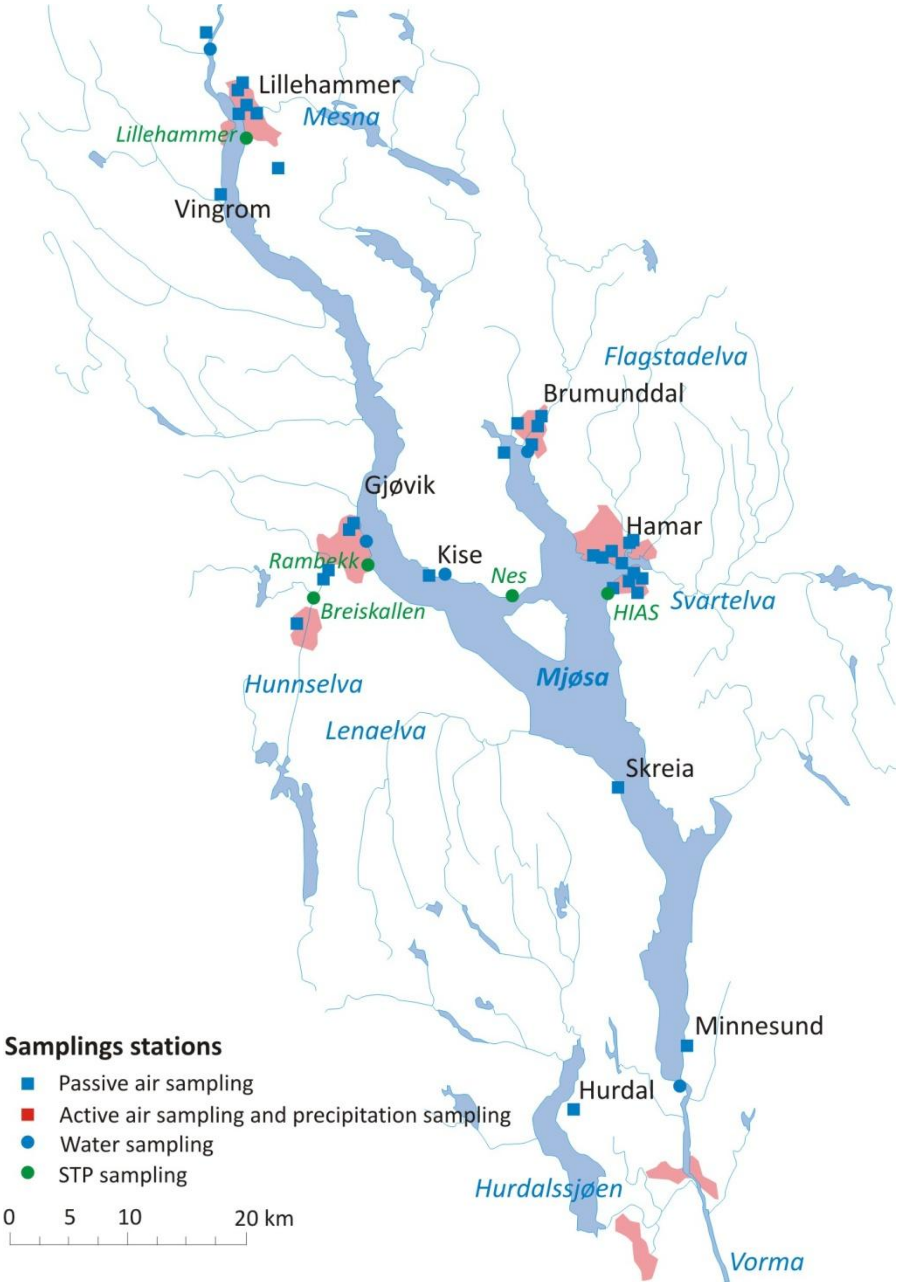


Figure 2: Position of the different sampling stations around Mjøsa.

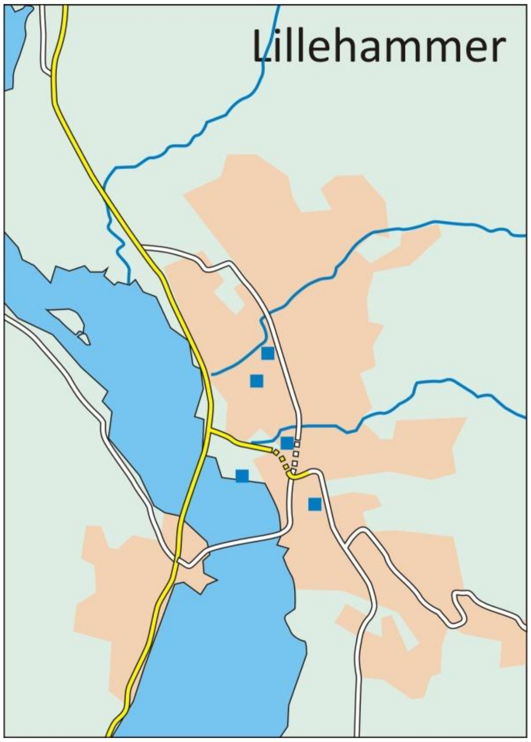


Figure 3: Position of the passive air sampling stations in and around Lillehammer, 2006.

Figure 4: Position of the passive air sampling stations in and around Gjøvik, 2008.

Figure 5: Position of the passive air sampling stations in and around Brumunddal, 2008.

Figure 6: Position of the passive air sampling stations in and around Hamar, 2008.

Table 1: UTM and geographical coordinates of the passive air sampling stations used in 2006 and 2008.

Sampling Site	84 EU89 Geographic coordinates		32 EU89 UTM coordinates		Year
Fåberg brua	61.1662	10.3970	6782104	575161	2006
Lillehammer Skjellerudvn	61.1211	10.4541	6777152	578344	2006
Lillehammer Gausdalsgt	61.1222	10.4561	6777267	578449	2006/2008
Lillehammer G.Uldvaref.	61.1155	10.4576	6776532	578543	2006
Lillehammer Bankplassen	61.1130	10.4647	6776256	578936	2006
Lillehammer Strandtorget	61.1123	10.4509	6776167	578189	2006
Lillehammer Roverudmyra	61.0786	10.5129	6772493	581624	2006
Vingrom	61.0458	10.4367	6768742	577591	2006
Kise Forsøksgård	60.7734	10.8055	6738895	598338	2006/2008
Raufoss Nammo	60.7301	10.6046	6733795	587516	2008
Gjøvik Mustad	60.7852	10.6812	6740031	591535	2008
Gjøvik Hunton	60.7924	10.6868	6740839	591818	2008
Gjøvik Rambekk RA	60.7770	10.7052	6739153	592866	2008
Gjøvik Oppland metall	60.7760	10.6463	6738962	589660	2008
Gjøvik Dalborgmarka	60.7675	10.6412	6738011	589409	2008
Brumunddal Nesvegen	60.8779	10.8946	6750677	602854	2008
Brumunddal Norsk stål	60.8903	10.9212	6752096	604258	2008
Brumunddal Buttekvern	60.8828	10.9503	6751302	605861	2008
Brumunddal Thore Bjerkesv.	60.8793	10.9513	6752144	605892	2008
Brumunddal Strandvegen	60.8764	10.9362	6750569	605116	2008
Hamar Vangsvegen	60.7992	11.1128	6742275	614982	2008
Hamar E6	60.7980	11.1196	6742147	615353	2008
Hamar bryggeri	60.7943	11.0583	6741637	612030	2008
Hamar Strandgata	60.7932	11.0723	6741529	612796	2008
Hamar park	60.7949	11.0841	6741749	613433	2008
Hamar Stangevegen	60.7885	11.0957	6741046	614085	2008
Hamar Sandvikavegen	60.7769	11.0920	6739748	613929	2008
Hurdal målestasjon	60.3724	11.0781	6694691	614596	2008

4.3 Updated mass balance calculations for PCBs in Lake Mjøsa

4.3.1 Background

Both primary and secondary sources may contribute to current levels of PCBs in Lake Mjøsa. A better knowledge about the relative importance of various sources and pathways is essential in order to evaluate sensible control options to reduce further environmental exposure in the lake. A relative simple mathematical model has previously been developed and parameterized for Lake Mjøsa. The model presents an initial mass balance for selected PCBs 2004 based on the limited empirical information that were available at the time (Breivik et al., 2005). Here, we present updated estimates taking into account new and improved information on concentrations in air (this study), rivers (Fjeld et al., 2007) and sewage treatment plant effluents (Fjeld and Enge, 2008, Fjeld et al., 2007) in an attempt to (*i*) better characterize the current environmental behavior of selected PCBs in the lake, and to (*ii*) identify aspects which may remain among the least understood features of the overall fate of these contaminants in this environment.

4.3.2 Model description

The model used is a dynamic (non-steady state) version of the so-called QWASI (Quantitative Water Air Sediment Interaction) model as originally developed by Don Mackay and co-workers (Mackay et al., 1983). More specifically, it is a non-spatially resolved version of the dynamic Oslofjord POP model previously used to evaluate and understand the fate of PCBs in the Inner Oslofjord (Breivik et al., 2004). In brief, it aims to describe the overall fate of PCBs in an aquatic system consisting of water and sediment on the basis of information on physical-chemical properties, environmental half-lifes, environmental characteristics and data related to chemical inflow, such as atmospheric concentrations, riverine inflows and direct releases. Model outputs include estimates of chemical concentrations in lake water and sediment, mass fluxes between various media and loss rates over time.

4.3.3 Model input

The model adapted for Lake Mjøsa now takes advantage of new information on air concentrations, river concentrations as well as direct sources (STP effluents) in an attempt to derive an improved characterization of both chemical inputs to the lake as well as current levels and fluxes of PCBs. The data used to describe current sources should ideally reflect the same time period to be able to present a “snapshot” of the actual situation for a given time. As the most recent data on aquatic inputs reflect the situation during 2006-2007, we used data for air reflecting the same time period as input to the model. However, air concentrations of PCBs tend to vary on a seasonal basis (e.g. Wania et al., 1998, Haugen et al., 1999) and data from 2006 is only available for the autumn. We therefore used data for 2007 only as model input to obtain an estimate of the annual average air concentrations. The new input data, and hence model results, represent an estimate of the mass balance at the time for which most data originates.

Concentrations of selected PCBs in 3 major rivers were recently reported by Fjeld et al. (2007). They collected 4 active high volume water samples from the rivers Lågen, Hunnselva and Svartelva between spring and winter of 2006. The data on river concentrations combined with data on water discharges were next used to estimate a flow-weighted fresh water inflow concentration (Table 2), mainly reflecting riverine inflows, and used as input to the model. For more detailed information on amounts of PCBs transported into lake Mjøsa from individual rivers, we refer to the original report (Fjeld et al., 2007).

Table 2: Model inputs describing chemical inflow of PCBs to Lake Mjøsa.

	Air (pg/m^3) [A]	Rivers (pg/L) [B]	STPs (g/year) [C]
PCB-28	2.17	3.3	5.11
PCB-52	1.96	3.7	12.25
PCB-101	1.17	7.2	22.84
PCB-118	0.43	3.0	12.52
PCB-138	0.66	5.4	10.86
PCB-153	1.01	8.4	21.63
PCB-180	0.26	2.3	8.75
ΣPCB7	7.66	33.2	93.96
Number of samples	18	12	~60

[A] Annual average concentration in 2007. This study. [B] Flow-weighted concentrations after Fjeld et al. (2007). [C] Based on information given in Fjeld et al. (2007) and Fjeld and Enge (2008) as detailed in text and Table 2.

With respect to direct sources, only sewage treatment plant (STP) effluents are characterized and considered by the model. The more recent data on STP effluents are reported in Fjeld et al. (2007) and Fjeld and Enge (2008), and information for five different STPs are included. The first report presents data for all stations, mainly reflecting the year 2006, while the latter report presents additional data for 2007 for the three major STPs; Lillehammer, Rambekk and HIAS. For these three STPs, we converted average daily mass flows of ΣPCB_7 as reported by Fjeld and Enge (2008) into annual average values (Table 3). For Breiskallen and Nes, we re-calculated daily mass flows on the basis of original data on concentrations and STP effluent water discharges as appended in Fjeld et al. (2007) in order to present annual release rates for individual PCBs as given in Table 3. The same calculation was done for the other three STPs, and the relative PCB pattern at each plant during 2006 (Fjeld et al., 2007) was used to derive an estimate of releases of individual PCBs for the 2006-2007 period (Fjeld and Enge, 2008). The data in Table 3 were next summarized and used as model input Table 2).

Table 3: Releases of PCBs from sewage treatment plants to Lake Mjøsa (g/year) (see text for details).

	Lillehammer [A]	Rambekk [A]	HIAS [A]	Breiskallen [B]	Nes [B]
PCB-28	1.06	0.61	3.25	0.16	0.02
PCB-52	4.07	0.70	7.33	0.14	0.02
PCB-101	2.94	0.95	18.75	0.17	0.03
PCB-118	2.72	0.84	8.74	0.15	0.06
PCB-138	3.25	1.22	6.11	0.19	0.09
PCB-153	7.61	2.41	10.96	0.44	0.21
PCB-180	3.74	2.48	2.22	0.22	0.10
ΣPCB7	25.40	9.23	57.34	1.47	0.53

[A] Data for ΣPCB7 derived from Fjeld and Enge (2008). Congener-specific releases for individual STP effluents were estimated on the basis of original data appended in Fjeld et al. (2007). [B] Data were re-calculated from original data appended in Fjeld et al. (2007).

The model furthermore requires information on physical-chemical characteristics and environmental half-lives of PCBs, including their temperature dependence. The model also includes a description of the environmental characteristics. These additional input parameters are listed and described in Breivik et al. (2005). Finally, the environmental levels of PCBs may be a legacy of past environmental releases. Thus, the simulations herein also includes predictions of the historical releases and behavior of PCBs, based on scenarios for historical releases as previously described (Breivik et al., 2005). Any deviations between model results presented in the following and the initial mass balance previously reported (Breivik et al., 2005) can thus be attributed to the improved characterization of contemporary inputs to the lake.

4.4 Mercury measurements

4.4.1 Introduction

Mercury is known to circulate between the earth's different environmental compartments through a complex biogeochemical cycle, and human activity has introduced additional processes that have increased the rate of distribution between the compartments (Stein et al., 1996). Environmental cycling of mercury can be described as a series of processes where chemical, biological and physical transformations are governing the factors controlling the distribution of mercury in and between different environmental compartments. Briefly, the global cycling involves natural and anthropogenic emission, dispersion in the atmosphere where chemical transformation may occur, dry and wet deposition to aquatic and terrestrial surfaces and finally re-emission (Baeyens, 1992, Mason et al., 1994).

Mercury (Hg) is emitted to the atmosphere by a variety of natural (volcanoes, wildfires, etc.) and anthropogenic (e.g., combustion of coal) sources (Nriagu and Pacyna, 1988). While anthropogenic Hg emissions have decreased over North America and Europe during the 1990s, emissions in Asia have strongly increased and China is now the country with the by far largest Hg emissions worldwide (Pacyna et al., 2006). Once released into the atmosphere, mercury can undergo long-range atmospheric transport. Hence, the atmosphere is the most important pathway for the worldwide dispersion and transport of mercury in the environment (Cheng and Schroeder, 2000). In the atmosphere, Hg exists predominantly as gaseous elemental mercury (GEM), which under normal conditions is relatively inert, allowing for homogenous mixing within each hemisphere. Complex processes in the atmosphere convert mercury between its various forms, and this makes the overall behavior of mercury difficult to predict. GEM can be converted to various oxidized compounds in the gas or particulate phase, which have a much shorter atmospheric lifetime than GEM. Mercury may be scavenged from the atmosphere by either dry or wet deposition. Wet deposition fluxes are relatively straight forward to measure and determine, whereas dry deposition fluxes are often lacking in atmospheric mercury budgets to water bodies due to the lack of direct measurement methods and available data (Vette et al., 2002). However, studies have shown that dry deposition of mercury may contribute up to 65% of the total atmospheric deposition (Shannon and Voldner, 1995).

In the water column, Hg^{2+} can undergo microbial methylation-demethylation, precipitation-remobilization in sediments and reduction to Hg^0 via abiotic and biotic reactions. In surface waters, Hg^0, the dominant form of dissolved gaseous mercury is generally supersaturated relative to the atmosphere, and therefore a net Hg^0 flux is typical from the surface waters to the atmosphere. Understanding the cycles and budgets of atmospheric mercury requires an assessment of air-surface exchange processes and rates. Figure 7 shows a simplified version of mercury's biogeochemical cycle at the water-air interface.

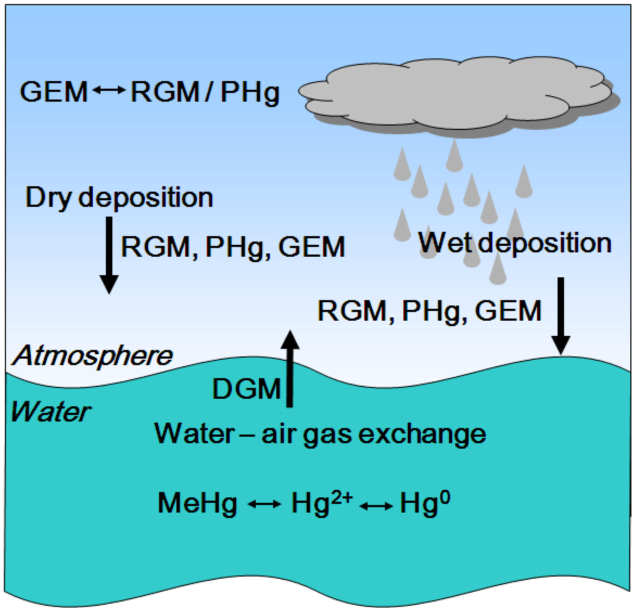


Figure 7: Simplified version of mercury's biogeochemical cycle at the air-water interface of Lake Mjøsa.

4.4.2 Gaseous elemental mercury (GEM)

Continuous sampling and analysis of GEM was performed with a Tekran Model 2537A Hg monitor (Tekran Inc, 1998). The technique is based on collection of GEM on gold traps followed by thermal desorbtion and detection of GEM as Hg^0 using atomic fluorescence spectrometry (AFS) ($\lambda = 253.7$ nm).

The sample collection period was from Mars 23. 2007 to July 1. 2009. The sample inlet was located 2.5 m above the ground, and mercury associated to particles was removed by a 0.45 µm Teflon particle filter. The sample inlet and inlet tube was heated to 45°C to avoid condensation inside the sample inlet tube during periods with high relative humidity. Sampling collection flow rate was 1.5 l/m with a time resolution of 5 min. The instrument was calibrated every 25 h using the instruments internal permeation source. The methods detection limit (MDL) was 0.21 ng/m^3 and was calculated according to Aspmo et at., 2005.

4.4.3 Wet deposition – mercury in precipitation

Mercury in wet deposition was collected from July 15. 2006 to July 1. 2009. Precipitation was collected using IVL bulk sampler custom made for mercury. The sampler is made of quartz and was located 2 m above ground and 4 m from the closest building. The sampler is shielded from UV light to avoid photochemical transformations of mercury species in the collected samples.

During winter, the sampler was heated. Samples were collected on a monthly basis and were always collected in parallels. Samples were shipped to NILUs laboratory in Kjeller for analysis. Dates given indicate starting date of sample collection and ends when the next sample starts.

Mercury in precipitation was determined as Hg-total. The principle is as follows: All mercury species in the sample were oxidized to Hg^{2+} with BrCl. Determination of Hg-total was performed using the fully automated Tekran 2600 system, where Hg^{2+} in the sample is reduced to Hg^0 using $SnCl_2$. Hg^0 is thus separated from the liquid using Argon gas and collected on a gold trap. Further, Hg^0 is then thermally desorbed and detected using AFS. In total, 36 samples were collected and analyzed. MDL is 2.0 ng/l.

From July 2006 to July 2008, a part of the collected precipitation samples were split and sent to IVL in Sweden for determination of methyl mercury (MeHg). MeHg in precipitation was analyzed using a procedure similar to those described by Liang et al., 1994 and Bloom, 1989. Prior to analysis a chelating agent APDC (Ammonium salt of Pyrrolidine-1-dithiocarboxylic acid) was added to 45 ml of the precipitation sample and the sample was distilled. A detailed description of the distillation procedure using APDC can be found in Horvat et al. (1993). The distillate was further treated with sodium tetraethylborate to form methylethylmercury (CH3HgC2H5). Inorganic Hg(II) species, that also may be present in the solution, are simultaneously converted to diethylmercury. The ethylated mercury species are volatile and was purged from the solution with N_2 and adsorbed on a Tenax trap. The Hg-species were then thermally desorbed from the Tenax trap in a stream of He and separated by means of isothermal gas chromatography. Finally, by heating to 700 – 800°C in a pyrolysis column the methyl/ethylated Hg species was decomposed to elemental mercury and detected using AFS. In total, 24 samples were collected and analyzed. MDL is 0.06 ng/l. Concentration values below MDL are represented in calculations as MDL/2.

4.4.4 Dry deposition

Mercury dry deposition was collected from July 2008 to July 2009. The dry deposition sampler was custom made for this project and is based on work described by Keeler and Dvonch, 2005. Dry deposition fluxes were measured directly using a surrogate surface technique. The samples consisted of a circular Teflon plate that served as a base for an exchangeable glass fiber filter. The Teflon plate was mounted on a telescopic pole 2 m above ground. The geometrical design intended to keep the air movements as undisturbed as possible. Before sample collection, the filters were cleaned at 500°C for at least 8 h to remove any mercury in the filters. The filters were then impregnated with 20% glycerol dissolved in methanol to make the filter surface more sticky. Samples were collected during no rain events. In total 23 samples were collected in addition to 3 blanks. The samples were shipped to NILUs laboratory in Kjeller for analysis.

Dry deposited mercury was dissolved according to method NS-4770 followed by analysis using the Tekran 2600 system. ½ filters were transferred to a 125 ml Duran bottle. 40 ml supra pure nitric acid was added (diluted 1:1 with Milli-Q water). The bottles were closed and heated to 120°C in a pressurized container for 30 minutes. Afterwards the samples were left to cool down to room temperature, followed by dilution to a total volume of 200 ml using Milli-Q water. For analysis, 50 ml were withdrawn from the sample and 0.5 ml BrCl was added. Determination of Hg-total was performed using the fully automated Tekran 2600 system as described above. Dry deposited mercury is presented as ng Hg / m^2 * day. MDL is calculated as 3*STD of blank filters, which correspond to a MDL of 2.5 ng dry deposited Hg / m^2 * day, based on 2 days sample collection time (average sampling time).

4.4.5 Mercury emission from Lake Mjøsa – Gas exchange from water to ambient air

Gas exchange of mercury from Lake Mjøsa was measured by determining the amount of dissolved gaseous mercury (DGM) in water and GEM in ambient air, in addition to a variety of meteorological parameters such as wind, air and water temperature and radiation intensity.

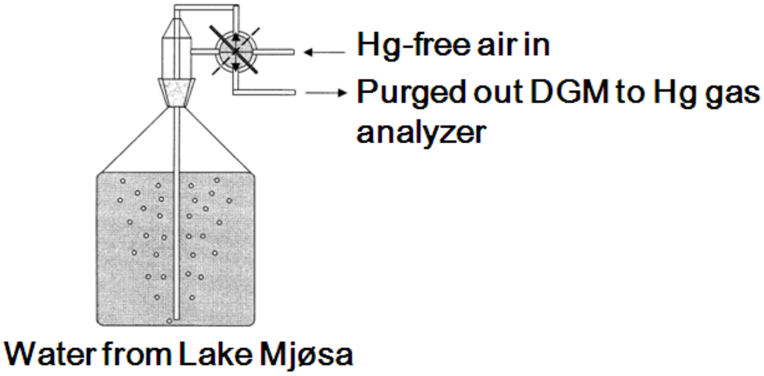


Figure 8: Operating principle of equipment used for purging DGM out of water from Lake Mjøsa.

DGM was measured four times during July 2008 to July 2009, while GEM and meteorological factors were collected continuously. The project proposal suggested DGM to be measured once pr season, but due to the fact that Lake Mjøsa is ice covered in winter, the measurements were shifted so that sampling occurred twice in the summer season. Surface water from Lake Mjøsa was collected from a small jetty close to the measurement station. Dark brown 2 l Duran bottles were filled to the rim and brought to the station for analysis. 2 l of the collected water was carefully transferred to a dark brown 5 l Duran bottle. The water was purged with Hg-free air and DGM in the water transferred to overlying air and into a mercury gas analyzer as described above (Figure 8). The measurement principle is in detail described in Lindberg et al., 2000. Meteorological data were provided by Bioforsk Meteorological Agricultural Service Bioforsk: (http://lmt.bioforsk.no/agrometbase/getweatherdata.php).

4.4.6 Calculating gas exchange (flux) of dissolved gaseous mercury (DGM) from water to atmosphere

Models to quantify water-air gas exchange are generally based on Fick's 1. law of Diffusion. In this study, calculations of gas exchange, also called flux, are mainly based on Poissant et al., 2000. The flux rate of DGM from water to the atmosphere can be approximated using the following equation:

$$Flux = F = k(C_w - C_{eq}) \quad (1)$$

where k = mass transfer coefficient (cm/hour), c_w = concentration of DGM in water near the surface (pg/l), and c_{eq} = concentration of DGM in water at solubility equilibrium with the atmosphere (pg/l).
The mass transfer coefficient of Hg through the water layer can be correlated with the mass transfer of CO_2 across the interface as:

$$k = 0.45u_{10}^{1.64}\left[\frac{Sc(Hg)}{Sc(CO_2)}\right]^{-\frac{1}{2}} \qquad (2)$$

where u_{10} er is wind speed at 10 m (m/s), Sc(Hg) = Schmidt number for Hg, $Sc(CO_2)$ = Schmidt number for CO_2.

$$u_{10} = \frac{10.4u_z}{\ln z + 8.1} \qquad (3)$$ (Andersson et al., 2008)

where z = height above ground where wind speed was measured (2 m).

$$Sc(Hg) = \frac{\nu}{D} = \frac{0.017\, e^{-0.025t}}{13.26*10^{-5} \Big/ n_w(t)^{1.14} * V^{0.589}} \qquad (4)$$ (Kirk et al., 2008)

where ν = kinematic viscosity (cm^2/s) and D = diffusivity of Hg^0 in water (cm^2/s). t = water temperature (°C), $n_w(t)$ = dynamic viscosity of water at a given temperature (details regarding $n_w(t)$ can be found in Kirk et al., 2008, Supporting Information) and V = molar volume of Hg (14.82 cm^3/mol).

$$Sc(CO_2) = 0.11\, t^2 - 6.16\, t + 644.7 \qquad (5)$$

$$C_{eq} = \frac{C_a RT}{H} \qquad (6)$$

where C_a = concentration of Hg^0 in the atmosphere (pg/l), R = ideal gas law constant ($Pa*m^3/mol*K$), T = temperature at the water-air interface (K) and H = Henry's law constant for Hg^0 ($Pa*m^3/mol$).

$$H = H'R\,T = (0.0074\, t + 0.1551)\, R\,T \qquad (7)$$

where H' = Henry's law constant corrected for water temperature.

In order to estimate the evasion of mercury from Lake Mjøsa during the complete measurement period, the concentration of DGM in Lake Mjøsa needed to be modeled. In the literature it can be found that DGM (C_w) varies with different environmental parameters. Radiation intensity seems to be the most dominant followed by water temperature (Amyot et al., 1997, Dill et al., 2006, Park et al., 2008). Concentrations values of DGM from the four sets of measurements were combined with radiation intensity and water temperature in order to model hourly average concentration values for DGM for the whole measurement period. The measurements showed that radiation intensity is of most importance for the concentration of DGM with the exception when radiation intensity is less than 40 W/m^2. During these periods, water temperature was of greatest importance for the concentration of DGM. Based on this, the following equations were used for model calculations of C_w:

Radiation intensity > 40 W/m^2 :

$$[c_w] = 17.986 \ln(rad) - 53.003 \qquad (8)$$

where rad = radiation intensity.

Radiation intensity < 40 W/m^2 :

$$[c_w] = 3 * 10^{-63}\, T^{\,26.067} \qquad (9)$$

where T = surface water temperature in Lake Mjøsa.

By applying this model to the measured data the deviation between measured and modelled fluxes of DGM was on average 3%.

4.5 FLEXPART modeling and plots

To identify the sources of measured GEM, 3-hourly backward simulations with the Lagrangian particle dispersion model FLEXPART were used (Stohl et al., 1998, 2005). FLEXPART was driven with 3-hourly operational meteorological data from the European Centre for Medium-Range Weather Forecasts with 1◦×1◦ resolution. The model calculates the trajectories of tracer particles using the mean winds from the analysis fields with additional random motions representing turbulence (Stohl and Thomson, 1999) and convection (Forster et al., 2007). During every 3-hour interval, 40000 particles were released at the measurement point and followed backward for 20 days to calculate emission sensitivity (ES) on a 1◦×1◦ grid, under the assumption that removal processes can be neglected. The ES (in units of s/m^3) in a particular grid cell is proportional to the particle residence time in that cell and measures the simulated concentration at the receptor that a source of unit strength (1 kg/s) in the cell would produce. The ES distribution in a 100 m layer adjacent to the surface (so-called footprint layer) was used as input to the statistical analyses of surface sources and sinks.

A statistical method was used to identify possible source regions of GEM based on the measurement data and the model output. The method is similar to older methods based on trajectory calculations (Ashbaugh, 1983, Ashbaugh et al., 1985) but takes advantage of the superior quality of FLEXPART ES fields compared to simple trajectories, which ignore turbulence and convection. Every one of M measurements was related to a modeled footprint ES field S and calculated as the total footprint ES

$$S_T(i,j) = \sum_{m=1}^{M} S(i,j,m) \qquad (10)$$

where i, j are grid indices of S. Then the subset of the data with the $L = \frac{M}{10}$ highest 10% (or, respectively, lowest 10%) of measured GEM concentrations were selected and S_P was calculated as

$$S_P(i,j) = \sum_{l=1}^{L} S(i,j,l) \qquad (11)$$

where the suffix P was either 10 or 90 and indicated the percentile. The ratio

$$R_P(i,j) = \frac{S_P(i,j)}{S_T(i,j)} \qquad (12)$$

with P being again either 10 or 90, was then used for identifying grid cells that were likely sources (or sinks) of GEM. If air mass transport patterns were the same for the data subset and for the full data set, R_P (i, j) = 0.1 for all i, j would be expected. Information on sources and sinks of GEM were contained in the deviations from this expected value. When using the top decile of the data, for instance, R_{90}(i, j) > 0.1 means that high measured GEM concentrations are associated with a high ES value in grid cell (i, j), indicating a likely source, whereas R_{90}(i, j) < 0.1 indicates a possible sink or at least the absence of a source. Conversely, when using the lowest decile of the data, R_{10}(i, j) > 0.1 indicates a likely sink in grid cell (i, j), and R_{10}(i, j) < 0.1 a source.

Not all features of R_P were statistically significant. Particularly where S_T values are low, spurious R_P values can occur. Therefore, calculation of R_P was limited to grid cells where $S_T > 5 \cdot 10^{-9}$ s/m^3. Furthermore, a bootstrap re-sampling analysis was employed (Devore et al., 1999) to identify non-significant values at the 90% level, which were then iteratively removed by smoothing the R_P field until all values were statistically significant. Bootstrapping was also used by Vasconcelos et al. 1996 to determine statistical significance of trajectory statistics.

4.5.1 Ancillary data

met.no’s official precipitation measurements at Kise (60°N 7733, 10°Ø 8055, 128 masl) are used for calculations of Hg deposition rather than the collected amount of precipitation in the collection bottle. The data are available from the internet service eKlima: (http://sharki.oslo.dnmi.no/portal/page?_pageid=33,6979,33_14938&_dad=portal&_schema=PORTAL)

5. Results and Discussion

5.1 PCB

5.1.1 Active air samples

The results for ΣPCB_7 are shown in Figure 9. ΣPCB_7 is the sum of the compounds PCB-28, 52, 101, 118, 138, 153 and 180. The relative distribution of the compounds in each sample is shown in Figure 10. As Figure 9 shows, PCB concentrations in air varied somewhat during the period. The average concentration of ΣPCB_7 in air for the whole period is 5,87 pg/m^3. The highest value was measured in the period 30.06. - 10.07.2006 (16,7 pg/m^3), while the lowest value was measured in the period 10.11. – 24.11.2008 (2,47 pg/m^3).

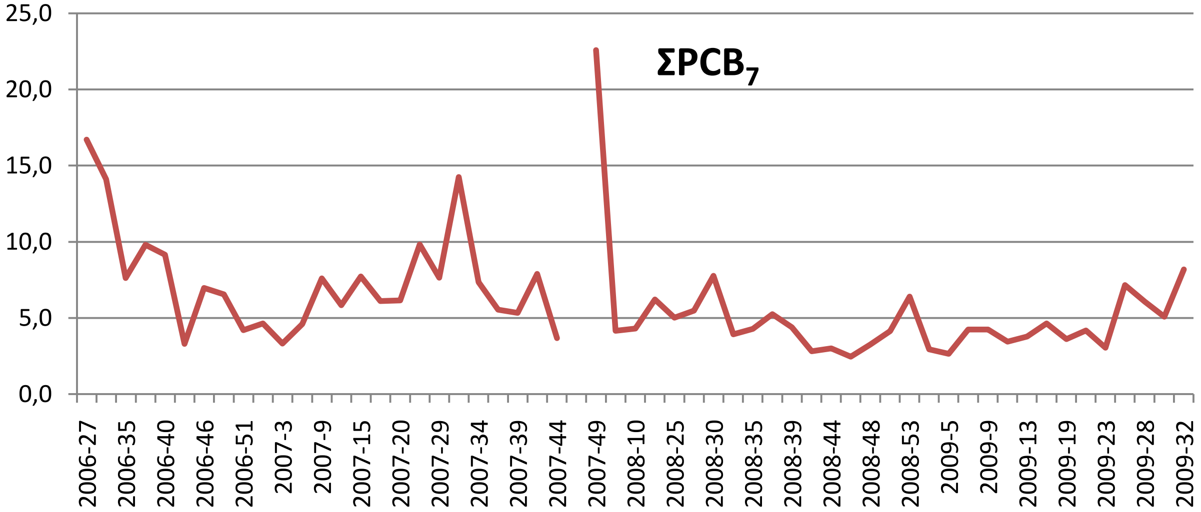


Figure 9: Concentrations of ΣPCB_7 in the air at Kise in pg/m^3. Data from June 2006 to August 2009.

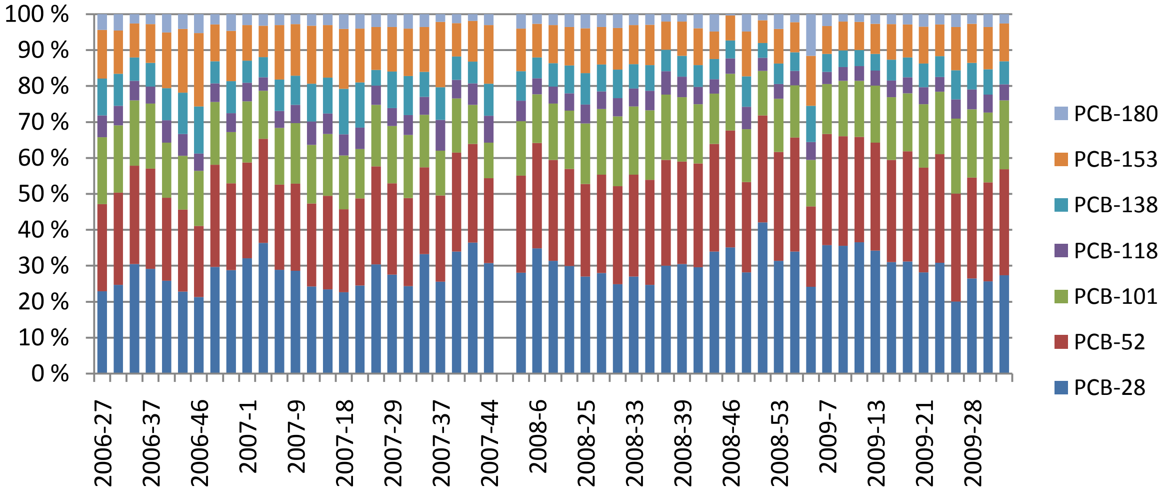


Figure 10: Relative distribution of different PCB compounds in the air samples from Kise (%)

This is in the same range as measured at Kise during the pre-study in 2004 with an average of 6.0 pg/m^3 for ΣPCB_7. No time-trend can be identified.

Interestingly, the measurements at Kise are identical with the levels measured at the Birkenes station (Southern Norway) over the last 5 years (2004-2008: 5.26, 6.97, 6.80, 4.55, and 6.12 pg/m3) (Aas et al., 2009). This suggests that the levels measured at Kise represent the normal Southern-Norwegian background level for PCBs in air. Thus, the active air results alone do not give indications for severe local emission sources. Neither for Birkenes nor for Kise there seems to be a short term reduction of PCB levels in air.

5.1.2 Passive air samples

The results of PCB-measurements in passive air samples are shown in Figure 11. Results are given in ng/sample. In this study, no attempt was made to determine the total sampling volumes for the samples. However, taking into account the results from newer studies at NILU, we expect a total sampling volume of roughly 200 to 400 m^3 (Halse, unpublished results).

The lowest concentrations of PCBs in air around Lake Mjøsa are observed at the rural and semi-rural sites Vingrom, Brumundal (Nesvegen), Hamar (Sandvikavegen), and Hurdal (1.2 – 2.1 ng/sample). The highest concentrations are detected in the two sites Gjøvik (Dalborgmarka) and Gjøvik (Oppland metall) (16.2 and 36.3 ng/sample). The other sites are varying between background and slightly above background levels (2.2 and 11.5 ng/sample).

At some sites it was measured both in the 2006 and 2008 campaign reported in this study and in the 2004 campaign reported in (Breivik et al., 2005). The results from the different campaigns are varying from 1.6 to 6.8 and 3.7 (Lillehammer Gausdalsgt. 2004, 2006, 2008), 1.6 to 3.0 and 2.2 (Kise, 2004, 2006, 2008), and 1.0 to 1.2(Hurdal 2004 and 2008). Similar variation could also be seen in the active air measurements from Kise and reflects the expected variability of the air concentration from year to year.

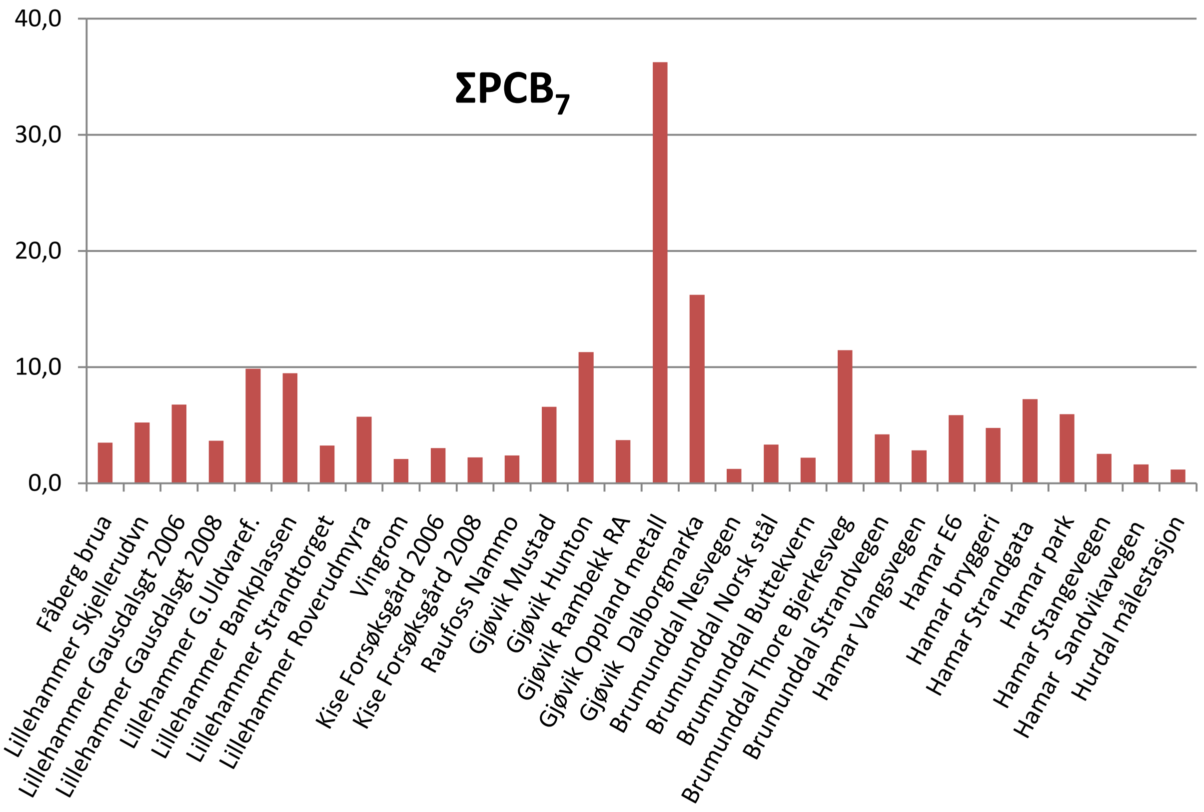


Figure 11: Concentrations of seven selected PCB compounds (ΣPCB$_7$) on the passive air samplers (ng/sample).

In the 2004 pre-study, passive samples were not only taken around Mjøsa, but also at Majorstua in Oslo. The results show a significantly higher burden for PCBs in Oslo, compared with the majority of samples from the Lake Mjøsa region. The stations around Lake Mjøsa show a PCB concentration variation from 1 to about 10 ng/sample, while the difference between Oslo (97,5 ng/sample) and the median for the Lake Mjøsa region (4,5 ng/sample) is a factor of ~22. This is not surprising, as British researchers have shown that the PCB levels in air are 10–100 times higher in urban areas of Europe, compared with the levels in more remote areas (Jaward et al., 2004). This can be interpreted as clear proof that densely-populated areas are still active sources of PCBs to air (Jaward et al., 2004).

Even though this data material is limited, there is little to indicate that the majority of the areas selected around Lake Mjøsa should be significant sources of emissions of PCBs to air, compared with Oslo. On the other hand, the elevated levels measured at the Gjøvik sites ”Oppland metall” and “Dalborgmarka” indicate that there are one or more active sources of PCBs to the atmosphere in this area. At present, the small number of samples excludes the possibility to unequivocally identify the specific source(s) responsible for the high concentrations recorded. Furthermore, it is either not possible to quantify the emission flux into air on the basis of the data presented herein. It may therefore be desirable to carry out follow up studies for the purpose of identifying the specific activity or activities responsible for these emissions. Secondly, it may

also be instructive to design a study in such a way that the emission flux can be estimated and compared and contrasted against the data presented in
Figure 13.

5.1.3 Mass balance for PCBs in Lake Mjøsa

Model evaluation

In order to have any confidence in model outputs, it is essential to confront the model with observations to assess whether it yield results which are in accordance with observations. Of particular relevance to the existing fish consumption advisory may be the predicted concentrations of PCBs in lake water due to its immediate relevance for further uptake in the aquatic food-chain. A total of 4 active high volume water samples collected by NIVA in September 2004 (Breivik et al., 2005) were used for comparison with model predictions. Figure 12 shows predicted and observed lake water concentrations at this point in time.

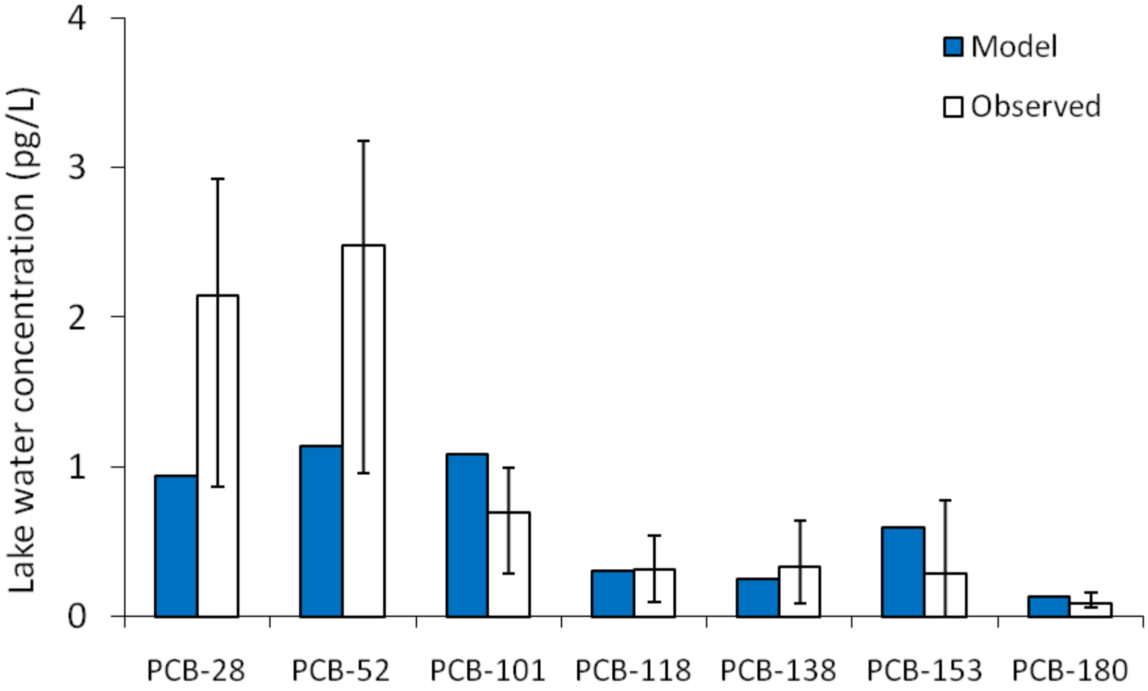


Figure 12: Predicted and observed lake water concentrations in 2004. Vertical lines indicate maximum and minimum observed values (N=4).

In general, the model predictions fall within the observed range for all selected PCBs with the exception of PCB-101. Furthermore, predicted concentrations of PCBs 28 and 52 fall in the lower range of observed values.

Model predictions are also in agreement for sediment concentrations. The model predicts a sediment concentration of 1.1 ng ΣPCB_7 per gram sediment in 2006, while measured data from two sites (outside Gjøvik and Skreia) were found to be 1.7 and 0.9 ng ΣPCB_7 per gram sediment (data from NIVA). At the same time, the model tend to overestimate net sedimentation rates (322 g ΣPCB_7 per year), as estimates derived on the basis of empirical data suggest a net sedimentation rate of 78 and 212 g ΣPCB_7 per year for Skreia and Gjøvik, respectively. This indicates that the balance between inputs and outputs in the sediment may not be accurately described in the model. Any sediment-related fluxes derived on the basis of these model predictions should therefore be considered with a healthy scepticism (see Table 4).

Overall, the agreement between predicted and observed concentrations in lake water is improved in comparison to the initial model assessment previously presented for the reference year 2004 (Breivik et al., 2005), which suggests that our knowledge about sources and inputs of PCBs to Lake Mjøsa has improved since the first study based on the updated information on riverine inputs (Fjeld et al., 2007), STP effluents (Fjeld et al., 2007, Fjeld and Enge, 2008) and concentrations in air (this study). At the same time, any model represents a simplification of reality and there are still uncertainties in both current inputs and process descriptions (Breivik et al., 2005). Nevertheless, the fair agreement between model and observations in this simple comparison suggest the model may be a useful tool to assess key pathways of PCBs into the lake.

Model application

The model was next applied to derive a simplified and improved – yet still uncertain – estimate of the overall environmental behaviour and fate of PCBs. The mass balance as estimated for the reference year 2007 is presented in Table 4.

Table 4: Mass balance for selected PCBs in Lake Mjøsa, 2007.

		28	52	101	118	138	153	180	ΣPCB_7
Input	Total (g/yr)	**86**	**97**	**125**	**52**	**81**	**133**	**39**	**613**
	Atmosphere (%)	56	50	25	23	22	22	20	32
	STPs (%)	6	12	18	22	13	16	22	15
	Inflow (%)	38	38	57	55	65	62	59	53
Output	Total (g/yr)	**102**	**164**	**252**	**128**	**192**	**313**	**93**	**1244**
	Volatilisation (%)	28	16	7	2	1	1	<1	7
	Deg., water (%)	23	9	2	1	<1	1	<1	4
	Deg., sed (%)	35	44	56	48	49	36	36	44
	Outflow (%)	8	6	4	3	2	2	1	3
	Burial (%)	6	24	31	48	49	61	62	42
	Input/Output (g/g)	0.83	0.59	0.50	0.41	0.42	0.43	0.42	0.49
Pools	Total (kg)	**0.3**	**1.6**	**3.1**	**2.4**	**3.7**	**7.5**	**2.3**	**20.7**
	Water (%)	16	3	2	<1	<1	<1	<1	1
	Sediment (%)	84	97	98	>99	>99	>99	>99	99

The new model results suggest fresh water inflow (i.e. mainly rivers) dominates inflow of ΣPCB_7 to the lake (53%), followed by atmospheric deposition (32%) and STPs (15%). There are notable differences in the relative importance of different pathways among individual PCBs whereby atmospheric deposition is predicted to be the dominant pathway for the more volatile PCBs (28 and 52). As previously discussed by Fjeld (2007), the model results confirm that riverine inflows is a key contemporary vector of PCBs in Lake Mjøsa. This is true, even when simultaneously including the updated contribution of atmospheric inputs based on the data presented herein. Fjeld estimated a total riverine inflow of 269 g/yr of ΣPCB_7. The model results indicate an even higher fresh water inflow of ΣPCB_7 (

Figure 13). This is because the model operates with a higher total freshwater inflow rate in comparison to the annual flow rate of the three major rivers considered by Fjeld. In other words, the model assumes any additional fresh water inflows to be equally contaminated as the river water reported by Fjeld.

In total, about 0.6 kg ΣPCB_7 is predicted to enter the lake in 2007. However, the annual loss of ΣPCB_7 is estimated to be about twice this value (~1.2 kg). The major loss processes of ΣPCB_7 during 2007 are predicted to be degradation in sediment (44%) and sediment burial (42%). For more volatile and less hydrophobic PCBs, losses by volatilization and degradation in water increases in relative significance (Table 3). Altogether, the results suggest the pool of ΣPCB_7 in Lake Mjøsa during 2007 to be ~20 kg, most of which is stored in sediments. This does not imply the model predicts sediments to be a net source back to the water column

Figure 13). According to model predictions, the net transport of ΣPCB_7 into the sediment is still almost twice the amount "leaching out" of the sediment back into the water column. However, the sediment is still experiencing a net loss of PCBs, mainly by sediment burial and degradation. Sediment burial in this context means that as materials come into deeper sediments they are less accessible, and ultimately the material becomes almost completely buried and inaccessible to the aquatic environment above (Mackay, 2001).

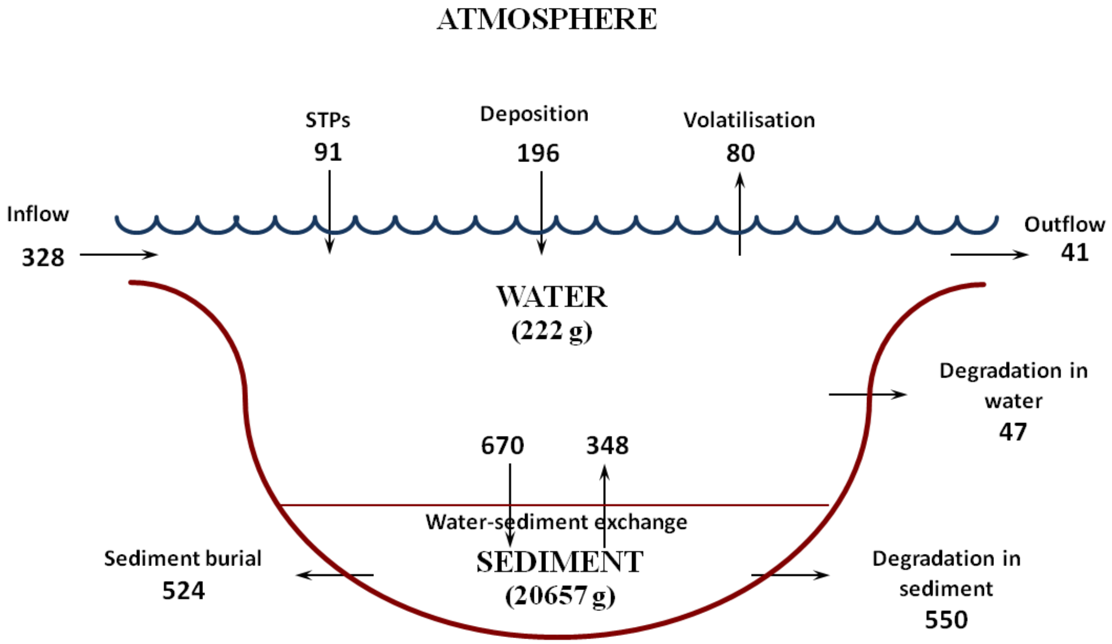


Figure 13: Predicted mass balance for ΣPCB7 in Lake Mjøsa, 2007 (g/year).

Discussion of the model

Mass balance calculations as presented herein may complement information on chemical behaviour and fate which cannot be deduced based on empirical data alone. However, any model of this kind represents a simplification of a more complex reality and predictions are inevitably affected by various uncertainties. The only way to gain confidence in model results is by critically comparing observed and predicted behaviour (e.g. concentrations), as it is considered impossible to validate model predictions of natural systems (Oreskes et al., 1994). This study only addresses ΣPCB_7, and similar investigations for other POPs and POP-like chemicals may be desirable in the future as empirical data becomes available for model parameterization (air, rivers, STPs etc) and evaluation (water, sediment). Ideally then, empirical data could be used to improve models of this kind, while model outputs may help assist in identifying processes that are poorly understood and help guide further monitoring needs and provide clues about sensible control strategies.

As previously recognized by Fjeld et al. (2007), inflow of PCBs by rivers may be much more significant than previously anticipated by Breivik et al. (2005). Average concentrations of ΣPCB_7 in the rivers Lågen, Hunnselva and Svartelva were 31.2 pg/L (range: 19.9-31.9), 96.1 pg/L (range: 63.4-145) and 79.6 pg/L (range: 16-212) during 2006, respectively. It is interesting to compare these values with measured lake water concentrations in 2004 which was 6.4 pg/L only (range: 2.4-9.2). The estimated volume-weighted concentration in inflowing water derived is 33.2 pg/L Table 2) while lake water concentrations 2 years earlier were about five times lower. A reason for this difference may be caused by seasonal variability in water concentrations. The lake water samples were collected in September (2004), while concentrations in river water were found to be highest during spring (Fjeld et al., 2007). Spatial variability is also noted for air based on the results of passive air sampling campaigns. Elevated atmospheric levels are typically found closer to more densely populated places around Lake Mjøsa in comparison to the background air monitoring site at Kise (Breivik et al., 2005). Hence atmospheric deposition to the lake may be expected to be locally elevated closer to more densely populated areas, which again tend to coincide with the location of major river mouths. In other words, significant spatial variability in lake water concentrations is expected due to the influence of localized elevated inputs by rivers, STPs and possibly also by atmospheric deposition.

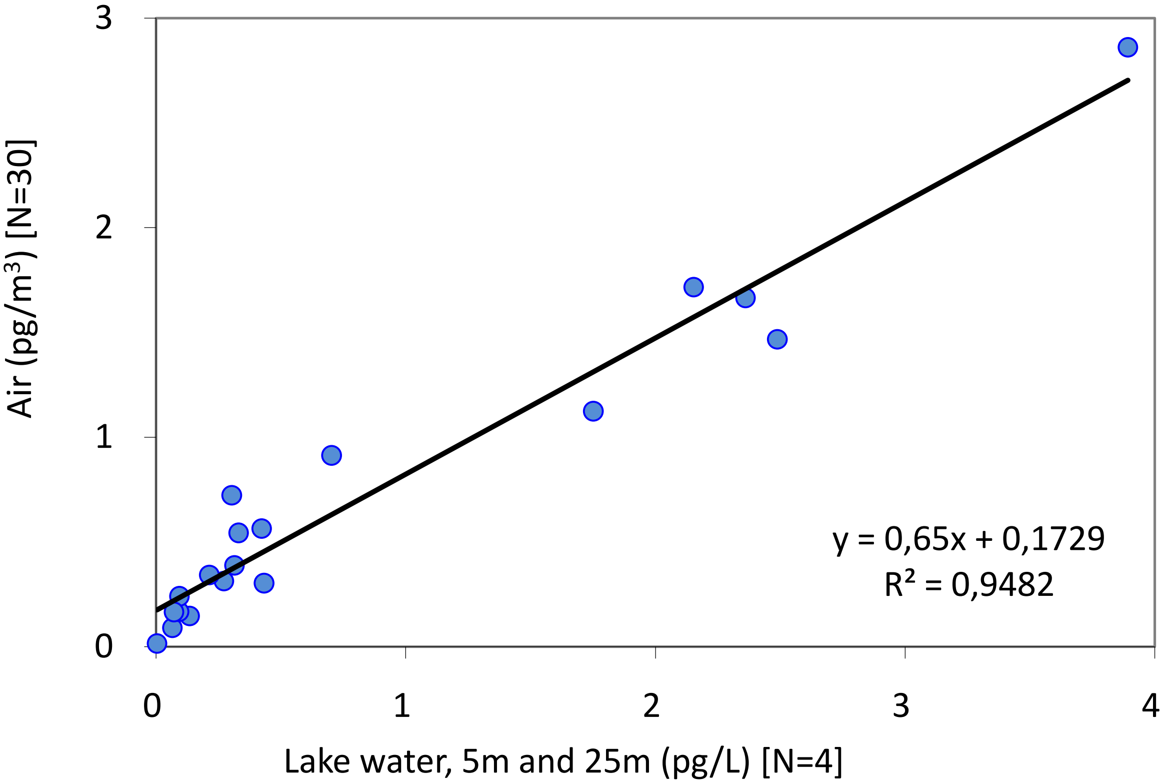


Figure 14: Comparison of average concentrations in air and lake water at Kise for those 19 individual PCB congeners that were found to be above detection limits in both media (data from Breivik et al. (2005).

It should be noted that the lake water samples during 2004 was taken close to Kise, a site which is located in the middle parts of the lake, close to the background air sampling station. At this site, there is empirical evidence of a very close coupling between measured levels in air and lake water as shown in Figure 14. Hence, there may be spatial variability in the relative importance of various pathways into the lake. The model used herein ignores spatial variability and cannot resolve spatial gradients.

Given the relative importance of riverine inputs, more attention should be directed towards this source as the empirical basis for these inputs is still relatively weak (N=12) in comparison to data for air and STPs. A better characterization of riverine inputs using an active high volume water sampling program may thus be considered to gain further confidence in current predictions of chemical inflow rates. It also seems like an open question to what extent levels of PCBs in rivers mainly are controlled by secondary or primary emissions. It would thus be interesting to assess whether elevated levels in some rivers are a result of leaching from more contaminated hot-spots upstream as polluted in the past or whether there are any significant ongoing inputs, e.g. from industrial sites. The role of atmospheric deposition in the catchment areas, run-off and further transport by rivers into the lake also remains largely unknown. These inputs may be elevated during snowmelt (Daly and Wania, 2004), which interestingly mirrors the pattern in observed seasonal trends in rivers. In order to answer some of these unresolved issues, it may be feasible to use passive water samplers rivers (e.g. Allan et al., 2009) in a similar fashion as presented for air (e.g. Mariussen et al., 2008) to track potential hot-spots responsible for elevated levels observed in the rivers.

5.2 PBDE

5.2.1 Active air samples

The results for PBDE are given as the sum of the 5 dominating congeners BDE-28, 47, 99, 100 and 153 abbreviated as $\Sigma PBDE_5$. $\Sigma PBDE_5$ in air from Kise are shown in Figure 15. Their relative distribution is shown in Figure 16. The average for $\Sigma PBDE_5$ is 0.88 pg/m^3 during the period. The highest value was measured in the period 30.06. - 10.07.2006 (4.28 pg/m^3), while the lowest value was measured in the period 26.08. - 09.09.2008 (0,19 pg/m^3).

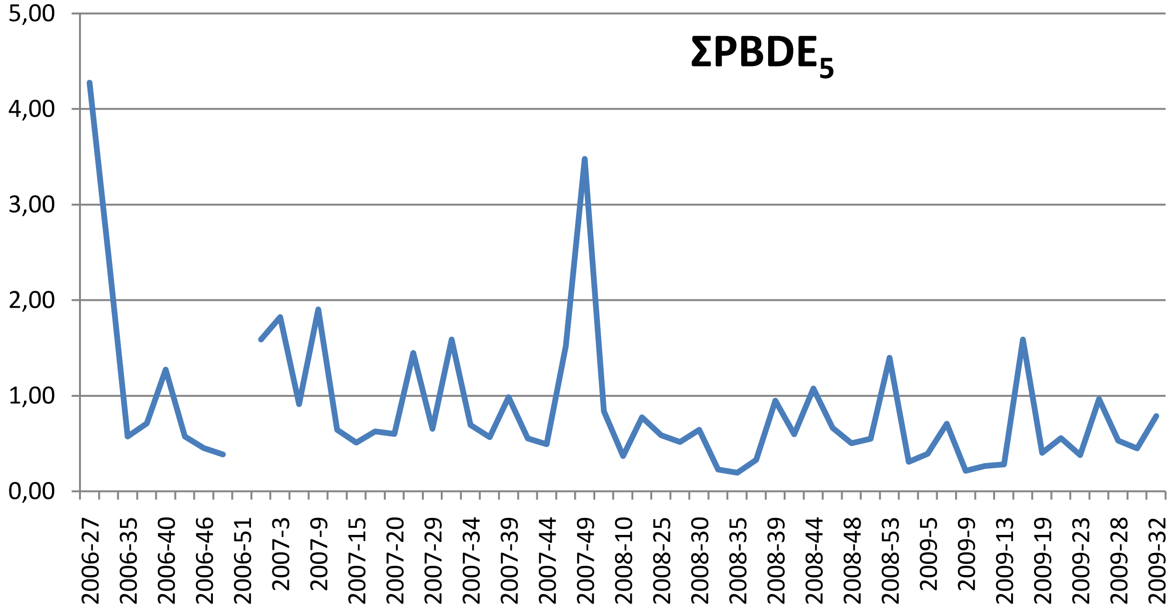


Figure 15: Concentrations of $\Sigma PBDE_5$ (sum of BDE-28, 47, 99, 100 and 153) in air in Kise in pg/m3. Data from June 2006 to August 2009.

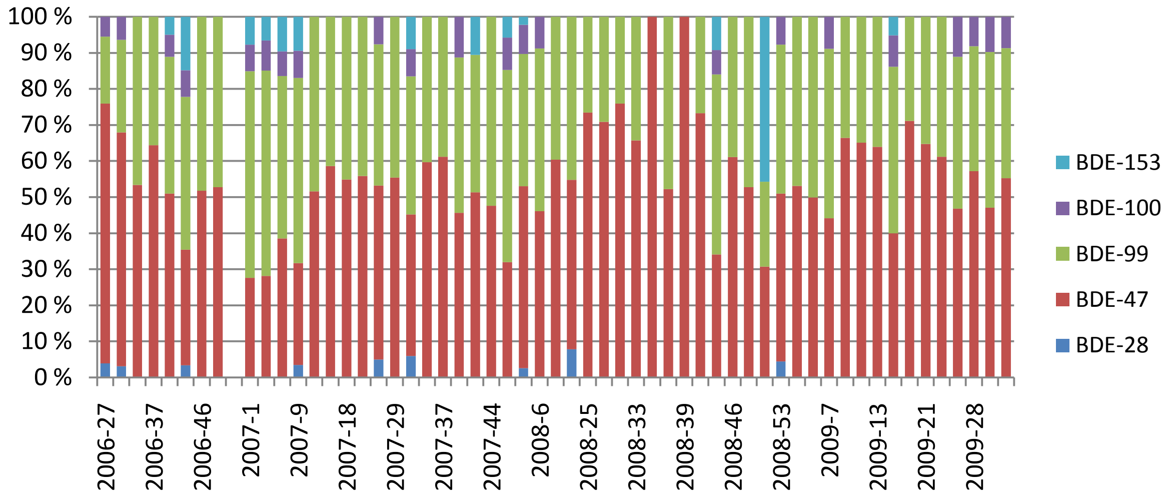


Figure 16: Relative distribution of different BDE compounds in the air samples from Kise (%).

The results for BDE-2009 are shown in Figure 17.

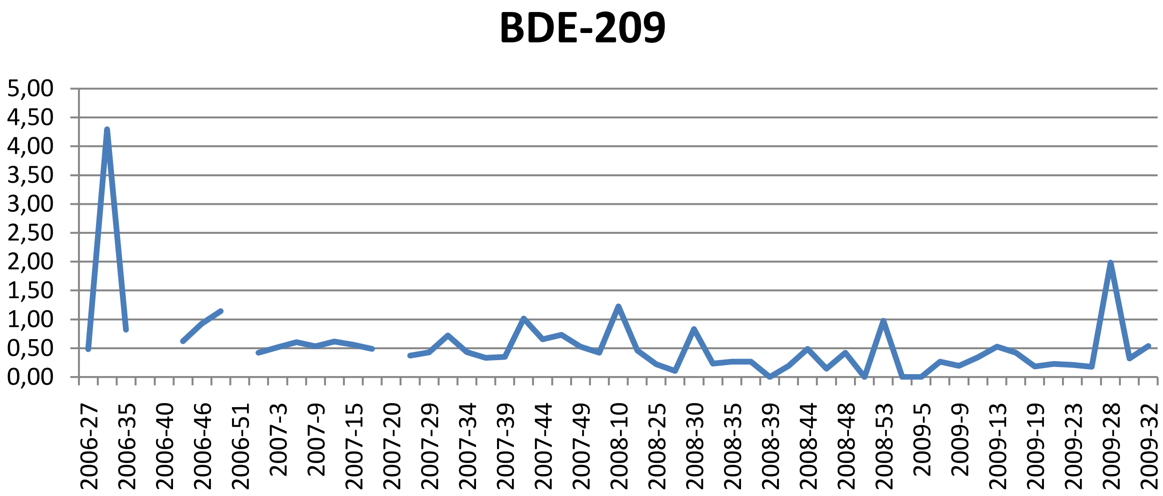


Figure 17: Concentrations of BDE-209 in the air in Kise in pg/m3. Data from June 2006 to August 2009.

The average for BDE-209 is 0,55 pg/m^3 for the entire period.

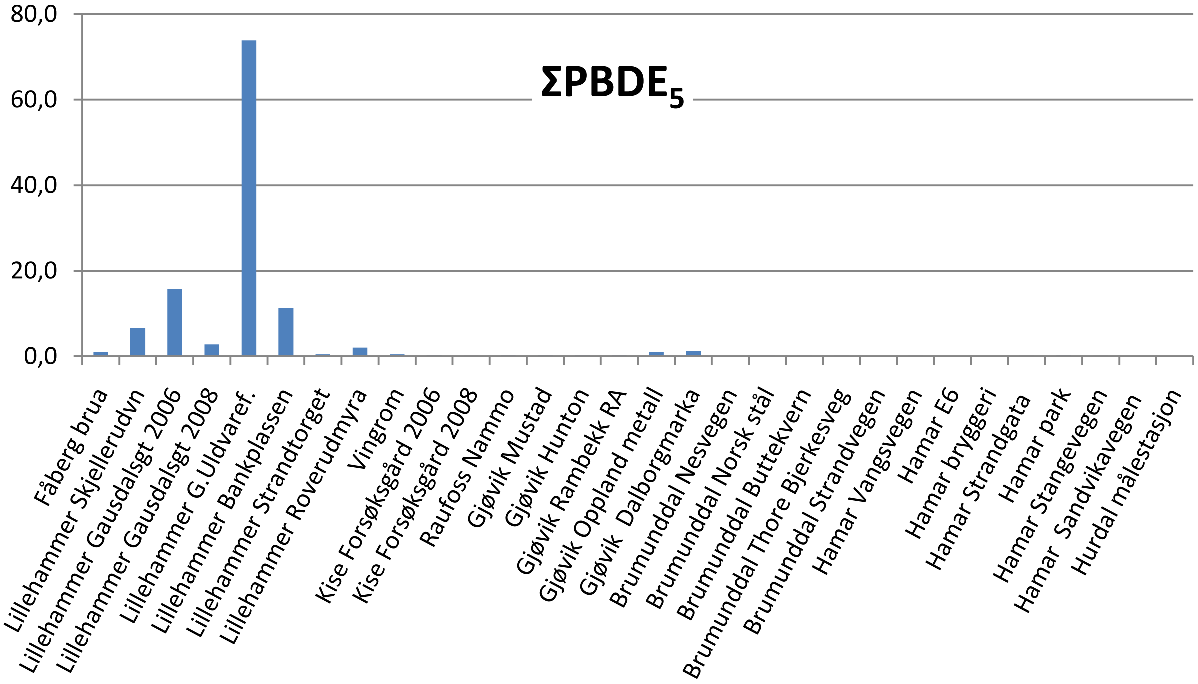
The average of $\Sigma PBDE_5$ from this study (0.88 pg/m3) are much lower than the average of $\Sigma PBDE_4$ measured during the pre-study in 2004 (3.5 pg/m^3). This can, of course, be taken as a downward time-trend. However, it is important to remember that during the pre-study the sampling time was limited to 2-days compared to 14-days in this study and that the majority of the samples showed low concentrations. The increased average was mainly caused by 2 very extreme values which may have been related to long-range atmospheric transport from Great

Britain (Breivik et al., 2005). On the other hand, most of the biota samples studied during the last years showed a decreasing time-trend (Fjeld et al., 2009), which are a good indication for a general reduction of the total PBDE contamination in the environment in the Mjøs region.

In Birkenes an average ΣPBDE of 1.0 pg/m3 was measured in 2008 (Manø et al., 2008a). This suggests that the levels measured at Kise today are close to the expected Southern-Norwegian background level for PBDE in air.

5.2.2 Passive air samples

The results of PCB-measurements in passive air samples are shown in Figure 18. Results are given as ng/sample only. In this study no attempt was made to determine the total sampling volumes for the samples. However, taking into account the results from newer studies at NILU, we expect a total sampling volume of roughly 200 to 400 m^3 (Halse, unpublished results).



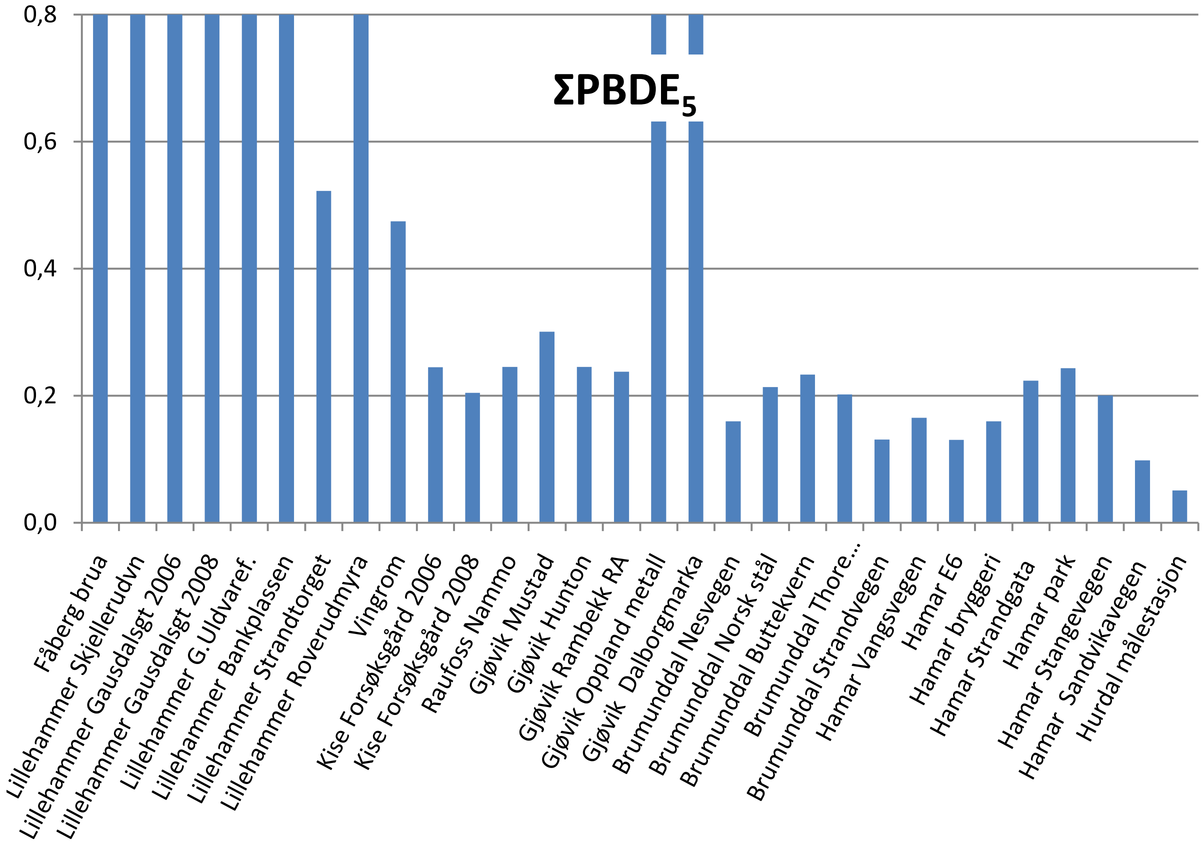


Figure 18: Concentrations of five selected BDE compounds (ΣPBDE$_5$) on the passive air samplers (ng/sample). (upper chart: axis scale 0 – 80 ng/sample, lower chart: 0 – 0.8 ng/sample).

With exception of the Lillehammer region the majority of the samples have a ΣPBDE$_5$ level in the range of 0.1 to 0.3 ng/sample. On the other hand all samples from the Lillehammer region are much higher ranging from 0.5 ng/sample at Lillehammer Strandtorget up to 74 ng/sample in the sample taken at Gudbrandsdalen Uldvarefabrikk. As known from other studies and as reported to SFT this textile factory used a commercial pentabromo diphenylether mixture to produce flame resistant fabrics. In 2003 the company was forced to stop these emissions (SFT, 2003). However, the passive air samples in and around Lillehammer were taken summer/autumn 2006 indicating that this region even three years after cessation of PentaBDE usage still is emitting PBDE to the atmosphere. These continuing elevated levels in Lillehammer may be due to a "memory effect" from previous emissions. "Memory effect" means evaporation of PBDEs to air from contaminated media that previously have been exposed to direct emissions/sources (water, sediment, soil). On the other hand one cannot exclude that Gudbrandsdalen Uldvarefabrikk may still be a primary emission sources of PBDEs to air in the Lillehammer region, not necessary due to an ongoing use of the Penta-mixture but by emission of residues stored in machines and ventilation channels. The distribution pattern which can be identified in Figure 18 suggest that within the area covered by the sampling site “Gudbrandsdalen Uldvarefabrikk”, the strongest source of PBDE to air is located.

As for ΣPBC_7 also $\Sigma PBDE_5$ are elevated at the two Gjøvik sites Oppland metall and Dalborgmarka (1.0 and 1.2 ng/sample) and are showing a higher level than measured in the 2004 sample from Majorstua in Oslo (0,6 ng/sample) (Breivik et al., 2005).

5.2.3 Mass balance for PBDE in Lake Mjøsa

In contrast to PCB where one can see a quite homogeneous distribution of the contamination in nearly all environmental samples, the PBDE levels in environmental samples are heavily influence by one dominating source. This is true for both water-borne and air-borne emissions. Thus, it is not appropriate to use a simple one-box model describing the mass balance for PBDE and only some measured levels are shown in Figure 19Figure 22 in order to illustrate the PBDE mass balance. The outflow loss rate is based on the assumption that the outflow concentration equals the concentration in the central part of the lake.

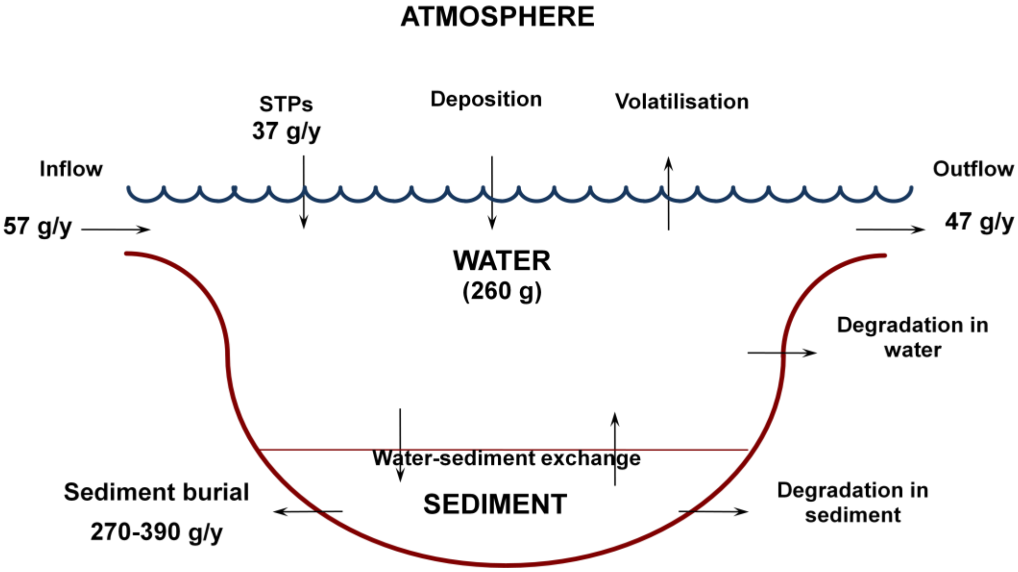


Figure 19: Measured mass balance for PentaBDE in Lake Mjøsa, 2007 (g/year).

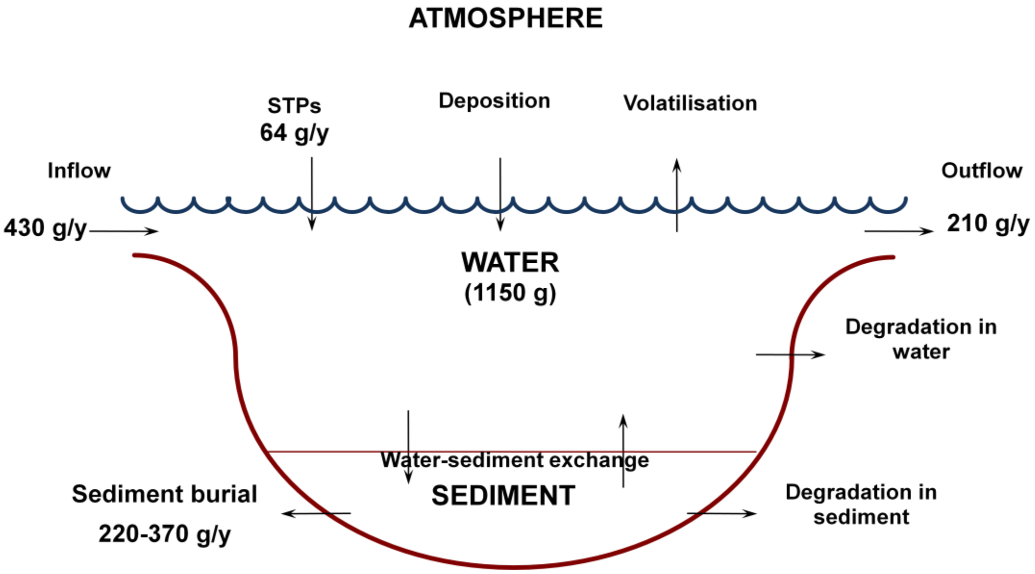


Figure 20: Measured mass balance for OctaBDE in Lake Mjøsa, 2007 (g/year).

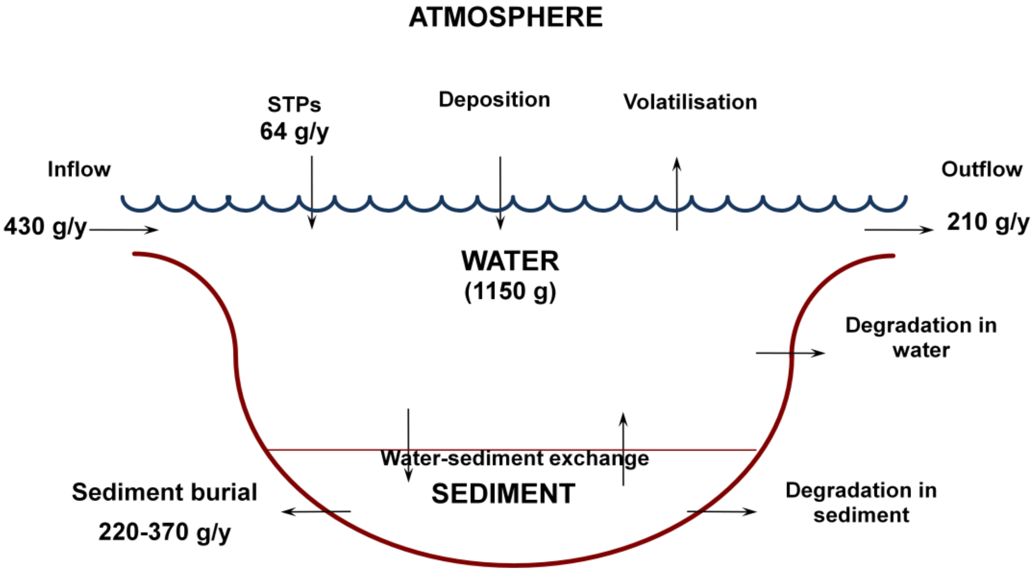


Figure 21: Measured mass balance for DecaBDE in Lake Mjøsa, 2007 (g/year).

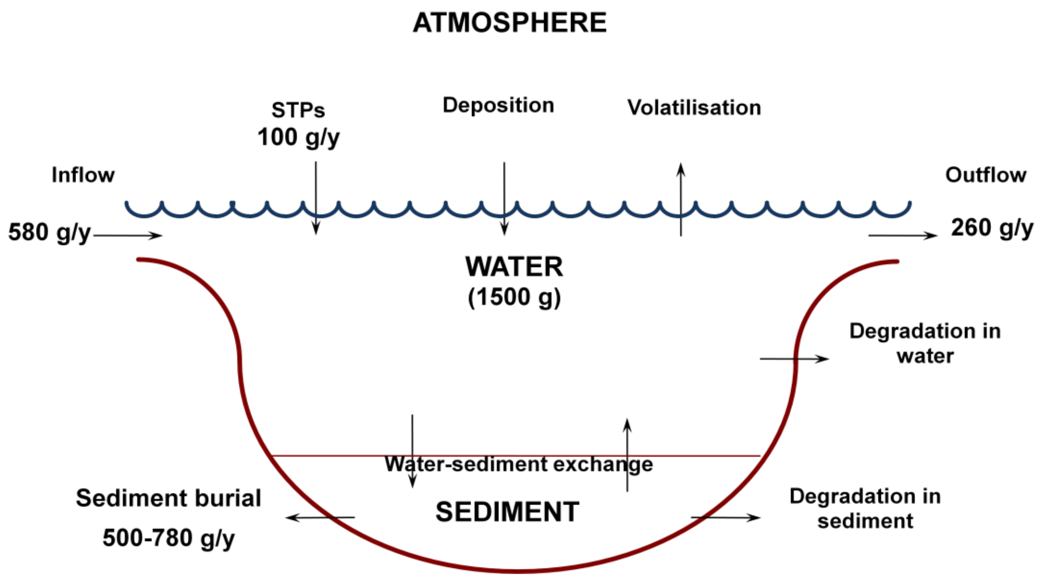


Figure 22: Measured mass balance for $\Sigma PBDE_5$ in Lake Mjøsa, 2007 (g/year).

The passive air samples clearly prove that there is one or more significant local source of PBDEs located in Lillehammer as late as in 2008, even after a known point source became controlled. PBDEs were also found to be elevated at the two Gjøvik sites “Oppland metal” and “Dalborgmarka”, but not as significant as the Lillehammer area.

In general, decreasing levels of PBDE are now observed for most environmental samples from the region over the latest five-six years (Fjeld et al., 2009). This suggests that the contemporary loading of PBDEs to the lake have been reduced in response to control strategies and remediation measures directed towards the point source at Lillehammer. International control strategies may have further contributed to reduce long-range atmospheric transport of PBDEs to Kise, although the relative importance of historical and contemporary atmospheric inputs to the contaminant loads within the lake has not been evaluated.

PBDEs are, as PCBs, regarded as persistent organic pollutants. Degradation is slow and any long-lived contaminants are likely to experience a long residence time in the lake, simply because of the long residence time of water in Lake Mjøsa. It is therefore expected that it will take several years until normal background levels will be reached.

5.3 HBCDD

5.3.1 Active air samples

The results for HBCDD are given as the sum of the 2 dominating congeners α- and γ-HBCDD (ΣHBCDD). ΣHBCDD in air from Kise are shown in Figure 15. The average for ΣHBCDD is 0,49 pg/m^3 during the period. The highest value was measured in the period 29.09-13.10.2006 (5,20 pg/m^3). In contrast to PCB and PBDE it was not possible to detect HBCDD in all samples. For 20 samples both α- and γ-HBCDD were below the limit of detection.

HBCDD was not measured during the pre-study. The average of ΣHBCDD measured at Birkenes is with 4.2 pg/m^3 much higher (Manø et al., 2008a).

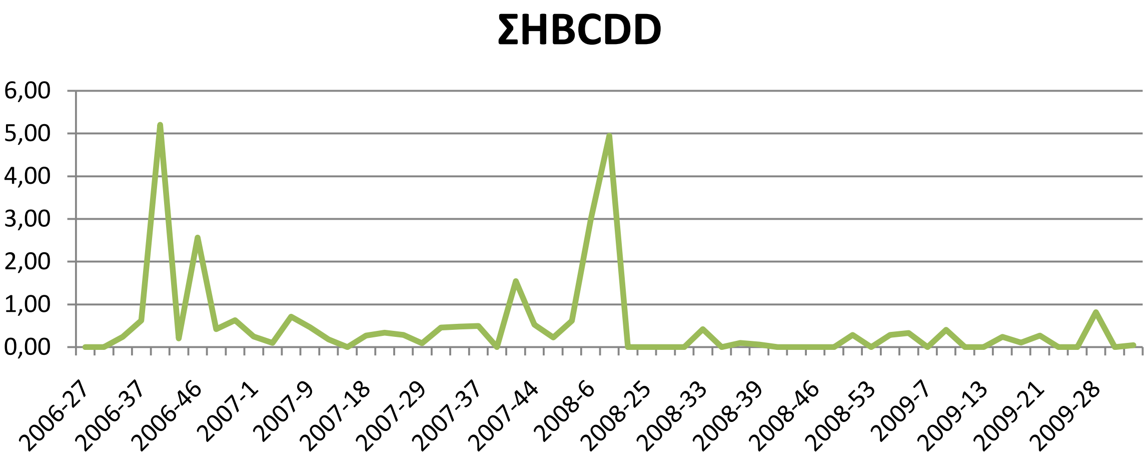


Figure 23: Concentrations of ΣHBCDD (sum of α- and γ-HBCDD) in air in Kise in pg/m3. Data from June 2006 to August 2009.

5.3.2 Passive air samples

Most of the HBCDD results of the passive samples are close to or even below to the limit of detection (Figure 24). Only three samples from Gjøvik (“Mustad”, “Oppland metall” and “Dalborgmarka”) are slightly elevated compared to the other urban samples. Regrettably, HBCDD have not been included in the 2006 campaign around Lillehammer. However, other environmental data points towards elevated levels in the northernmost part of the lake(Fjeld et al., 2006), suggesting that one or more local sources of HBCDD are/have been active in this region.

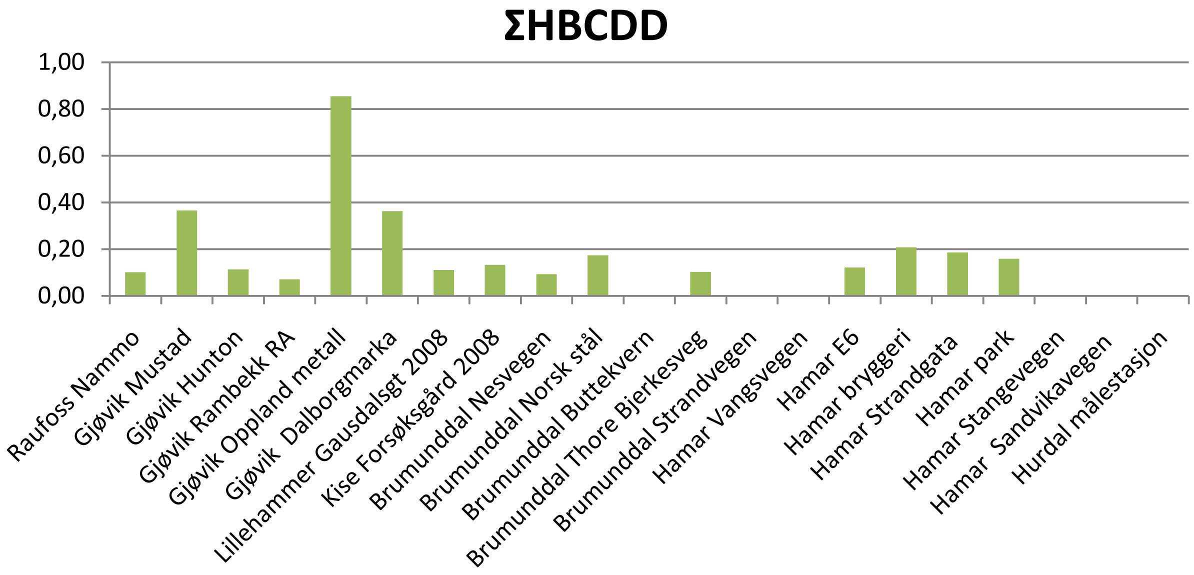


Figure 24: Concentrations of ΣHBCDD (sum of α- and γ-HBCDD) on the passive air samplers (ng/sample).

As both the active and passive air measurements presented herein as well as the river water measurements presented earlier (Fjeld et al., 2007) were close to detection limit, the determined average concentrations and inflows remain quite uncertain. Furthermore, data for air from the northernmost part are lacking. Hence, no attempt has been made to estimate a mass balance for HBCDD in Lake Mjøsa. Given the elevated levels recorded in the northernmost part of the lake and the relatively low levels in background air (Kise), further studies should be directed towards a better characterization of contemporary sources, fluxes and pathways of HBCDD in the more contaminated parts of the lake. For example, a passive air sampling strategy around Lillehammer may be desirable to track potential active sources of HBCDD to air, which in turn could be compared and contrasted against levels recorded elsewhere (Gjøvik, Kise).

5.4 Mercury measurements

5.4.1 Gaseous elemental mercury (GEM)

GEM concentration values measured during the complete measurement period ranged between 0.84 til 3.88 ng/m^3. Results are summarized in Table 5 and shown as time series in Figure 7. A more comprehensive statistical summary is given in Appendix, Table 13. The mean concentration value of GEM was 1.61 ± 0.19 ng/m^3. This is comparable to mean GEM concentration values form other Norwegian sites, such as Birkenes (≈58°N) (1.65 ng/m^3) and Ny-Ålesund (≈79°N) (1.58 ng/m^3), and the northern hemispheric mean concentration value for rural areas (1.7 ng/m^3) (Slemr et al., 2003). The median value for the complete measurement period was 1.59 ng/m^3, which might indicate that the mean is influenced by fewer high concentrations most likely caused by advection of Hg rich air masses from Europe, though the difference is not significant.

Table 5: Summary of GEM data pr year

Year	Average ± STD	Median	Max	Min
2007$^{\$}$	1.61 ± 0.21	1.60	3.15	0.84
2008	1.63 ± 0.20	1.59	3.72	0.92
2009*	1.60 ± 0.16	1.58	3.88	1.11
Total	1.61 ± 0.19	1.59	3.88	0.84

$^{\$}$ From March 2007.

* Only includes the first six months of 2009

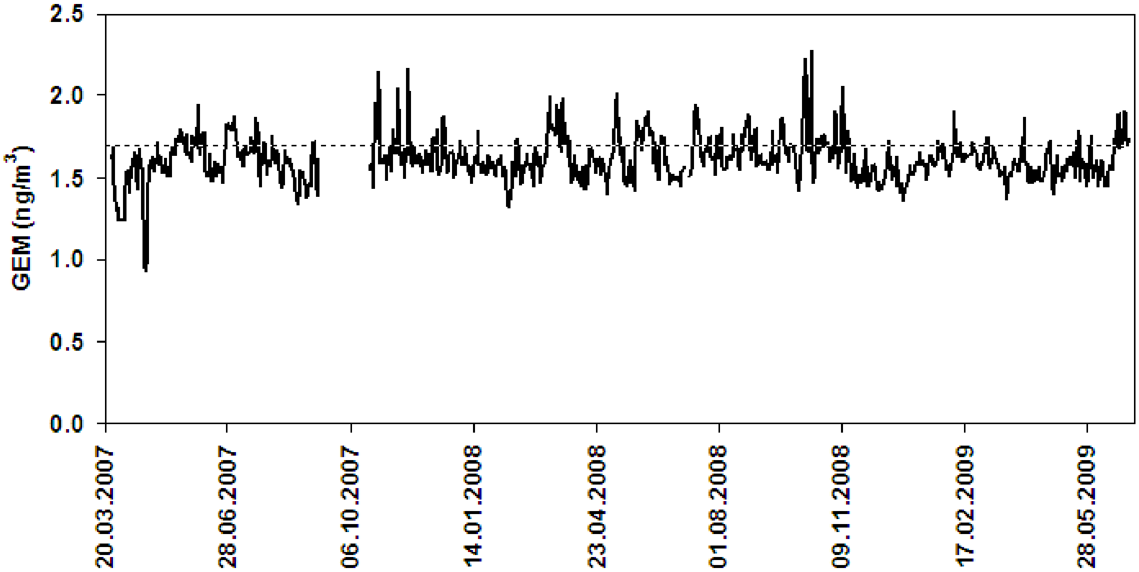


Figure 25: Time series of daily average GEM concentration values. The dotted line indicates the northern hemispheric mean concentration for GEM.

The distribution of GEM concentration values throughout the measurement period is demonstrated as box and whisker plots in Figure 26, panel A and B. The distribution of concentration values between the years are similar (panel A), whereas seasonal variation is observed in panel B. Winter covers the months December to February, spring March to May, summer June to August and Fall September to November. During winter, little variation in the concentration values is observed. This is a time of the year with relatively stable air masses and little exchange towards the south, due to the large atmospheric circulation system termed Polar Front. During spring, the lowest concentration values are observed. This is caused by transport of Hg-depleted air from the Arctic (see details below). The highest concentration values are observed during summer and fall. During summer, the radiation is at its most intense, causing re-emission of previously deposited mercury. As a result, strong correlation between radiation and GEM is observed. Diurnal variation is hardly observed in fall, indicating that the high concentration values are not of local origin.

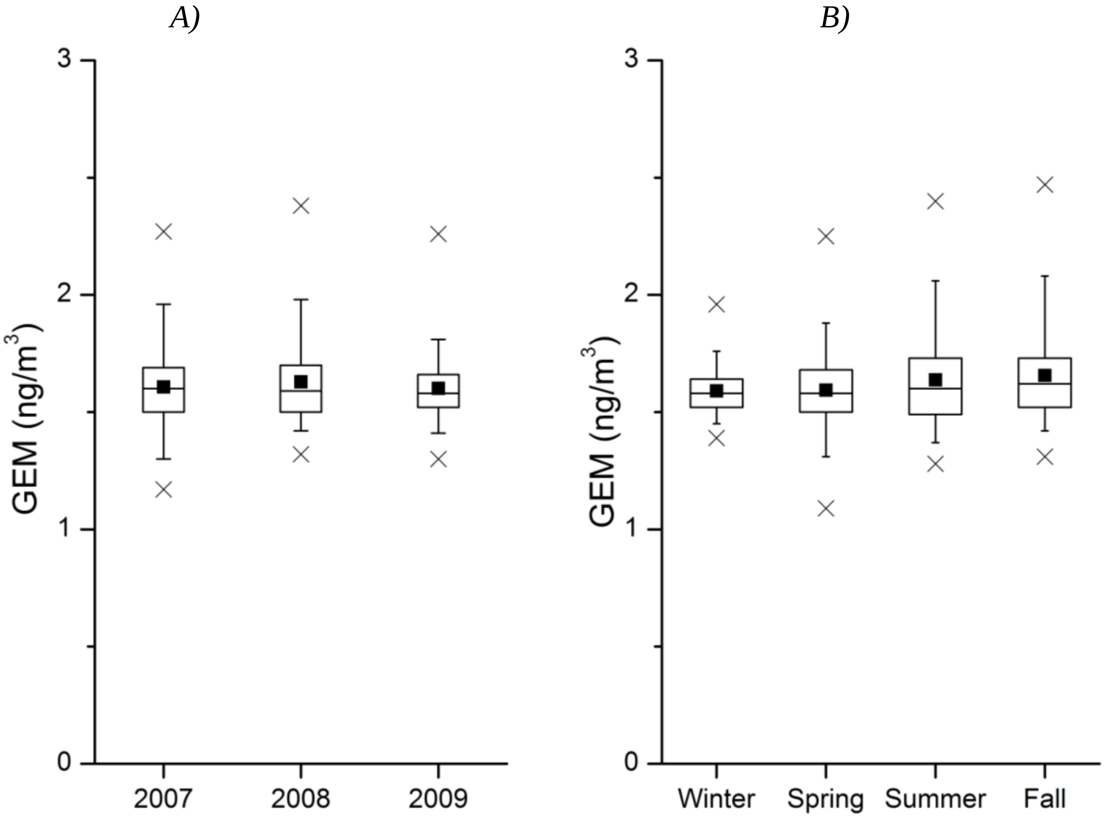


Figure 26: Box and whisker-plot showing the distribution of GEM concentration values separated in A) years and B) seasons. The box indicates 25 and 75 percentile, and the whiskers indicate 10 and 90 percentile. The crosses indicate 5 and 95 percentile, while the filled square is the mean.

In spring, surprisingly low concentration values are observed. Figure 27 show a section of the complete GEM time-series from Kise combined with GEM measurements from Ny-Ålesund. On April 19. 2007, a depletion event was observed in Ny-Ålesund with GEM concentration values down to 0.08 ng/m^3. Two days later, the same event was observed at Kise, though weaker. Figure xx B shows a 7 days back trajectory plot for air masses arriving at Kise April 21 2007 which shows transport of air transported from the Arctic to the measurement site at Kise. Depletion events occur only during spring in the Arctic, and are observed as periodic sudden decreases in GEM concentration values. Depletion events are caused by light induced oxidation reactions involving halogen radicals and ozone (e.g Steffen et al., 2008), where GEM is transformed into oxidized forms of mercury, more prone to deposition compared to GEM (e.g Lingberg et al., 2002). Depletion events are a circumpolar phenomenon and they are believed to be responsible for the increase of mercury in Polar marine environments. Transport of depleted air masses southwards have been reported from Andøya at ~70°N (Berg et al., 2008) but this is the first time depleted air is observed as far south as Kise. It should be mentioned that although remnants of depletion events are observed at Kise, it is unlikely that oxidized mercury forms deposit in the Lake Mjøsa region due to these forms short atmospheric lifetime. The oxidized mercury forms are already scavenged from the atmosphere elsewhere before the air masses reaches Kise.

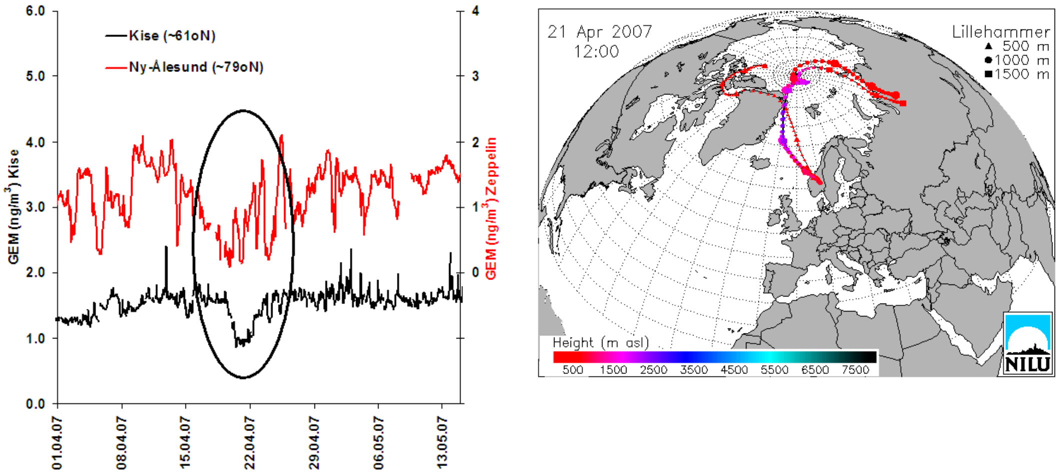


Figure 27: GEM concentration values from Kise and Ny-Ålesund and back trajectories for air masses arriving at Kise April 21. 2007.

Source regions of GEM to the Lake Mjøsa region

Figure 28 shows the combined output from FLEXPART, a Lagrangian particle dispersion mode, and GEM measurements which give a statistical analysis of GEM source and sink regions. The upper row of the figure indicates source regions of GEM, and values exceeding 0.2 indicates direct transport of anthropogenic GEM emissions. The lower row of the figure indicates sink regions of GEM, hence transport of air masses low in GEM. For both rows values less than 0.1 indicates that the air masses avoid surface contact.

Figure 28 shows that high GEM concentration values are associated with transport form Europe all year round. Combustion of fossil fuel for power and heating is the major contributor to European anthropogenic GEM emissions hence European anthropogenic GEM emissions might be subject to seasonal variation. Metal production, waste incineration and chlor-alkali industry are other large contributors of European anthropogenic emission. In fall and winter, increased demand for electricity and heating poses an increased emission burden to the atmosphere, as can be seen in the fall plot. In winter, transport of polluted air from Europe to the Mjøsa region appears less frequent possibly due the Polar front, a large atmospheric circulation systems dominating at this time of the year. Consequently, Europe appears not to be a strong source region of GEM to the Mjøsa region during winter. Given that China has the largest global anthropogenic GEM emissions one would expect China to appear as a source region. However, transport from China occurs too infrequent on the 20-day time scale of the FLEXPART calculations to be represented in the statistics.

Apart from the summer season, the figure shows further that low GEM concentrations values are mainly associated with transport from the Arctic. In spring, air masses low in GEM originates from the Arctic Ocean and especially coastal areas off Canada. These are areas believed to be the areas where AMDEs occur. During fall, the values are almost everywhere below 0.1. This indicates that air masses associated with low GEM concentrations avoid surface contact and, therefore, must descend from above the boundary layer.

During the summer season, southern and south-eastern Europe appears as both a source and sink of mercury. There might be several explanations for this, e.g. that air mass transport from southern Europe is what occurs most often and consequently brings air masses rich and poor in mercury.

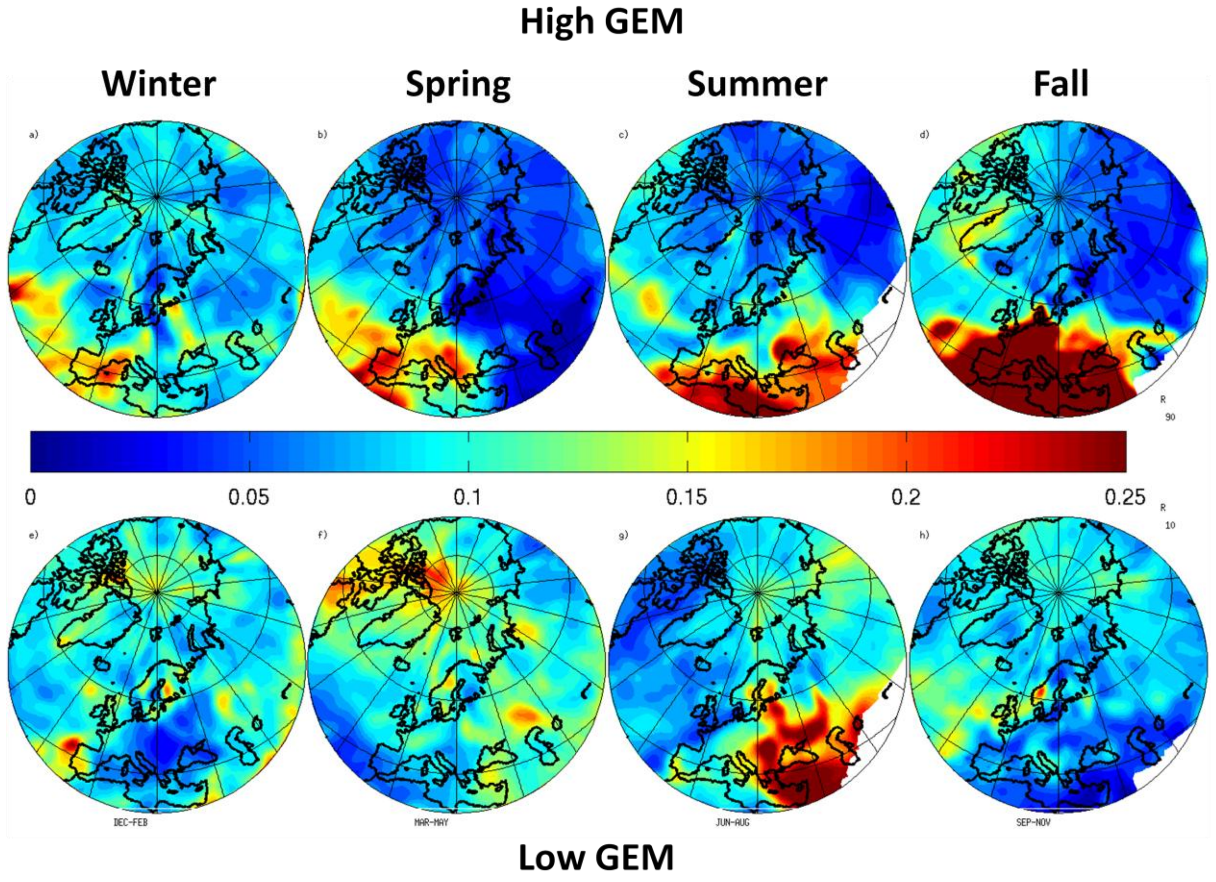
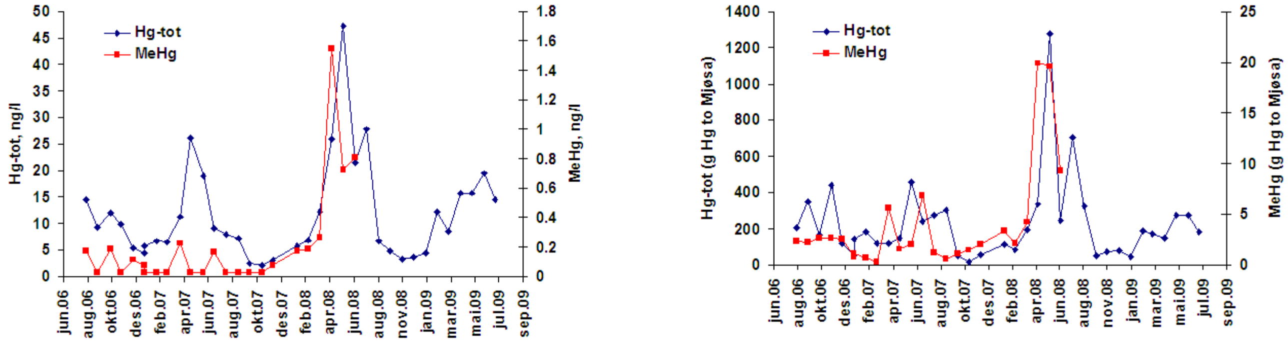


Figure 28: Source (upper row) and sink (bottom row) region plots for GEM at Kise during the years 2007-2009. The plots are split in seasons; winter (left), spring (middle left), summer (middle right) and fall (right). The color scale ranges to 0.25 for all panels. Values exceeding 0.2 indicates frequent transport from these areas.

5.4.2 Wet deposition

Total mercury in precipitation was measured in the range from 2.0 to 47.2 ng/l whereas methyl mercury in precipitation was measured in the range from <MDL to 1.55 ng/l (Figure 29, panel A.). The average concentration value for Hg-tot in precipitation was 11.6 ng/l and 0.21 ng/l for MeHg. The median concentration value for Hg-tot in precipitation was 8.9 ng/l and 0.075 ng/l for MeHg. A summary of the data can be found in Table 6. Concentration values of Hg-tot and MeHg in precipitation show a weak seasonal trend, with maximum concentration values for both species in summer. Though never measured on mainland Norway, it is expected that the

atmospheric concentration of oxidized mercury species are higher in summer compared to the rest of the year due to increased oxidation strength in the summer atmosphere, which may cause higher concentration values of mercury species in precipitation during summer.


A) Concentrations

B) Deposition

Figure 29: Monthly wet deposition of Hg-tot and MeHg. Panel A) Monthly concentration values of Hg-tot and MeHg in precipitation. Panel B) Monthly et deposition fluxes of Hg-tot and MeHg to lake Mjøsa.

The concentration values of Hg-tot in precipitation are slightly higher at Kise compared to values from other Norwegian sites such as Birkenes in Austagder from the same time period (average 7.6 ng/l and median 6.3 ng/l), though the difference is not significant. MeHg in precipitation from Kise constitutes on average 2% of Hg-tot, and varies between 0.01 and 6%. In comparison, MeHg in precipitation from Langtjern in Buskerud constitutes up to 11% of Hg-tot, and varies between 0.5 and 11% (Larsen et al., 2008). Very limited amounts of data on MeHg in precipitation from Norway exist. Langtjern is forested site, quite different to Kise so differences in species distribution may be expected. When comparing results from Kise to studies from the Great Lakes Region (Hall et al., 2005), the species concentration values and distribution are similar.

Table 6: Summary of wet deposition fluxes for Hg-tot and MeHg. Concentrations given are annual averages. For the years 2006 and 2009 only the 6 last and first months respectively are included in the data.

Year	Hg-tot, annual average ng/l	MeHg, annual average ng/l	Precipitation, mm/year	Deposition Hg-tot, µg/m^2*year	Deposition MeHg, ng/m^2*year	Deposition of Hg-tot to Mjøsa	Deposition of MeHg to Mjøsa
2006	9.2	0.1	393.6	3.63	36.4	1327	13.3
2007	8.9	0.06	589.5	5.78	67.2	2112	24.6
2008	14.2	0.61	642.3	9.64	160.3	3519	58.5
2009	14.4	N/A	243.5	3.4	N/A	1240	N/A
Total	11.6	0.21	1868.9	22.45	263.9	8198	96.4

Annual wet deposition fluxes of Hg-tot and MeHg are summarized in Table 6. For the years 2006 and 2009 only the 6 last and first months respectively are included in the data. Monthly wet deposition fluxes of Hg-tot and MeHg are summarized in Table 6. A more comprehensive summary of the data is given in the Appendix, Table 14 and Table 15. When extrapolating data from the years 2006 and 2009 to full years, the average annual deposition of Hg-tot was 7.37 µg/m^2*year. This is within the same range as for the preliminary study performed in 2004 and 2005. Though the average annual concentration value for Hg-tot in precipitation at Kise is higher compared to Birkenes i Austagder, the deposition at Kise is smaller. The annual average deposition during 2006-2008 at Birkenes was 11.8 µg/m^2*year. The precipitation amount at Birkenes is almost double the amount at Kise, which explains the differences in deposition. Deposition at Kise is comparable to remote Swedish and Northern European sites (Wangberg et al., 2007) and sites in the Great Lakes region (Lai et al., 2007).

5.4.3 Dry deposition

The measured average mercury dry deposition flux was 5.04 ± 3.92 ng/m^2*day during periods without precipitation. Median dry deposition flux was 4.38 ng/m^2*day. Dry deposition fluxes were measured in the range 1.37 to 17.80 ng/m^2*day. To the authors' best knowledge, mercury dry deposition fluxes have never been measured before in Norway. Comparing these data with estimates and measurements from North America (Lai et al., 2007, Marsik et al., 2007, Poissant et al., 2004), the measurements from Kise appears lower. There may be several reasons for this. The year 2008-2009 was a year with more precipitation (648 mm) compared to a normal year (556 mm), which may result in less dry deposition than normal. One factor controlling the dry deposition flux is the concentration of particle associated mercury. At remote locations, particle associated mercury constitutes about 1-2% of the total airborne mercury. Though not measured at Kise, one might speculate that the concentration of particle associated mercury at Kise was lower compared to the North American sites, due to location of the measurement site in relation to distance to local particle sources. As for wet deposition fluxes, a weak seasonal signal in dry deposition flux was observed, with higher dry deposition in summer (Figure 30). One might again speculate that this is caused by increased oxidation strength in the summer atmosphere, resulting in a higher concentration of particle associated mercury during summer compared to the rest of the year, and hence a larger dry deposition flux in during summer.

Extrapolating the average mercury dry deposition flux to periods without rain during the whole measurement period, a total of 0.76 µg Hg / m^2*year deposited. This constitutes 11% of the total amount of mercury deposited to Lake Mjøsa.

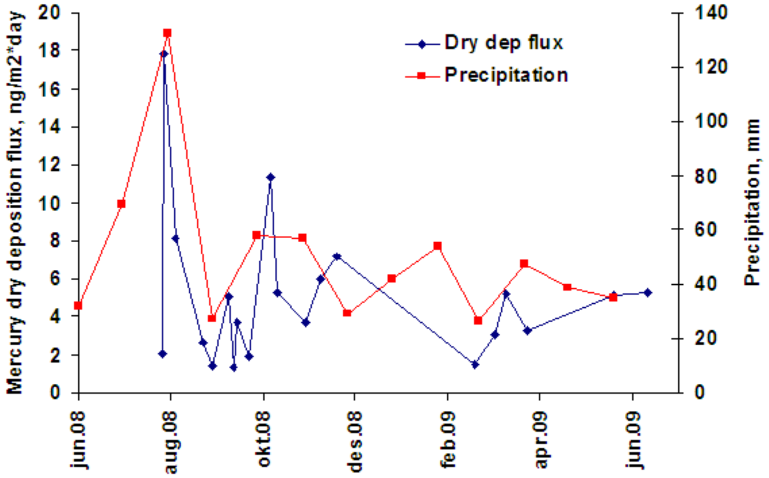


Figure 30: Time series of mercury dry deposition and precipitation.

As mentioned in the report from the preliminary study, the Lake Mjøsa region is no hotspot when it comes to atmospheric deposition of mercury. Results from the National surveys on heavy metals in moss shows an average concentration of mercury in moss in the Lake Mjøsa region of 0.08 – 0.1 µg/g (Steinnes et al., 2007). These results are from the survey conducted in 2005, and show a decrease since the previous survey in 2000.

5.4.4 Gas exchange

DGM concentrations were measured in the range from 14.5 to 98.0 pg/l. Measurement results and the most important meteorological factors are summarized in Table 7. A more comprehensive summary of the measurement is given in the Appendix. Maximum concentration was surprisingly observed in late fall, when the water was cold and radiation weak. Minimum concentration was observed in spring at a day with cold water, low radiation intensity and relatively strong wind for the location. DGM concentrations have, to the authors' best knowledge, never been measured in a Norwegian lake before. DGM concentrations measured in this study are comparable to values from North American lakes (average 38 ± 16 pg/l) (Sullivan and Mason, 1998, Zhang and Lindberg, 2002).

A simple method validation (trueness of measurements) can be found in the Appendix.

Table 7: Summary of water-air gas exchange measurements.

Dato	Tid	Flux, ng/m^2*time	C_w pg/l	C_a pg/l	T_{vann}, °C	Vind, u_{10} (m/s)	Radiation W/m^2
17.07.2008	10:20	0.37	57.8	1.78	19	1.2	639
17.07.2008	10:20	0.35	56.0	1.78	19	1.2	639
17.07.2008	14:45	0.91	58.2	1.78	20	2.0	458
17.07.2008	14:45	0.95	60.4	1.78	20	2.0	458
12.11.2008	10:15	1.74	52.7	1.62	2	4.5	119
12.11.2008	11:20	2.84	98.0	1.62	2	3.9	162
12.11.2008	12:30	1.36	92.0	1.62	2	2.6	130
08.05.2009	08:25	0.17	19.4	1.80	0	3.1	60
08.05.2009	09:55	0.07	14.5	2.01	0	3.2	50
08.05.2009	11:00	0.26	17.1	2.02	0	4.8	52
01.07.2009	08:30	0.22	61.7	1.33	19	0.8	425
01.07.2009	09:30	0.35	64.5	1.37	19	1.1	559
01.07.2009	10:45	0.60	68.9	1.42	19	1.4	720

Based on the four days of DGM measurements, DGM concentrations are modeled and water-air exchange has been calculated for the whole study period. Calculated Hg^0 fluxes are shown in Figure 7. A strong seasonal trend is observed with maximum fluxes during summer and hardly any flux in winter. This is in strong correlation (r = 0.6) with the annual radiation intensity.

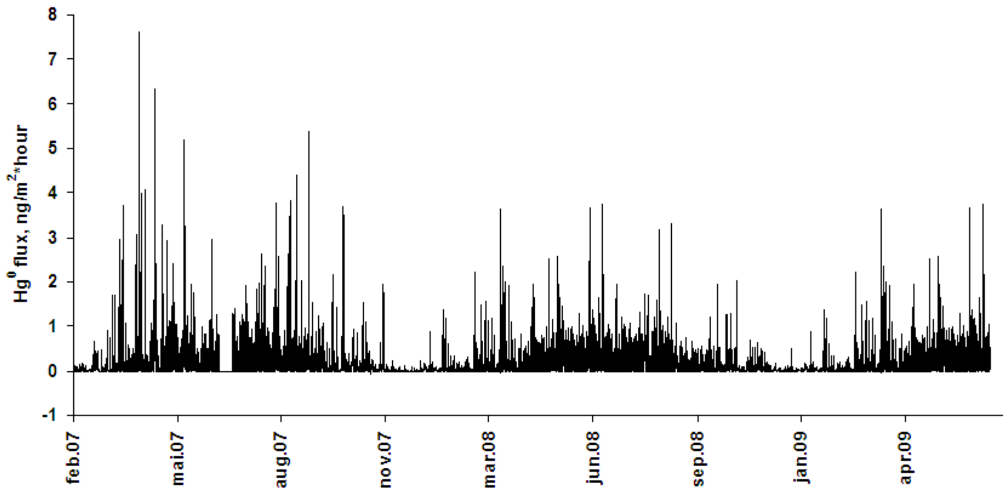


Figure 31: Time series of Hg-fluxes based on modeled DGM concentrations.

The total budget of atmospheric mercury input and output to Lake Mjøsa is summarized in Table 8. On average approximately 20% of mercury deposited to Lake Mjøsa is lost to the atmosphere through evasion from the water surface.

Table 8: Hg-tot budget for Lake Mjøsa based on measured total deposition and estimated evasion

	Deposition, g to Mjøsa	Evasion, g from Mjøsa	% lost through evasion	Net deposition, g
2006	1327	N/A	-	-
2007	2112	588	27.8	1524
2008	3519	493.8	14.0	3025.2
2009	1240	261.6	21.1	978.4

5.4.5 Mercury mass balance

A simplified one-box model

We have no detailed study or model of mercury fluxes within the aquatic environment of Lake Mjøsa, hence we use a simple one-box model (Schwartzenbach et al., 2003) assuming steady state conditions to estimate a simplified mercury mass balance for Lake Mjøsa.

The mercury concentrations in lake water were measured at three different sites at two depths (10 m and 25 m) in 2006. All concentrations were found to be below the method's detection limit (< 1 ng/L), except one which was 1 ng/L (Fjeld, unpublished results). The analytical read-outs varied between 0.30 and 0.99 ng/L, with a mean of 0.5 ng/L – and we use this figure as an estimate of the mercury concentration in the lake and at its outlet.

The mass of mercury in the lake water (28 kg) and the annual output at the outlet (5 kg) can be estimated as the product of the mercury concentration and lake volume (56240 10^6 m^3) or annual flow rate (10123 10^6 m^3/y), respectively.

The annual input of mercury from the main sewage treatment plants have been estimated by (Fjeld et al., 2007) and amounts to 1100–1850 g. The annual atmospheric deposition and volatilisation from the lake surface have previously in this report been estimated to be 1200–3000 g and 260–590 g, respectively.

The main rates remaining to be estimated are the inflow with the inlet water (I_{iw}) and the net sedimentation rate. The inflow rate is difficult to estimate as we have no measures of mercury concentrations in the main rivers, but the net sedimentation rate can be estimated based on information on dated sediment cores (see the following sub-chapter)

However, the simple steady state one-box model conceal the potentially important flux of mercury from the surface sediments to the water phase (O_{ss}) due to remobilization, and we have therefore included this factor as an unknown rate (I_{iw}) in the schematic representation of the mass balance in Figure 32. Practically, this expands the model to a two-box model. If this rate are greater than the output to the surface sediments (O_{ss}), then the sediments are a net mercury source to the lake water. The anthropogenic mercury inventory in the lake sediments is considerable, and has been estimated to be about 1.8 tonnes (Rognerud, 1985).

Under the assumption of a steady state condition, the outputs of mercury have to balance the inputs. If we assume there is no net output of mercury from the surface sediments, then the mercury transported with the inlet water (I_{iw}) has to be in the range of 25–36 kg/y, which implies a mean mercury concentration of 2.5–3.5 ng/L. The lower range of this is not improbable, but further monitoring programs should consider the opportunity to include such measurements in their activities.

However, if we allow the inlet water concentration to be lower than this, then there has to be a mercury flux from the sediments to the water phase to sustain a steady state mass balance. As an example we can assume an inlet concentration of 0.5 ng/L (the same we have assumed for the outlet) and that the output to the sediment surface equals the sediment burial rate. Under these conditions the input of mercury from the sediments to the lake water is estimated be 20–35 kg/y. We have combined the rates from these two alternative models to produce the ranges in Figure 32, therefore there are mutual dependencies between the rates for inflow, outflow and water-sediment exchanges.

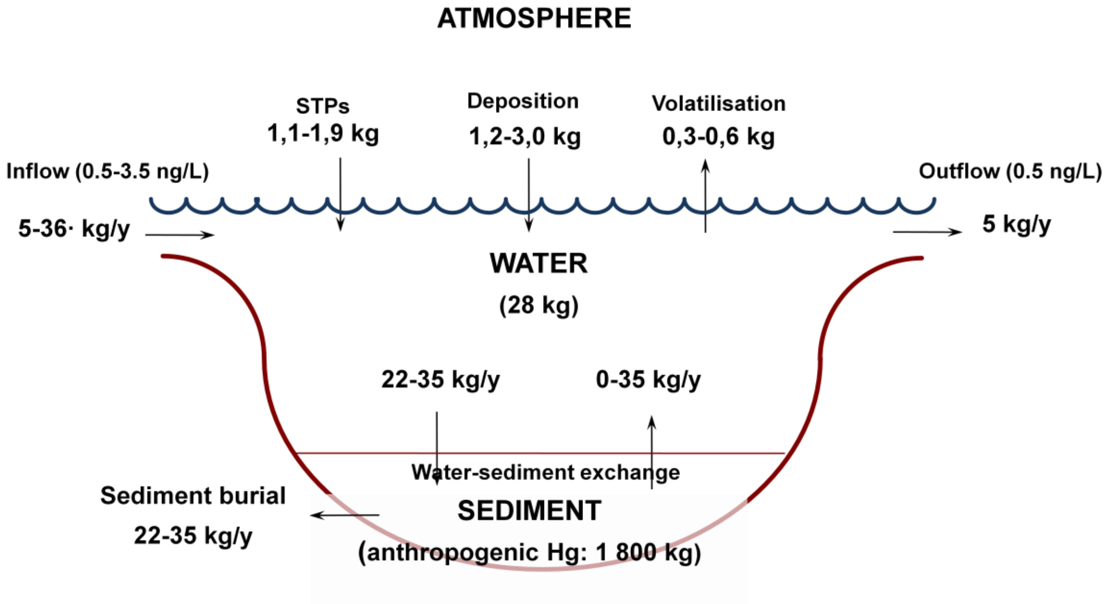


Figure 32: Predicted mass balance for mercury in Lake Mjøsa, 2007. The input from sewage treatment plants (STP) and atmospheric exchanges are based on empirical measurements, whereas the sediment burial rates are based on results from dated sediment cores. The ranges for inflow, outflow and water-sediment exchanges are combined results from two simplified on-box models (steady state) respectively assuming (i) no input from surface sediments and inflow as a free parameter, and (ii) output from surface sediments equals sediment burial and a fixed inflow concentration of 0.5 ng/L Hg.

Net Hg sedimentation rate (sediment burial)

Hg sedimentation rates in Lake Mjøsa can be estimated by utilizing the information on dated sediment cores, sampled in 2006 (Fjeld et al., 2007). In this study sediment cores were taken at two different sites in the main basin of the lake: one core outside the city of Gjøvik and one core at the main sampling station at Skreia. The cores were dated using a modified CRS method (Constant Rate of Supply), and for an introduction to the method, see (Appleby, 2001).

The dating procedure supplies us with the necessary site specific information, such as sediment accumulation rate and unsupported ^{210}Pb activity in respective sediment layers. This information (Table 9), together with Hg concentrations in sediments and regional data on precipitation and atmospheric depositions of ^{210}Pb (
Table 10), can be used for estimating the net Hg sedimentation rate of the lake.

Table 9: Site specific sediment data at the Skreia and Gjøvik coring stations in Lake Mjøsa. The data relates to the upper 0-1 cm sediment layer (surface sediments).

	Skreia	Gjøvik
210Pb activity, unsupported, Bq·kg-1	290	200
sediment accumulation rate (dry weight), kg·m^{-2}·y^{-1}	0.7	0.76
Hg concentration, µg·g^{-1}	0.26	0.28

Table 10: Regional data used for estimating net Hg flux to sediments (sediment burial)

average annual precipitation, mm	670
atmospheric flux of ^{210}Pb per m precipitation, Bq·m^{-2}·y^{-1}·m^{-1}	70[a]
lake surface area, km^{2}	365
catchment/surface area ratio	46

[a] (Appleby, 2000)

Fluxes of mercury to sediments can be calculated as the product of the annual sediment accumulation rate and the mercury concentrations of the respective sediment layers. For the sampling stations at Skreia and Gjøvik, these are estimated to be 182 and 213 µg Hg m^{-2} y^{-1}, respectively. However, these numbers are site specific mercury fluxes for the deep sediment accumulation zones of the lake. They are not representative for the lake as a whole, as these zones are influenced by sediment focusing (transfer of re-suspended sediments from the shallower erosional or transportational zones to the deeper accumulation zones of the lake). Therefore, they can't be used unadjusted for calculating the total mercury flux to the sediments.

The activity of ^{210}Pb in the surface sediments can be used to adjust the site specific mercury fluxes for the influence of sediment focusing. The total ^{210}Pb activity in sediments has two sources, one from *in situ* decay of the parent radionuclide ^{226}Ra (*supported*), and one from the atmospheric flux. *Unsupported* ^{210}Pb is determined by subtracting supported activity from the total activity.

The constant atmospheric flux of ^{210}Pb to a location (P) can be calculated as the product of the regional atmospheric flux per meter of precipitation (F) and the annual precipitation (z) for the site. We have here used the mean of 30-year precipitation normals from four weather stations in the surroundings of Lake Mjøsa.

$$P = F \cdot z = 47\ Bq\ m^{-2}\ y^{-1} \qquad (13)$$

An empirically derived flux of unsupported ^{210}Pb to the sediments ($P_{s\text{-}obs}$) can be calculated by multiplying the sediment accumulation rate in the surface sediments (based on the results from the sediment dating) with the activity of unsupported ^{210}Pb in the same sediment layer. Elevated unsupported ^{210}Pb activity compared to the expected activity derived from the atmospheric deposition fluxes to the lake surface may be caused by (*i*) export from the lake catchments and (*ii*) sediment focusing.

The influence from the catchments on the flux of unsupported ^{210}Pb to the sediments, without the effects of sediment focusing, may be described by the equation

$$P_s = F_{Pb}(1+\alpha\eta_{Pb})P \qquad (14)$$

where P is the constant atmospheric flux, α is the catchment/lake area ratio, η_{Pb} a catchment/lake transport parameter, and F_{Pb} a water column transport parameter (Appleby 1997). For lakes with a long residence time, such as Lake Mjøsa with a residence time of 5.6 years, F_{Pb} can practically be set close to unity (Appleby 1997). The catchment contribution of atmospheric ^{210}Pb is usually minor or negligible relative to the amount deposited on the lake surface, except for lakes with a relatively large catchment area. For lake Mjøsa, with a catchment/lake area ratio of 46, even a small catchment/lake transport parameter of 1-2% can contribute significant to the supply of ^{210}Pb to the sediments. Such removal rates from catchments have been reported from a number of studies (Appleby 1997), and here we use a factor of 1% in the further calculations.

A sediment focusing factor can be calculated as the ratio between the empirically derived flux of unsupported ^{210}Pb ($P_{s\text{-}obs}$) (Skreia: 203 Bq m^{-2} $y^{-1;}$; Gjøvik: 152 Bq m^{-2} y^{-1}) and the estimated flux for a situation without sediment focusing (P_s). By dividing the site specific flux of mercury to sediments with the sediment focusing factor, a more representative and unbiased flux for the lake as a whole can be estimated. The net sedimentation rate of mercury for the lake can then be calculated by multiplying this flux with the lake area. Based on the data from the cores from Skreia and Gjøvik, net sedimentation rates of 22 kg and 35 kg of mercury per year were estimated, respectively.

6. Conclusions

PCB

The measured atmospheric PCB levels for the Mjøs region reflects typical Norwegian background levels as also seen at the Birkenes observatory in Aust-Agder. The measured concentrations show some year-to-year variation. However, no long-term time trend can be identified on the basis of data presented herein.

The Mjøs region as a whole does not seem to act as a major source of PCB emission to air. However, two passive sampling sites close to Gjøvik (“Oppland metal” and “Dalborgmarka”) show elevated PCB concentrations and indicate that there are one or more active sources of PCB to the atmosphere in this area. At present, the small number of samples excludes the possibility to unequivocally identify the specific source(s) responsible for the high concentrations recorded. Furthermore, it is not possible to quantify the emission flux into air on the basis of the data presented herein. It may therefore be desirable to carry out follow up studies for the purpose of (*i*) identifying the specific activities responsible for these emissions, and (*ii*) to estimate the total flux of these sources to assess its potential significance with respect to the contaminant mass balance in Lake Mjøsa.

The results from this study and from earlier studies were used to build an improved mass balance model for PCBs for Lake Mjøsa. The model results suggest fresh water inflow (i.e. mainly rivers) is dominating inflow of ΣPCB_7 to the lake (~53%), followed by atmospheric deposition (~32%) and STPs (~15%). It is therefore recommended that further studies should be directed towards (*i*) an improved characterisation of inflows from the more contaminated rivers and (*ii*) identification of the possible sources (e.g. atmospheric deposition, local emissions direct to the water, and re-suspension from river sediments) that are responsible for the elevated concentrations observed in rivers. In total, about 0.6 kg ΣPCB_7 is predicted to enter the lake in 2007. However, the annual loss of ΣPCB_7 is estimated to be about twice this value (~1.2 kg), indicating that the contaminant burden is gradually being reduced. The major loss processes of ΣPCB_7 during 2007 are predicted to be degradation in sediment (44%) and sediment burial (42%). Altogether, the results suggest the pool of ΣPCB_7 in Lake Mjøsa during 2007 amounts to ~20 kg, most of which is stored in sediments.

Although, any future attempts to further reduce the contemporary loading of PCBs to Lake Mjøsa via STPs, river and air will contribute to further reduce the levels in the lake as well as in fish, the effect of any such measures may be limited in the short-term because of the long residence time of these persistent chemicals within the lake.

PBDE

The atmospheric PBDE load measured at Kise from 2006 to 2009 reflects most likely a “typical” Norwegian background level as also seen at the Birkenes observatory in Aust-Agder. From 2004 to 2009 there may have been a downward time-trend at Kise. However, as the 2004/5 measurements were discontinuous but the new measurements were continuous, the average for 2004/5 may be overestimated due to some single extreme values during late autumn 2004.

The passive air samples clearly prove that there is a very strong local source of PBDEs located in Lillehammer as late as in 2008, even after one known point source was forced to stop the use of PBDEs. PBDEs were also found to be elevated at the two Gjøvik sites “Oppland metal” and “Dalborgmarka”, but not as significant as the Lillehammer area.

In general, decreasing levels of PBDE are now observed for most environmental samples from the region over the latest five-six years. This suggests that the contemporary loading of PBDEs to the lake have been reduced in response to control strategies and remediation measures directed towards the point source at Lillehammer. International control strategies may have further contributed to reduce long-range atmospheric transport of PBDEs to Kise, although the relative importance of historical and contemporary atmospheric inputs to the contaminant loads within the lake has not been evaluated.

PBDEs are, as PCBs, regarded as persistent organic pollutants. Degradation is slow and any long-lived contaminants are likely to experience a long residence time in the lake, simply because of the long residence time of water in Lake Mjøsa. It is therefore expected that it will take several years until normal background levels will be reached.

HBCDD

The measured levels of HBCDD were in general close to the limit of detection. The concentrations measured in air samples from Kise seem to be lower than in samples from Birkenes. Hence, background atmospheric levels in the area seem to be low. The passive air samples are close to the limit of detection as well. Only three passive air samples from Gjøvik were found to be slightly elevated above detection limit (“Mustad”, Oppland metall” and “Dalborgmarka”), indicating the presence of one or more local sources in this area. However, other environmental data points towards elevated levels in the northernmost part of the lake(Fjeld et al., 2006), suggesting that one or more local sources of HBCDD are/have been active in this region.

As both the active and passive air measurements presented herein as well as the river water measurements presented earlier (Fjeld et al., 2007) were close to detection limit, the determined average concentrations and inflows remain quite uncertain. Detailed data for air from the northernmost part are furthermore lacking. Hence, no attempt has been made to estimate a mass balance for HBCDD in Lake Mjøsa. Given the elevated levels recorded in the northernmost part of the lake and the relatively low levels in background air (Kise), further studies should be directed towards a better characterization of contemporary sources, fluxes and pathways of HBCDD in the more contaminated parts of the lake. For example, a passive air sampling strategy around Lillehammer may be desirable to track potential active sources of HBCDD to air, which in turn could be compared and contrasted against levels recorded elsewhere (Gjøvik, Kise).

Hg

The average concentration of elemental mercury in air at Kise during the study period was comparable to the northern hemispheric background mean.

Episodes with high concentrations of atmospheric mercury were observed year round, mainly associated with transport of polluted air from Europe.

The annual total mercury deposition to Lake Mjøsa is 2.9 kg. Bio-available methylmercury constitutes 2% of the wet deposition. Dry deposition accounts for approximately 11% of the total deposition to Lake Mjøsa, indicating that the majority of deposited mercury to Lake Mjøsa is of long-range origin. Approximately 20% of the total Hg deposition to Lake Mjøsa is lost to the atmosphere through evasion from the water surface due to reduction reactions in the water column. STPs emit about 1.1-1.9 kg Hg per year.

As there are no measurements of the mercury concentration in the inlet and outlet rivers, an empirically based mass balance cannot be established. Hence, we have not the necessary information needed to determine whether the contaminant burden is increasing or decreasing. However, under the assumption of a steady state condition and the need to balance the mass flow the main contributor of Hg to the water must be the inflow from rivers and the sediment-water exchange which account for up to 35 kg/year (inflow 5-35 kg/y and sediment-water 0-35 kg/y). The river water concentrations and the sediment-water exchange have never been determined. Taking into account the potential importance of these two transport pathways, follow-up studies should measure the flux of both riverine input and sediment re-suspension.

From 2005 to 2008 the mercury contamination of trout in Mjøsa has increased with about 50 %. The atmospheric measurements do not show any significant time-trend which could explain the observed trend in trout.

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8. Appendix A - POP measurement data

Table 11: Active PCB, PBDE, and HBCDD measurements (pg/m^3) at Kise

Start sampling period Year-Week	Sampling volume m3	PeCB	HCB	2,2',5-TriCB 18	2,4,4'-TriCB 28	2,4',5-TriCB 31	2',3,4-TriCB 33	3,4,4'-TriCB 37	Sum-TriCB	2,2',4,4'-TetCB 47
2006-27	6800	3,31	27,66	6,46	3,83	3,98	2,30	0,34	25,93	24,61
2006-29	9589	1,48	14,95	4,21	3,48	3,56	2,19	0,32	21,29	20,32
2006-35	9580	2,81	25,76	3,67	2,33	2,18	1,28	0,20	14,60	8,78
2006-37	9648	2,90	27,66	4,96	2,86	2,76	1,62	0,27	18,76	6,76
2006-40	9662	4,27	34,25	4,04	2,37	2,25	1,33	0,25	15,29	4,87
2006-42	18156	5,98	30,51	1,30	0,76	0,70	0,40	0,08	4,90	1,25
2006-46	9776	7,80	58,29	2,83	1,49	1,45	0,88	0,15	10,26	1,90
2006-48	9716	7,86	53,09	3,62	1,95	1,93	1,19	0,23	13,51	2,49
2006-51	9749	10,59	57,86	2,50	1,21	1,25	0,78	0,15	8,94	1,96
2007-1	9574	8,40	56,54	2,77	1,49	1,48	0,93	0,19	10,43	4,33
2007-3	9962	13,78	57,81	2,23	1,22	1,19	0,76	0,14	8,62	1,83
2007-6	9938	11,01	49,98	2,76	1,33	1,30	0,79	0,18	10,05	7,77
2007-9	9776	5,19	39,18	4,48	2,18	2,08	1,33	0,28	16,22	11,43
2007-13	9781	5,76	41,55	2,84	1,42	1,37	0,83	0,17	10,55	12,19
2007-15	9730	3,46	29,76	3,55	1,82	1,69	0,95	0,22	12,86	14,51
2007-18	9625	4,57	25,24	2,39	1,38	1,37	0,81	0,18	10,00	18,80
2007-20	9628	3,04	20,33	2,46	1,51	1,50	0,90	0,22	10,75	18,41
2007-23	9561	2,11	17,72	3,37	2,99	2,94	1,78	0,37	18,32	22,84
2007-29	9534	1,44	13,18	2,62	2,11	2,04	1,28	0,32	13,45	22,45
2007-31	8702	1,62	15,28	3,77	3,46	3,31	1,98	0,46	20,42	25,76
2007-34	9381	3,96	35,73	4,38	2,44	2,49	1,77	0,45	18,04	6,04
2007-37	9334	3,90	43,26	2,37	1,42	1,37	0,85	0,17	9,28	3,37
2007-39	9535	7,67	47,04	3,48	1,81	1,77	1,14	0,19	11,17	2,06
2007-42	9531	6,74	53,78	4,63	2,88	2,79	1,87	0,42	19,01	2,27
2007-44	9574	10,35	54,01	1,98	1,13	1,08	0,70	0,12	7,53	1,20
2007-47	9555	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-49	9651	15,06	58,60	7,09	6,34	6,02	3,73	0,93	36,92	30,64
2008-6	9640	10,52	48,60	2,44	1,45	1,40	0,93	0,17	9,69	2,15
2008-10	9464	10,13	54,87	2,91	1,36	1,32	0,83	0,13	8,79	2,91
2008-23	7366	7,79	48,96	2,88	1,86	1,83	1,20	0,26	12,81	13,08
2008-25	9318	1,59	11,41	1,31	1,36	1,29	0,83	0,20	7,54	5,82
2008-28	9295	1,16	9,28	1,21	1,54	1,48	0,91	0,19	7,77	6,66
2008-30	9305	1,07	9,70	1,45	1,93	2,03	1,25	0,32	10,36	8,47
2008-33	9313	1,29	13,78	1,23	1,06	0,99	0,63	0,14	6,32	3,75
2008-35	9356	1,21	9,83	1,14	1,06	1,02	0,67	0,13	5,90	4,69
2008-37	9502	1,35	12,99	2,47	1,58	1,52	0,97	0,18	9,99	2,87
2008-39	9407	1,70	18,70	2,08	1,34	1,26	0,84	0,18	8,39	2,64
2008-42	9421	2,32	20,79	1,39	0,84	0,84	0,53	0,11	5,31	2,29
2008-44	9573	3,25	26,85	1,93	1,03	1,01	0,68	0,14	7,16	0,98
2008-46	9527	5,55	37,27	1,59	0,89	0,87	0,54	0,09	5,95	0,78
2008-48	9565	7,17	38,34	2,51	0,92	1,08	0,79	0,18	8,48	0,74
2008-50	9613	5,41	35,53	3,01	1,75	1,66	1,16	0,27	11,85	1,00
2008-53	3968	9,83	87,00	4,05	2,02	1,92	1,22	0,25	14,58	1,72
2009-3	9588	7,65	39,46	2,04	1,01	0,96	0,59	0,09	7,12	0,78
2009-5	9756	11,87	45,18	1,39	0,64	0,63	0,40	0,07	4,83	0,34
2009-7	9677	6,15	47,98	3,05	1,52	1,48	1,00	0,17	11,03	0,77
2009-9	9553	5,42	35,09	2,80	1,51	1,42	0,93	0,16	10,27	1,05
2009-11	9569	4,45	34,40	2,07	1,27	1,25	0,85	0,15	7,90	1,08
2009-13	9530	2,76	23,88	2,02	1,30	1,29	0,81	0,14	7,92	1,25
2009-15	9489	2,20	18,66	2,12	1,45	1,39	0,87	0,16	8,49	2,21
2009-19	9424	1,28	15,09	1,48	1,13	1,11	0,68	0,12	6,27	3,30
2009-21	9369	2,09	13,23	0,98	1,18	1,16	0,74	0,15	6,04	5,47
2009-23	9356	1,50	12,36	1,25	0,94	0,93	0,56	0,10	5,53	3,78
2009-26	9106	0,95	8,65	1,02	1,44	1,43	1,02	0,26	7,34	11,16
2009-28	9200	0,99	9,67	1,58	1,60	1,54	0,96	0,20	8,41	6,15
2009-30	9200	0,96	9,36	1,10	1,31	1,22	0,73	0,15	6,42	5,33
2009-32	3900	1,93	16,82	2,83	2,24	2,15	1,27	0,24	12,59	7,86

Start sampling period	2,2',5,5'-TetCB	2,3',4,4'-TetCB	2,4,4',5-TetCB	Sum-TetCB	2,2',4,4',5-PenCB	2,2',4,5,5'-PenCB	2,3,3',4,4'-PenCB	2,3,4,4',5-PenCB	2,3',4,4',5-PenCB	2'3,3',4,5-PenCB
Year-Week	52	66	74		99	101	105	114	118	122
2006-27	4,05	1,12	0,64	46,15	1,21	3,11	0,33	0,02	1,01	-0,01
2006-29	3,63	0,92	0,52	38,38	0,91	2,63	0,25	-0,06	0,78	-0,06
2006-35	2,09	0,59	0,36	19,44	0,50	1,39	0,13	-0,06	0,41	-0,06
2006-37	2,74	0,64	0,51	19,22	0,46	1,77	0,15	-0,06	0,47	-0,06
2006-40	2,12	0,63	0,39	14,40	0,56	1,40	0,16	-0,06	0,57	-0,06
2006-42	0,76	0,22	0,14	4,40	0,21	0,50	0,06	0,01	0,20	0,00
2006-46	1,38	0,34	0,23	7,14	0,38	1,07	0,09	-0,06	0,34	-0,06
2006-48	1,87	0,51	0,33	10,26	0,38	1,15	0,08	-0,06	0,34	-0,06
2006-51	1,01	0,28	0,17	6,14	0,28	0,60	-0,06	-0,06	0,22	-0,06
2007-1	1,24	0,37	0,21	10,91	0,32	0,79	0,07	-0,06	0,24	-0,06
2007-3	0,97	0,21	0,15	6,22	0,19	0,45	-0,06	-0,06	0,12	-0,06
2007-6	1,09	0,32	0,19	16,23	0,51	0,73	0,07	-0,06	0,22	-0,06
2007-9	1,84	0,56	0,33	24,93	0,88	1,28	0,12	-0,06	0,39	-0,06
2007-13	1,35	0,41	0,24	22,52	0,72	0,95	0,11	-0,06	0,38	-0,06
2007-15	2,02	0,54	0,34	27,46	0,70	1,33	0,15	-0,06	0,44	-0,06
2007-18	1,41	0,41	0,23	30,49	0,50	0,92	0,11	-0,06	0,36	-0,06
2007-20	1,49	0,48	0,28	31,15	0,44	0,85	0,12	-0,06	0,36	-0,06
2007-23	2,68	0,72	0,48	40,83	0,58	1,68	0,18	-0,06	0,53	-0,06
2007-29	1,94	0,63	0,37	37,64	0,43	1,22	0,13	-0,06	0,39	-0,06
2007-31	3,50	1,13	0,67	48,27	0,85	2,50	0,26	-0,06	0,78	-0,06
2007-34	1,78	0,78	0,44	16,01	0,31	1,07	0,12	-0,06	0,37	-0,06
2007-37	1,33	0,51	0,29	9,72	0,41	0,69	0,13	-0,06	0,48	-0,06
2007-39	1,47	0,37	0,23	4,14	0,25	0,80	0,09	-0,06	0,28	-0,06
2007-42	2,17	0,87	5,28	12,34	0,41	0,85	0,15	-0,06	0,48	-0,06
2007-44	0,87	0,31	0,19	5,04	0,21	0,37	0,08	-0,06	0,27	-0,06
2007-47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-49	6,10	2,31	1,40	67,15	1,28	3,43	0,38	-0,06	1,28	-0,06
2008-6	1,22	0,31	2,11	7,44	0,18	0,56	0,06	-0,06	0,19	-0,06
2008-10	1,22	0,35	0,20	4,68	0,23	0,68	0,06	-0,06	0,20	-0,06
2008-23	1,68	0,49	0,26	30,73	0,30	1,01	0,08	-0,06	0,30	-0,06
2008-25	1,29	0,41	0,24	13,33	0,24	0,84	0,08	-0,06	0,27	-0,06
2008-28	1,51	0,43	0,26	14,59	0,30	1,00	0,08	-0,06	0,27	-0,06
2008-30	2,12	0,63	0,36	18,92	0,42	1,51	0,12	-0,06	0,40	-0,06
2008-33	1,11	0,30	0,19	8,84	0,22	0,75	-0,06	-0,06	0,20	-0,06
2008-35	1,26	0,35	0,21	10,32	0,25	0,83	0,07	-0,06	0,23	-0,06
2008-37	1,55	0,39	0,26	9,10	0,34	0,96	0,12	-0,06	0,34	-0,06
2008-39	1,25	0,35	0,20	5,87	0,21	0,79	0,07	-0,06	0,25	-0,06
2008-42	0,82	0,24	0,14	5,98	0,15	0,47	-0,06	-0,06	0,14	-0,06
2008-44	0,90	0,23	0,15	4,43	0,14	0,42	-0,06	-0,06	0,12	-0,06
2008-46	0,82	0,19	0,12	3,79	0,13	0,40	-0,06	-0,06	0,11	-0,06
2008-48	0,82	0,24	0,14	3,87	0,18	0,48	0,07	-0,06	0,21	-0,06
2008-50	1,24	0,41	0,27	6,62	0,17	0,51	-0,06	-0,06	0,15	-0,06
2008-53	1,94	0,41	0,30	9,08	0,30	0,95	0,09	-0,06	0,26	-0,06
2009-3	0,94	0,20	0,13	4,32	0,15	0,43	-0,06	-0,06	0,12	-0,06
2009-5	0,60	0,11	0,08	2,48	0,10	0,34	-0,06	-0,06	0,13	-0,06
2009-7	1,32	0,23	0,19	5,46	0,17	0,59	-0,06	-0,06	0,15	-0,06
2009-9	1,29	0,33	0,22	6,16	0,21	0,66	-0,06	-0,06	0,16	-0,06
2009-11	1,02	0,29	0,18	2,99	0,17	0,54	-0,06	-0,06	0,14	-0,06
2009-13	1,14	0,28	0,18	3,34	0,18	0,60	-0,06	-0,06	0,16	-0,06
2009-15	1,33	0,37	0,23	4,79	0,24	0,81	0,07	-0,06	0,22	-0,06
2009-19	1,11	0,29	0,17	5,60	0,19	0,59	-0,06	-0,06	0,16	-0,06
2009-21	1,22	0,32	0,20	8,53	0,22	0,74	0,06	-0,06	0,20	-0,06
2009-23	0,93	0,22	0,14	6,09	0,15	0,53	-0,06	-0,06	0,13	-0,06
2009-26	2,16	0,60	0,37	15,95	0,40	1,50	0,11	-0,06	0,38	-0,06
2009-28	1,71	0,47	0,29	9,84	0,32	1,15	0,11	0,01	0,34	0,00
2009-30	1,40	0,38	0,24	8,37	0,27	0,99	0,08	0,01	0,26	0,01
2009-32	2,42	0,62	0,39	12,81	0,42	1,57	0,11	0,02	0,37	0,01

Start sampling period	2',3,4,4',5-PenCB	Sum-PenCB	2,2',3,3',4,4'-HexCB	2,2',3,4,4',5'-HexCB	2,2',3,4,5,5'-HexCB	2,2',3,4',5',6-HexCB	2,2',4,4',5,5'-HexCB	2,3,3',4,4',5-HexCB	2,3,3',4,4',5'-HexCB	2,3',4,4',5,5'-HexCB
Year-Week	123		128	138	141	149	153	156	157	167
2006-27	0,04	9,68	0,21	1,72	0,56	2,39	2,26	0,11	0,01	0,05
2006-29	-0,06	7,79	0,18	1,25	0,42	1,73	1,70	0,09	-0,06	-0,06
2006-35	-0,06	4,18	0,06	0,50	0,16	0,90	0,72	-0,06	-0,06	-0,06
2006-37	-0,06	4,74	0,08	0,65	0,22	1,22	1,06	-0,06	-0,06	-0,06
2006-40	-0,06	4,33	0,10	0,82	0,16	0,81	1,41	0,06	-0,06	-0,06
2006-42	0,00	1,50	0,05	0,38	0,05	0,26	0,59	0,02	0,00	0,01
2006-46	-0,06	2,78	0,11	0,91	0,14	0,71	1,42	-0,06	-0,06	-0,06
2006-48	-0,06	2,95	-0,06	0,40	0,12	0,73	0,67	-0,06	-0,06	-0,06
2006-51	-0,06	1,41	-0,06	0,38	-0,06	0,29	0,59	-0,06	-0,06	-0,06
2007-1	-0,06	2,25	-0,06	0,29	0,09	0,49	0,46	-0,06	-0,06	-0,06
2007-3	-0,06	1,39	-0,06	0,19	-0,06	0,24	0,29	-0,06	-0,06	-0,06
2007-6	-0,06	2,55	-0,06	0,41	0,09	0,43	0,70	-0,06	-0,06	-0,06
2007-9	-0,06	4,70	0,07	0,62	0,22	1,00	1,09	-0,06	-0,06	-0,06
2007-13	-0,06	3,91	0,07	0,61	0,21	0,88	0,94	-0,06	-0,06	-0,06
2007-15	-0,06	4,77	0,09	0,78	0,27	1,12	1,13	-0,06	-0,06	-0,06
2007-18	-0,06	3,46	0,10	0,77	0,25	0,94	1,02	-0,06	-0,06	-0,06
2007-20	-0,06	3,34	0,10	0,78	0,22	0,81	0,92	-0,06	-0,06	-0,06
2007-23	-0,06	5,39	0,13	0,43	0,29	1,16	1,18	-0,06	-0,06	-0,06
2007-29	-0,06	3,94	0,10	0,78	0,22	0,85	0,95	-0,06	-0,06	-0,06
2007-31	-0,06	8,28	0,23	1,56	0,48	1,86	1,88	0,09	-0,06	-0,06
2007-34	-0,06	3,40	0,06	0,52	0,14	0,76	0,91	-0,06	-0,06	-0,06
2007-37	-0,06	2,76	0,06	0,51	0,09	0,47	1,01	-0,06	-0,06	-0,06
2007-39	-0,06	1,44	-0,06	0,35	0,10	0,46	0,50	-0,06	-0,06	-0,06
2007-42	-0,06	3,17	0,06	0,48	0,10	0,52	0,89	-0,06	-0,06	-0,06
2007-44	-0,06	1,44	-0,06	0,33	-0,06	0,26	0,60	-0,06	-0,06	-0,06
2007-47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-49	-0,06	10,87	0,23	1,86	0,55	2,37	2,67	0,12	-0,06	0,06
2008-6	-0,06	1,67	-0,06	0,24	0,07	0,37	0,39	-0,06	-0,06	-0,06
2008-10	-0,06	1,18	-0,06	0,28	0,10	0,41	0,46	-0,06	-0,06	-0,06
2008-23	-0,06	2,72	0,08	0,48	0,18	0,70	0,67	-0,06	-0,06	-0,06
2008-25	-0,06	2,47	0,07	0,44	0,14	0,59	0,63	-0,06	-0,06	-0,06
2008-28	-0,06	2,82	0,08	0,41	0,14	0,65	0,57	-0,06	-0,06	-0,06
2008-30	-0,06	4,17	0,10	0,62	0,22	1,00	0,90	-0,06	-0,06	-0,06
2008-33	-0,06	2,01	-0,06	0,27	0,10	0,52	0,43	-0,06	-0,06	-0,06
2008-35	-0,06	2,18	-0,06	0,31	0,13	0,60	0,48	-0,06	-0,06	-0,06
2008-37	-0,06	2,99	0,06	0,31	0,10	0,48	0,42	-0,06	-0,06	-0,06
2008-39	-0,06	2,25	0,07	0,26	0,09	0,47	0,42	-0,06	-0,06	-0,06
2008-42	-0,06	1,23	-0,06	0,17	0,07	0,30	0,29	-0,06	-0,06	-0,06
2008-44	-0,06	1,10	-0,06	0,17	-0,06	0,25	0,23	-0,06	-0,06	-0,06
2008-46	-0,06	1,14	-0,06	0,13	-0,06	0,21	0,18	-0,06	-0,06	-0,06
2008-48	-0,06	1,56	-0,06	0,28	0,06	0,28	0,41	-0,06	-0,06	-0,06
2008-50	-0,06	1,56	-0,06	0,17	-0,06	0,29	0,26	-0,06	-0,06	-0,06
2008-53	-0,06	2,73	0,06	0,37	0,13	0,65	0,62	-0,06	-0,06	-0,06
2009-3	-0,06	1,23	-0,06	0,15	-0,06	0,27	0,25	-0,06	-0,06	-0,06
2009-5	-0,06	1,06	-0,06	0,27	0,09	0,31	0,37	-0,06	-0,06	-0,06
2009-7	-0,06	1,61	-0,06	0,21	0,07	0,35	0,33	-0,06	-0,06	-0,06
2009-9	-0,06	1,81	-0,06	0,20	0,07	0,40	0,34	-0,06	-0,06	-0,06
2009-11	-0,06	0,91	-0,06	0,15	0,06	0,29	0,27	-0,06	-0,06	-0,06
2009-13	-0,06	1,00	-0,06	0,18	0,07	0,34	0,32	-0,06	-0,06	-0,06
2009-15	-0,06	1,36	-0,06	0,27	0,10	0,50	0,46	-0,06	-0,06	-0,06
2009-19	-0,06	1,00	-0,06	0,20	0,07	0,35	0,33	-0,06	-0,06	-0,06
2009-21	-0,06	1,24	-0,06	0,28	0,09	0,46	0,43	-0,06	-0,06	-0,06
2009-23	-0,06	0,86	-0,06	0,18	0,06	0,33	0,27	-0,06	-0,06	-0,06
2009-26	-0,06	2,41	0,08	0,59	0,20	1,02	0,86	-0,06	-0,06	-0,06
2009-28	0,01	1,94	0,06	0,45	0,15	0,76	0,66	0,03	0,01	0,01
2009-30	0,01	1,61	0,05	0,36	0,13	0,70	0,60	0,02	0,01	0,01
2009-32	0,01	2,50	0,08	0,52	0,19	1,07	0,87	0,03	0,01	0,02

Start sampling period Year-Week	Sum-HexCB	2,2',3,3',4,4',5-HepCB 170	2,2',3,4,4',5,5'-HepCB 180	2,2',3,4,4',5',6-HepCB 183	2,2',3,4',5,5',6-HepCB 187	2,3,3',4,4',5,5'-HepCB 189	Sum-HepCB	2,2',3,3',4,4',5,5'-OctCB 194	2,2',3,3',4,4',5,5',6-NonCB 206	DecaCB 209
2006-27	11,42	0,26	0,73	0,20	0,49	0,01	2,34	0,03	0,01	0,01
2006-29	8,53	0,24	0,64	0,15	0,37	-0,06	1,90	-0,06	-0,06	-0,06
2006-35	3,40	0,07	0,20	0,07	0,15	-0,06	0,54	-0,06	-0,06	-0,06
2006-37	5,04	0,09	0,27	0,09	0,21	-0,06	0,96	-0,06	-0,06	-0,06
2006-40	4,95	0,13	0,47	0,10	0,21	-0,06	1,16	-0,06	-0,06	-0,06
2006-42	1,70	0,05	0,14	0,03	0,10	0,00	0,36	0,01	0,01	0,01
2006-46	4,16	0,13	0,37	0,10	0,20	-0,06	0,90	0,06	-0,06	-0,06
2006-48	2,67	0,06	0,19	0,06	0,16	-0,06	0,59	-0,06	-0,06	-0,06
2006-51	1,68	0,07	0,19	0,06	0,10	-0,06	0,46	-0,06	-0,06	-0,06
2007-1	1,99	-0,06	0,14	0,06	0,12	-0,06	0,44	-0,06	-0,06	-0,06
2007-3	1,34	-0,06	0,11	0,06	0,06	-0,06	0,35	-0,06	-0,06	-0,06
2007-6	2,61	-0,06	0,14	0,06	0,10	-0,06	0,51	-0,06	-0,06	-0,06
2007-9	4,99	0,07	0,21	0,09	0,21	-0,06	0,88	-0,06	-0,06	-0,06
2007-13	4,42	0,06	0,19	0,08	0,16	-0,06	0,75	-0,06	-0,06	-0,06
2007-15	5,65	0,07	0,24	0,10	0,24	-0,06	1,00	-0,06	-0,06	-0,06
2007-18	5,03	0,07	0,25	0,10	0,21	-0,06	0,93	-0,06	-0,06	-0,06
2007-20	4,57	0,08	0,25	0,09	0,20	-0,06	0,98	-0,06	-0,06	-0,06
2007-23	5,90	0,11	0,35	0,11	0,28	-0,06	1,38	-0,06	-0,06	-0,06
2007-29	4,78	0,08	0,27	0,09	0,20	-0,06	0,98	-0,06	-0,06	-0,06
2007-31	10,01	0,19	0,57	0,20	0,45	-0,06	2,24	-0,06	-0,06	-0,06
2007-34	3,89	0,07	0,26	0,08	0,19	-0,06	0,82	-0,06	-0,06	-0,06
2007-37	3,14	-0,06	0,12	-0,06	0,13	-0,06	1,47	-0,06	-0,06	-0,06
2007-39	1,49	-0,06	0,13	0,06	0,11	-0,06	0,33	-0,06	-0,06	-0,06
2007-42	3,20	0,06	0,15	-0,06	0,13	-0,06	0,52	-0,06	-0,06	-0,06
2007-44	1,86	-0,06	0,11	-0,06	0,09	-0,06	0,30	-0,06	-0,06	-0,06
2007-47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-49	12,33	0,34	0,90	0,22	0,51	-0,06	2,88	0,08	0,06	0,23
2008-6	1,80	0,06	0,11	0,06	0,08	-0,06	0,35	-0,06	-0,06	-0,06
2008-10	1,31	-0,06	0,13	0,06	0,09	-0,06	0,32	-0,06	-0,06	-0,06
2008-23	3,19	0,07	0,22	0,08	0,18	-0,06	0,72	-0,06	-0,06	-0,06
2008-25	2,92	0,08	0,20	0,06	0,14	-0,06	0,67	-0,06	-0,06	-0,06
2008-28	2,96	0,08	0,20	0,06	0,14	-0,06	0,68	-0,06	-0,06	-0,06
2008-30	4,55	0,11	0,30	0,09	0,20	-0,06	1,03	-0,06	-0,06	-0,06
2008-33	1,95	-0,06	0,12	0,06	0,11	-0,06	0,44	-0,06	-0,06	-0,06
2008-35	2,25	0,06	0,13	0,06	0,11	-0,06	0,34	-0,06	-0,06	-0,06
2008-37	2,19	-0,06	0,11	0,06	0,08	-0,06	0,35	-0,06	-0,06	-0,06
2008-39	1,50	-0,06	0,09	0,06	0,08	-0,06	0,17	-0,06	-0,07	-0,06
2008-42	1,30	-0,06	0,11	0,06	0,08	-0,06	0,30	-0,06	-0,06	-0,06
2008-44	1,12	0,08	0,14	0,06	0,07	-0,06	0,44	-0,06	-0,06	-0,06
2008-46	0,87	-0,06	-0,06	-0,06	-0,06	-0,06	0,16	-0,06	-0,06	-0,06
2008-48	1,54	0,06	0,16	0,06	0,10	-0,06	0,45	-0,06	-0,06	-0,06
2008-50	1,36	-0,06	0,07	0,06	0,06	-0,06	0,26	-0,06	-0,06	-0,06
2008-53	3,01	0,09	0,26	0,07	0,19	-0,06	0,85	-0,06	-0,06	-0,06
2009-3	1,24	-0,06	0,07	0,06	-0,06	-0,06	0,22	-0,06	-0,06	-0,06
2009-5	1,75	0,11	0,31	0,06	0,14	-0,06	0,83	-0,06	-0,06	-0,06
2009-7	1,63	-0,06	0,14	0,06	0,09	-0,06	0,42	-0,06	-0,06	-0,06
2009-9	1,70	-0,06	0,09	0,06	0,08	-0,06	0,32	-0,06	-0,06	-0,06
2009-11	0,82	-0,06	0,08	0,06	0,07	-0,06	0,19	-0,06	-0,06	-0,06
2009-13	0,95	-0,06	0,10	0,06	0,08	-0,06	0,25	-0,06	-0,06	-0,06
2009-15	1,41	-0,06	0,13	0,06	0,11	-0,06	0,33	-0,06	-0,06	-0,06
2009-19	1,02	-0,06	0,10	0,06	0,09	-0,06	0,26	-0,06	-0,06	-0,06
2009-21	1,34	-0,06	0,15	0,06	0,12	-0,06	0,36	-0,06	-0,06	-0,06
2009-23	0,89	-0,06	0,09	0,06	0,07	-0,06	0,22	-0,06	-0,06	-0,06
2009-26	2,81	0,09	0,25	0,08	0,19	-0,06	0,62	-0,06	-0,06	-0,06
2009-28	2,14	0,06	0,16	0,05	0,14	0,00	0,42	0,01	0,00	0,00
2009-30	1,87	0,05	0,18	0,06	0,16	0,01	0,46	0,03	0,01	0,01
2009-32	2,79	0,05	0,21	0,08	0,21	0,00	0,56	0,02	0,01	0,01

Start sampling period	Sum 7 PCB	Sum PCB	TBA	4,4'-DiBB	2,2',4,4',5,5'-HexBB	2,4,4'-TriBDE	2,2',4,4'-TetBDE	2,3',4,4'-TetBDE	2,2',4,5' + 2,3',4',6-TetBDE	3,3',4,4'-TetBDE
Year-Week				15	153	28	47	66	49 + 71	77
2006-27	16,72	95,51	6,07	-0,06	-0,06	0,17	3,08	0,17	0,28	-0,06
2006-29	14,12	77,88	1,49	-0,06	-0,06	0,08	1,58	0,13	0,15	-0,06
2006-35	7,63	42,17	5,18	-0,06	-0,06	-0,06	0,31	-0,06	-0,06	-0,06
2006-37	9,82	48,73	5,55	-0,06	-0,06	-0,06	0,46	0,07	0,10	-0,06
2006-40	9,16	40,13	7,84	-0,06	-0,06	-0,06	0,65	0,07	0,10	-0,06
2006-42	3,31	12,86	6,17	0,01	0,00	0,02	0,18	0,01	0,03	0,00
2006-46	6,97	25,24	11,83	-0,06	-0,06	-0,06	0,23	-0,06	-0,06	-0,06
2006-48	6,57	29,98	11,97	-0,06	-0,06	-0,06	0,20	-0,06	-0,06	-0,06
2006-51	4,21	18,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-1	4,65	26,03	9,46	-0,06	-0,06	-0,06	0,44	0,07	0,07	-0,06
2007-3	3,34	17,92	8,24	-0,06	-0,06	-0,06	0,51	0,06	0,06	-0,06
2007-6	4,61	31,96	40,32	-0,06	-0,06	-0,06	0,35	-0,06	-0,06	-0,06
2007-9	7,61	51,72	4,35	-0,06	-0,06	0,07	0,54	-0,06	0,07	-0,06
2007-13	5,84	42,14	3,60	-0,06	-0,06	-0,06	0,33	-0,06	-0,06	-0,06
2007-15	7,75	51,74	4,21	-0,06	-0,06	-0,06	0,30	-0,06	-0,06	-0,06
2007-18	6,11	49,91	2,91	-0,06	-0,06	-0,06	0,34	-0,06	-0,06	-0,06
2007-20	6,16	50,78	2,29	-0,06	-0,06	-0,06	0,34	-0,06	-0,06	-0,06
2007-23	9,84	71,82	3,91	-0,06	-0,06	0,07	0,70	0,06	0,09	-0,06
2007-29	7,66	60,78	2,54	-0,06	-0,06	-0,06	0,36	-0,06	-0,06	-0,06
2007-31	14,25	89,22	3,24	-0,06	-0,06	0,10	0,62	-0,06	0,09	-0,06
2007-34	7,35	42,16	5,17	-0,06	-0,06	-0,06	0,41	-0,06	-0,06	-0,06
2007-37	5,55	26,36	7,27	-0,06	-0,06	-0,06	0,35	-0,06	-0,06	-0,06
2007-39	5,34	18,58	7,12	-0,06	-0,06	-0,06	0,45	-0,06	-0,06	-0,06
2007-42	7,91	38,24	11,72	-0,06	-0,06	-0,06	0,28	-0,06	-0,06	-0,06
2007-44	3,69	16,17	8,09	-0,06	-0,06	-0,06	0,23	-0,06	-0,06	-0,06
2007-47	0,00	0,00	9,95	-0,06	-0,06	-0,06	0,49	-0,06	-0,06	-0,06
2007-49	22,59	130,15	9,09	-0,06	-0,06	0,09	1,76	0,16	0,16	-0,06
2008-6	4,17	20,95	3,20	-0,06	-0,06	-0,06	0,39	-0,06	-0,06	-0,06
2008-10	4,33	16,28	3,87	-0,06	-0,06	-0,06	0,22	-0,06	-0,06	-0,06
2008-23	6,22	50,18	28,58	0,00	0,00	0,06	0,36	-0,06	-0,06	-0,06
2008-25	5,02	26,93	6,64	0,00	0,00	-0,06	0,43	-0,06	-0,06	-0,06
2008-28	5,50	28,82	6,81	0,00	0,00	-0,06	0,36	-0,06	-0,06	-0,06
2008-30	7,77	39,02	2,42	0,00	0,00	-0,06	0,49	-0,06	-0,06	-0,06
2008-33	3,93	19,55	2,77	0,00	0,00	-0,06	0,15	-0,06	-0,06	-0,06
2008-35	4,30	20,99	2,04	0,00	0,00	-0,06	0,19	-0,06	-0,06	-0,06
2008-37	5,26	24,63	1,82	0,00	0,00	-0,06	0,17	-0,06	-0,06	-0,06
2008-39	4,41	18,18	2,92	0,00	0,00	-0,06	0,95	-0,06	-0,06	-0,06
2008-42	2,83	14,12	3,73	0,00	0,00	-0,06	0,44	-0,06	-0,06	-0,06
2008-44	3,02	14,26	2,52	0,00	0,00	-0,06	0,37	-0,06	-0,06	-0,06
2008-46	2,47	11,91	9,24	0,00	0,00	-0,06	0,41	-0,06	-0,06	-0,06
2008-48	3,26	15,89	11,12	0,00	0,00	-0,06	0,27	-0,06	-0,06	-0,06
2008-50	4,15	21,65	3,60	0,00	0,00	-0,06	0,17	-0,06	-0,06	-0,06
2008-53	6,42	30,25	6,85	0,00	0,00	0,06	0,65	-0,06	0,10	-0,06
2009-3	2,96	14,13	3,49	0,00	0,00	-0,06	0,16	-0,06	-0,06	-0,06
2009-5	2,66	10,94	3,56	0,00	0,00	-0,06	0,20	-0,06	-0,06	-0,06
2009-7	4,25	20,14	3,20	0,00	0,00	-0,06	0,31	-0,06	-0,06	-0,06
2009-9	4,24	20,26	1,98	0,00	0,00	-0,06	0,14	-0,06	-0,06	-0,06
2009-11	3,46	12,81	1,53	0,00	0,00	-0,06	0,17	-0,06	-0,06	-0,06
2009-13	3,79	13,46	1,49	0,00	0,00	-0,06	0,18	-0,06	-0,06	-0,06
2009-15	4,66	16,38	1,03	0,00	0,00	-0,06	0,64	-0,06	0,06	-0,06
2009-19	3,62	14,14	0,61	0,00	0,00	-0,06	0,28	-0,06	-0,06	-0,06
2009-21	4,20	17,52	0,96	0,00	0,00	-0,06	0,36	-0,06	-0,06	-0,06
2009-23	3,06	13,58	1,13	0,00	0,00	-0,06	0,23	-0,06	-0,06	-0,06
2009-26	7,18	29,14	0,72	0,00	0,00	-0,06	0,45	-0,06	-0,06	-0,06
2009-28	6,07	22,74	0,98	0,00	0,00	-0,06	0,30	-0,06	-0,06	-0,06
2009-30	5,09	18,73	1,11	0,00	0,00	-0,06	0,21	-0,06	-0,06	-0,06
2009-32	8,19	31,26	1,35	0,00	0,00	-0,06	0,43	-0,06	-0,06	-0,06

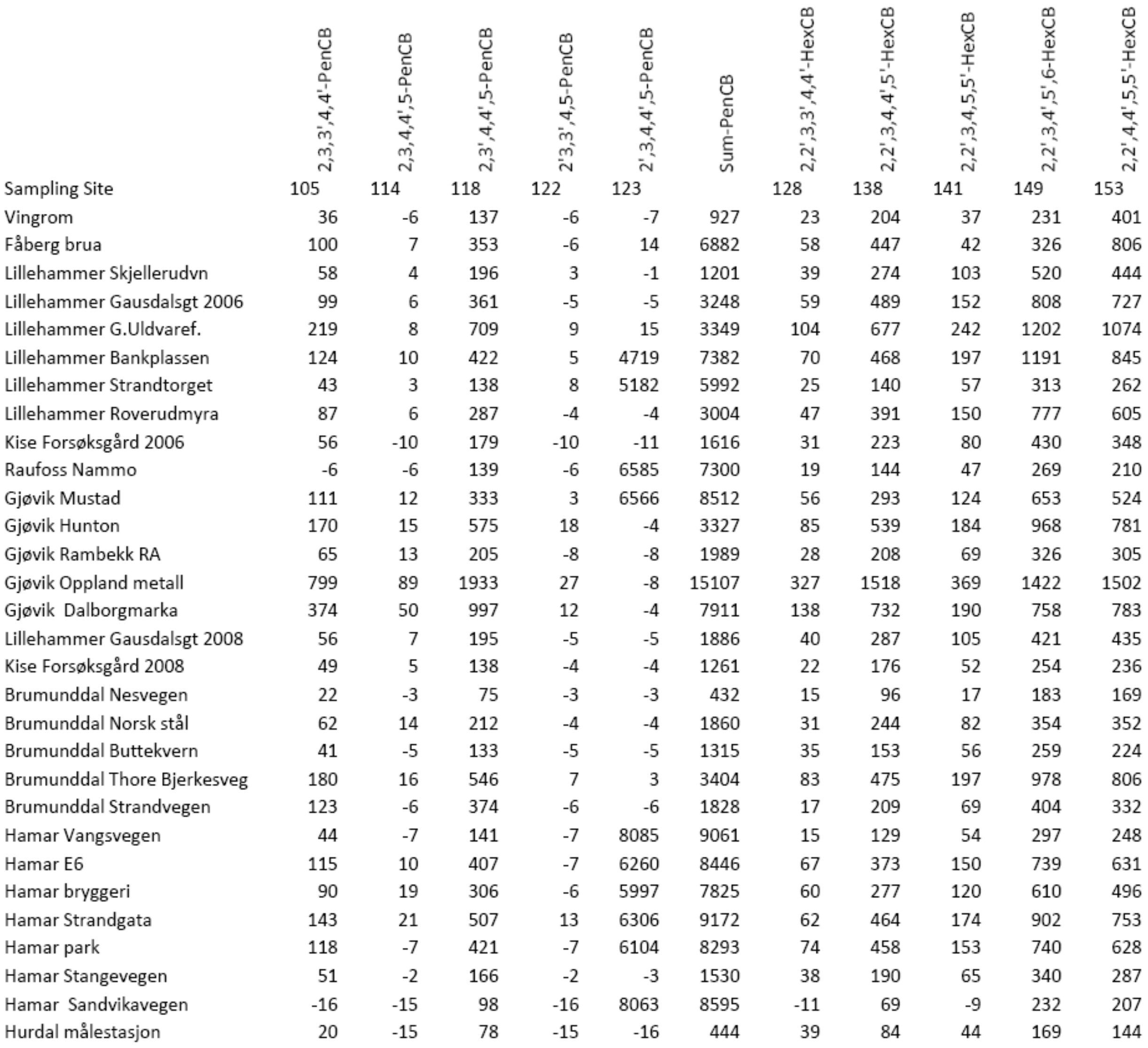
Start sampling period Year-Week	2,2',3,4,4'-PenBDE 85	2,2',4,4',5-PenBDE 99	2,2',4,4',6-PenBDE 100	2,3',4,4',6-PenBDE 119	2,2',3,4,4',5'-HexBDE 138	2,2',4,4',5,5'-HexBDE 153	2,2',4,4',5,6'-HexBDE 154	2,2',3,4,4',5',6-HepBDE 183	2,2',3,3',4,4',5,6'-OctBDE 196	2,2',3,3',4,4',5,5',6-NonBDE 206
2006-27	-0,06	0,80	0,23	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2006-29	-0,06	0,63	0,16	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,16
2006-35	-0,06	0,27	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,10
2006-37	-0,06	0,25	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,06	0,21
2006-40	-0,06	0,48	0,08	-0,06	-0,06	0,06	0,06	-0,06	-0,12	1,14
2006-42	0,01	0,24	0,04	0,02	0,01	0,09	0,05	0,06	0,06	0,09
2006-46	-0,06	0,22	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,11
2006-48	-0,06	0,18	-0,06	-0,06	-0,06	-0,06	-0,06	0,07	0,12	0,17
2006-51	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2007-1	-0,06	0,91	0,12	-0,06	-0,06	0,12	0,08	-0,06	-0,06	0,06
2007-3	-0,06	1,04	0,15	-0,06	-0,06	0,12	0,09	-0,06	-0,06	0,07
2007-6	-0,06	0,41	0,06	-0,06	-0,06	0,09	-0,06	0,08	0,54	-0,47
2007-9	-0,06	0,98	0,14	-0,06	-0,06	0,18	0,11	0,16	0,07	0,09
2007-13	-0,06	0,31	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,11
2007-15	-0,06	0,21	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,08
2007-18	-0,06	0,28	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,07
2007-20	-0,06	0,27	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,70
2007-23	-0,06	0,57	0,11	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2007-29	-0,06	0,29	-0,06	-0,06	-0,06	-0,06	-0,06	0,26	-0,06	0,06
2007-31	-0,06	0,61	0,12	-0,06	-0,06	0,14	0,08	0,27	0,22	0,14
2007-34	-0,06	0,28	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2007-37	-0,06	0,22	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2007-39	-0,06	0,43	0,11	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2007-42	-0,06	0,21	-0,06	-0,06	-0,06	0,06	-0,06	-0,06	0,10	0,15
2007-44	-0,06	0,26	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,07
2007-47	-0,06	0,81	0,14	-0,06	-0,06	0,09	-0,06	0,06	-0,06	0,09
2007-49	-0,06	1,28	0,28	-0,06	-0,06	0,08	0,09	0,06	0,06	0,07
2008-6	-0,06	0,38	0,07	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,08
2008-10	-0,06	0,15	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,06	0,20
2008-23	-0,06	0,35	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-25	-0,06	0,16	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-28	-0,06	0,15	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-30	-0,06	0,15	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-33	-0,06	0,08	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-35	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-37	-0,06	0,16	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-39	-0,06	-0,06	-0,06	-0,06	-0,07	-0,06	-0,06	-0,06	-0,20	-0,16
2008-42	-0,06	0,16	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-44	-0,06	0,54	0,07	-0,06	-0,06	0,10	0,08	0,08	0,08	0,13
2008-46	-0,06	0,26	-0,06	0,08	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-48	-0,06	0,24	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2008-50	-0,06	0,13	-0,06	-0,06	-0,06	0,25	-0,06	-0,06	-0,29	-0,26
2008-53	-0,06	0,58	0,11	-0,06	-0,06	-0,06	0,09	0,16	0,21	0,36
2009-3	-0,06	0,14	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,12	-0,12
2009-5	-0,06	0,20	-0,06	-0,06	-0,06	-0,06	-0,06	0,08	-0,34	-0,32
2009-7	-0,06	0,33	0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-9	-0,06	0,07	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,06	0,07
2009-11	-0,06	0,09	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	0,07
2009-13	-0,06	0,10	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-15	-0,06	0,73	0,14	-0,06	-0,06	0,08	0,06	0,07	-0,06	0,11
2009-19	-0,06	0,12	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-21	-0,06	0,20	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-23	-0,06	0,15	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-26	-0,06	0,41	0,11	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-28	-0,06	0,18	0,04	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-30	-0,06	0,19	0,04	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06
2009-32	-0,06	0,28	0,07	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06	-0,06

Start sampling period	DecaBDE	a-HBCD	b-HBCD	g-HBCD
Year-Week	209			
2006-27	0,48	-1,00	-0,70	-0,81
2006-29	4,29	-0,47	-0,34	-0,40
2006-35	0,82	-0,42	-0,24	0,24
2006-37	5,17	0,21	-0,16	0,41
2006-40	36,05	-8,22	-5,60	5,20
2006-42	0,62	0,09	-0,06	0,12
2006-46	0,93	0,47	0,05	2,04
2006-48	1,14	0,23	-0,08	0,20
2006-51	0,00	0,31	-0,04	0,32
2007-1	0,42	0,14	-0,08	0,11
2007-3	0,51	-0,20	-0,09	0,10
2007-6	0,60	0,23	-0,09	0,48
2007-9	0,53	0,20	-0,11	0,27
2007-13	0,61	0,08	-0,10	0,10
2007-15	0,56	-0,35	-0,15	-0,22
2007-18	0,49	0,17	-0,12	0,10
2007-20	15,60	0,20	-0,09	0,14
2007-23	0,37	-0,34	-0,09	0,28
2007-29	0,42	-0,21	-0,06	0,09
2007-31	0,72	0,21	-0,03	0,24
2007-34	0,43	0,21	-0,06	0,27
2007-37	0,33	0,28	-0,11	0,21
2007-39	0,35	-0,09	-0,03	-0,08
2007-42	1,02	0,67	-0,09	0,87
2007-44	0,65	0,24	-0,06	0,29
2007-47	0,73	0,23	-0,92	-1,05
2007-49	0,52	0,55	0,06	-0,45
2008-6	0,42	1,04	-0,07	1,94
2008-10	1,23	1,02	-0,51	3,93
2008-23	0,46	-0,24	-0,19	-0,12
2008-25	0,22	-0,13	-0,13	-0,09
2008-28	0,11	-0,15	-0,19	-0,09
2008-30	0,83	-0,11	-0,15	-0,08
2008-33	0,23	0,42	-0,13	-0,07
2008-35	0,26	-0,10	-0,13	-0,08
2008-37	0,26	0,10	-0,19	-0,09
2008-39	-0,28	-0,22	0,06	-0,06
2008-42	0,19	-0,20	-0,17	-0,11
2008-44	0,49	-1,48	-9,77	-0,91
2008-46	0,14	-2,53	-1,55	-1,35
2008-48	0,42	-0,58	-0,29	-0,31
2008-50	-0,70	0,28	-0,44	-0,24
2008-53	0,98	-0,67	-0,96	-0,56
2009-3	-0,35	0,28	-0,44	-0,24
2009-5	-1,12	0,20	-0,45	0,13
2009-7	0,27	-0,41	-0,51	-0,37
2009-9	0,19	0,23	-0,48	0,18
2009-11	0,35	-0,38	-0,44	-0,44
2009-13	0,53	-0,51	-0,71	-0,62
2009-15	0,42	0,24	-0,71	-0,66
2009-19	0,18	0,10	-0,35	-0,29
2009-21	0,23	0,27	-0,73	-0,53
2009-23	0,21	-0,26	-0,35	-0,31
2009-26	0,18	-0,46	-0,44	-0,28
2009-28	1,98	0,30	-0,42	0,52
2009-30	0,32	-0,10	-0,10	-0,07
2009-32	0,54	0,04	-0,20	-0,20

Table 12: Passive PCB, PBDE, and HBCDD measurements (pg/sample)

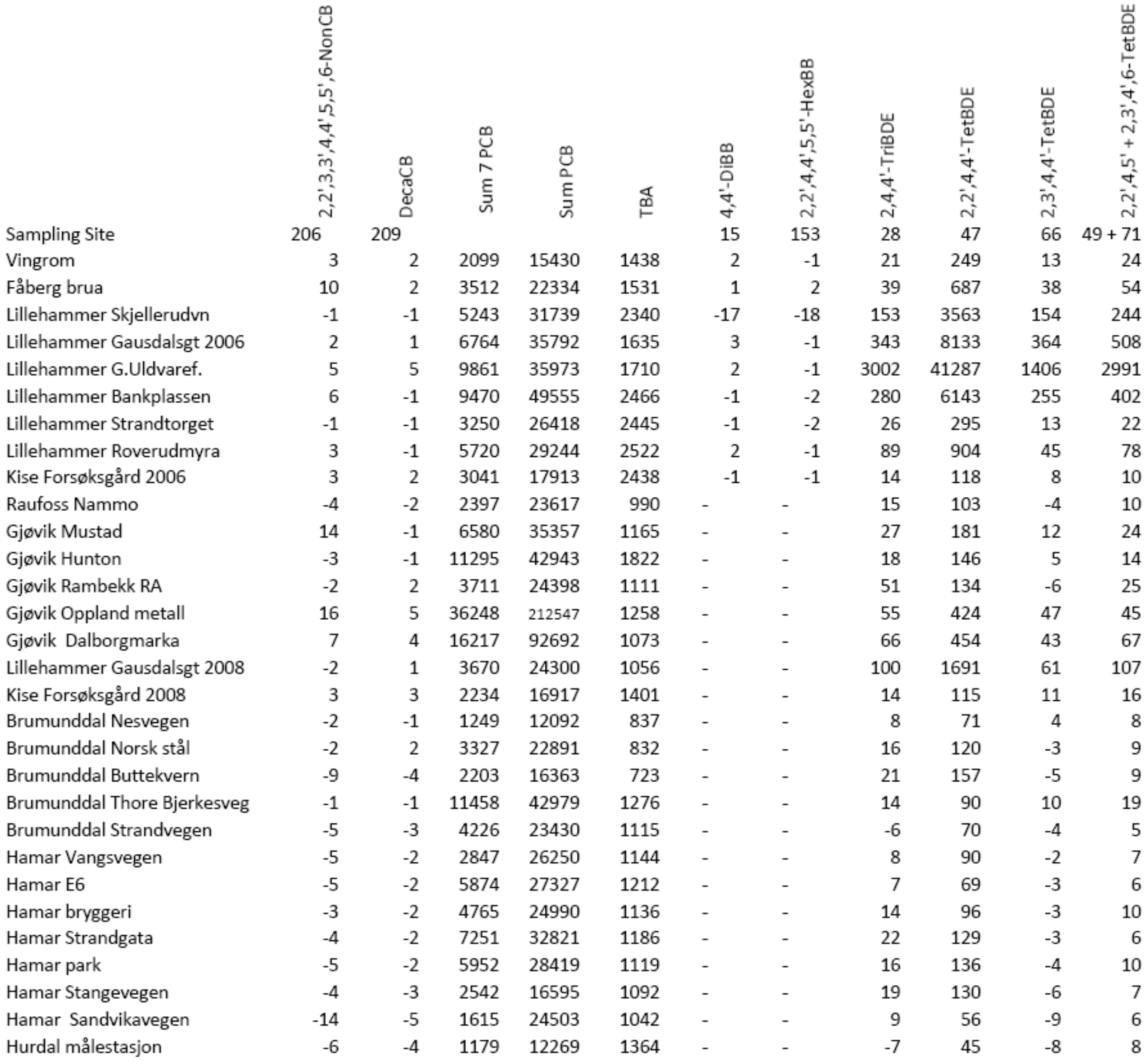
	Coordinates								
Sampling Site	32 EU89 UTM		84 EU89 Geographic		Year	PeCB	HCB	2,2',5-TriCB 18	2,4,4'-TriCB 28
Vingrom	61,0458	10,4367	6768742	577591	2006	1351	7470	714	495
Fåberg brua	61,1662	10,3970	6782104	575161	2006	1040	7343	720	505
Lillehammer Skjellerudvn	61,1211	10,4541	6777152	578344	2006	1535	9025	3449	2253
Lillehammer Gausdalsgt 2006	61,1222	10,4561	6777267	578449	2006	1265	9314	3039	2221
Lillehammer G.Uldvaref.	61,1155	10,4576	6776532	578543	2006	1297	9243	4096	3056
Lillehammer Bankplassen	61,1130	10,4647	6776256	578936	2006	1598	10294	4593	3463
Lillehammer Strandtorget	61,1123	10,4509	6776167	578189	2006	1433	9675	1758	1371
Lillehammer Roverudmyra	61,0786	10,5129	6772493	581624	2006	1358	9851	2283	1564
Kise Forsøksgård 2006	60,7734	10,8055	6738895	598338	2006	1282	9458	1071	807
Raufoss Nammo	60,7301	10,6046	6733795	587516	2008	1359	8917	1177	690
Gjøvik Mustad	60,7852	10,6812	6740031	591535	2008	1315	8368	3434	2261
Gjøvik Hunton	60,7924	10,6868	6740839	591818	2008	1838	10971	5709	3929
Gjøvik Rambekk RA	60,7770	10,7052	6739153	592866	2008	1638	11125	1895	1186
Gjøvik Oppland metall	60,7760	10,6463	6738962	589660	2008	2078	9165	30723	17929
Gjøvik Dalborgmarka	60,7675	10,6412	6738011	589409	2008	1673	8866	11280	6649
Lillehammer Gausdalsgt 2008	61,1222	10,4561	6777267	578449	2008	1545	9741	1482	1068
Kise Forsøksgård 2008	60,7734	10,8055	6738895	598338	2008	1592	11779	909	578
Brumunddal Nesvegen	60,8779	10,8946	6750677	602854	2008	1154	7103	345	261
Brumunddal Norsk stål	60,8903	10,9212	6752096	604258	2008	1246	7961	1152	1069
Brumunddal Buttekvern	60,8828	10,9503	6751302	605861	2008	1093	7844	732	591
Brumunddal Thore Bjerkesveg	60,8793	10,9513	6752144	605892	2008	1667	9650	5518	4004
Brumunddal Strandvegen	60,8764	10,9362	6750569	605116	2008	1715	9934	1314	929
Hamar Vangsvegen	60,7992	11,1128	6742275	614982	2008	2267	11764	929	640
Hamar E6	60,7980	11,1196	6742147	615353	2008	1197	12430	1612	1438
Hamar bryggeri	60,7943	11,0583	6741637	612030	2008	1415	9544	1313	1055
Hamar Strandgata	60,7932	11,0723	6741529	612796	2008	1393	10214	2380	1658
Hamar park	60,7949	11,0841	6741749	613433	2008	1389	14400	2025	1437
Hamar Stangevegen	60,7885	11,0957	6741046	614085	2008	1267	8959	788	669
Hamar Sandvikavegen	60,7769	11,0920	6739748	613929	2008	1218	7962	631	418
Hurdal målestasjon	60,3724	11,0781	6694691	614596	2008	1419	8649	192	249

Sampling Site	2,4',5-TriCB 31	2',3,4-TriCB 33	3,4,4'-TriCB 37	Sum-TriCB	2,2',4,4'-TetCB 47	2,2',5,5'-TetCB 52	2,3',4,4'-TetCB 66	2,4,4',5-TetCB 74	Sum-TetCB	2,2',4,4',5-PenCB 99	2,2',4,5,5'-PenCB 101
Vingrom	444	295	56	11186	161	428	123	77	1853	108	314
Fåberg brua	460	302	58	10498	192	571	160	105	2304	232	550
Lillehammer Skjellerudvn	2144	1573	378	22990	469	1221	434	254	5692	162	742
Lillehammer Gausdalsgt 2006	2078	1496	304	21432	575	1624	543	321	7286	275	1177
Lillehammer G.Uldvaref.	2743	2047	541	19069	630	2235	692	418	9226	463	1888
Lillehammer Bankplassen	3275	2445	559	28267	783	2410	730	446	10152	360	1692
Lillehammer Strandtorget	1162	701	223	15639	309	797	310	183	3681	133	467
Lillehammer Roverudmyra	1484	933	195	16170	381	1609	405	253	6300	286	1097
Kise Forsøksgård 2006	734	474	97	10920	235	796	230	141	3331	172	610
Raufoss Nammo	683	475	102	14231	231	712	206	126	1273	124	453
Gjøvik Mustad	2252	1618	384	21375	592	1857	610	370	3434	296	1191
Gjøvik Hunton	3981	2797	688	30731	977	3307	984	609	5886	533	2017
Gjøvik Rambekk RA	1197	821	194	15484	406	1102	372	229	4859	207	646
Gjøvik Oppland metall	18212	13532	3190	137894	3544	9112	3953	2246	49432	1397	3901
Gjøvik Dalborgmarka	6696	4911	1164	57182	1592	4677	1750	1000	22275	769	2190
Lillehammer Gausdalsgt 2008	1030	738	158	16126	352	886	261	160	3449	149	696
Kise Forsøksgård 2008	555	370	84	11344	243	608	197	124	2510	130	442
Brumunddal Nesvegen	258	155	41	10460	114	345	104	62	625	70	265
Brumunddal Norsk stål	971	686	199	15222	299	784	312	179	3482	170	611
Brumunddal Buttekvern	567	405	101	11186	187	583	171	103	2236	113	473
Brumunddal Thore Bjerkesveg	3945	2675	758	30536	967	3385	999	671	6031	559	2093
Brumunddal Strandvegen	912	613	140	18285	312	1328	326	216	2181	324	1008
Hamar Vangsvegen	626	401	100	14732	250	1022	216	132	1620	170	621
Hamar E6	1376	1002	257	13744	538	1571	451	270	2830	327	1327
Hamar bryggeri	986	705	167	12953	371	1397	335	216	2318	276	1136
Hamar Strandgata	1634	1130	235	17627	521	1950	457	288	3217	423	1760
Hamar park	1417	1009	247	14919	540	1561	440	273	2815	327	1323
Hamar Stangevegen	622	431	96	10272	226	663	188	110	2696	138	507
Hamar Sandvikavegen	412	262	-20	14500	178	492	132	85	889	92	341
Hurdal målestasjon	241	150	52	10559	132	343	112	66	654	83	248

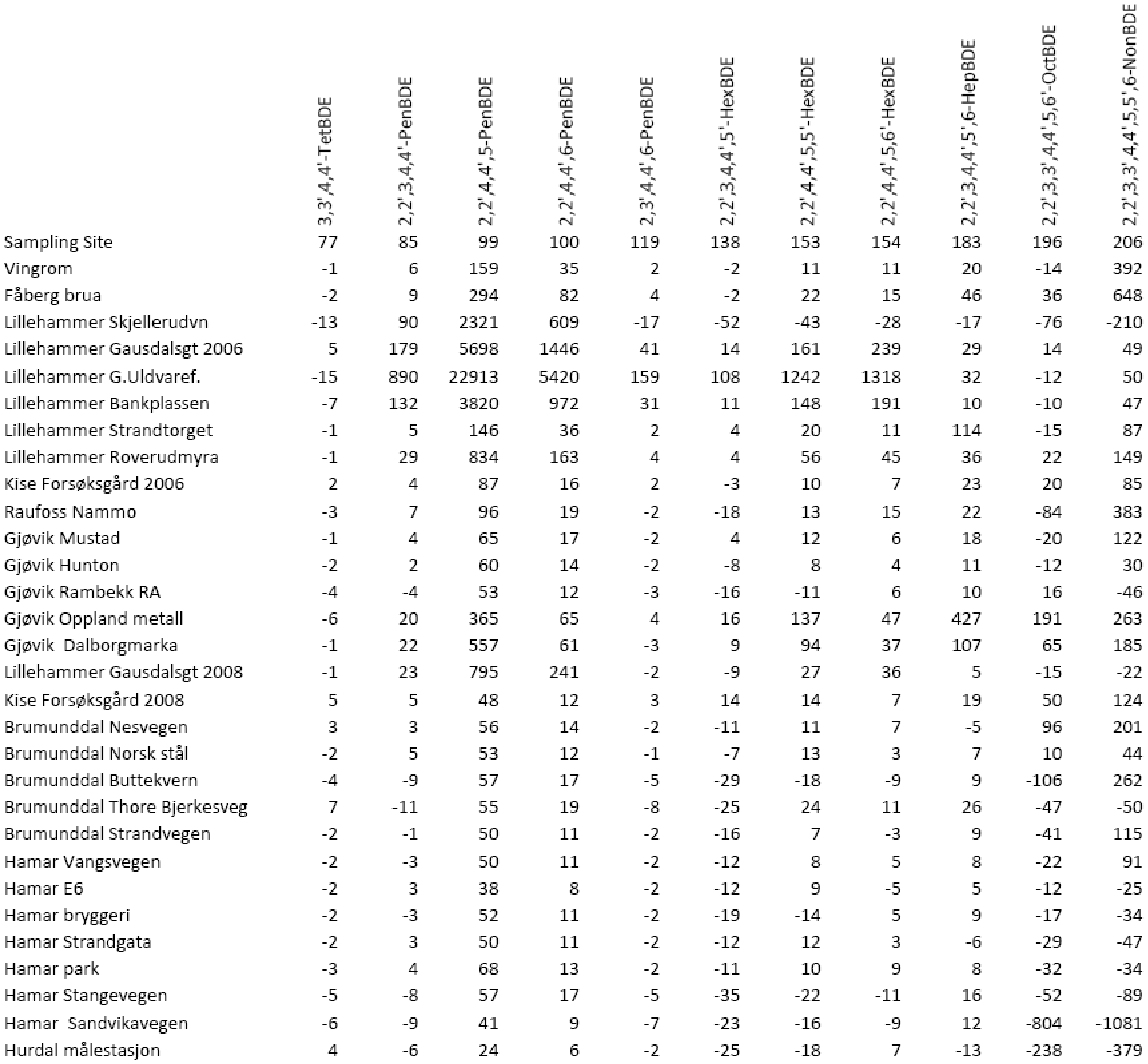


Sampling Site	2,3,3',4,4'-PenCB 105	2,3,4,4',5-PenCB 114	2,3',4,4',5-PenCB 118	2'3,3',4,5-PenCB 122	2',3,4,4',5-PenCB 123	Sum-PenCB	2,2',3,3',4,4'-HexCB 128	2,2',3,4,4',5'-HexCB 138	2,2',3,4,5,5'-HexCB 141	2,2',3,4',5',6-HexCB 149	2,2',4,4',5,5'-HexCB 153
Vingrom	36	-6	137	-6	-7	927	23	204	37	231	401
Fåberg brua	100	7	353	-6	14	6882	58	447	42	326	806
Lillehammer Skjellerudvn	58	4	196	3	-1	1201	39	274	103	520	444
Lillehammer Gausdalsgt 2006	99	6	361	-5	-5	3248	59	489	152	808	727
Lillehammer G.Uldvaref.	219	8	709	9	15	3349	104	677	242	1202	1074
Lillehammer Bankplassen	124	10	422	5	4719	7382	70	468	197	1191	845
Lillehammer Strandtorget	43	3	138	8	5182	5992	25	140	57	313	262
Lillehammer Roverudmyra	87	6	287	-4	-4	3004	47	391	150	777	605
Kise Forsøksgård 2006	56	-10	179	-10	-11	1616	31	223	80	430	348
Raufoss Nammo	-6	-6	139	-6	6585	7300	19	144	47	269	210
Gjøvik Mustad	111	12	333	3	6566	8512	56	293	124	653	524
Gjøvik Hunton	170	15	575	18	-4	3327	85	539	184	968	781
Gjøvik Rambekk RA	65	13	205	-8	-8	1989	28	208	69	326	305
Gjøvik Oppland metall	799	89	1933	27	-8	15107	327	1518	369	1422	1502
Gjøvik Dalborgmarka	374	50	997	12	-4	7911	138	732	190	758	783
Lillehammer Gausdalsgt 2008	56	7	195	-5	-5	1886	40	287	105	421	435
Kise Forsøksgård 2008	49	5	138	-4	-4	1261	22	176	52	254	236
Brumunddal Nesvegen	22	-3	75	-3	-3	432	15	96	17	183	169
Brumunddal Norsk stål	62	14	212	-4	-4	1860	31	244	82	354	352
Brumunddal Buttekvern	41	-5	133	-5	-5	1315	35	153	56	259	224
Brumunddal Thore Bjerkesveg	180	16	546	7	3	3404	83	475	197	978	806
Brumunddal Strandvegen	123	-6	374	-6	-6	1828	17	209	69	404	332
Hamar Vangsvegen	44	-7	141	-7	8085	9061	15	129	54	297	248
Hamar E6	115	10	407	-7	6260	8446	67	373	150	739	631
Hamar bryggeri	90	19	306	-6	5997	7825	60	277	120	610	496
Hamar Strandgata	143	21	507	13	6306	9172	62	464	174	902	753
Hamar park	118	-7	421	-7	6104	8293	74	458	153	740	628
Hamar Stangevegen	51	-2	166	-2	-3	1530	38	190	65	340	287
Hamar Sandvikavegen	-16	-15	98	-16	8063	8595	-11	69	-9	232	207
Hurdal målestasjon	20	-15	78	-15	-16	444	39	84	44	169	144

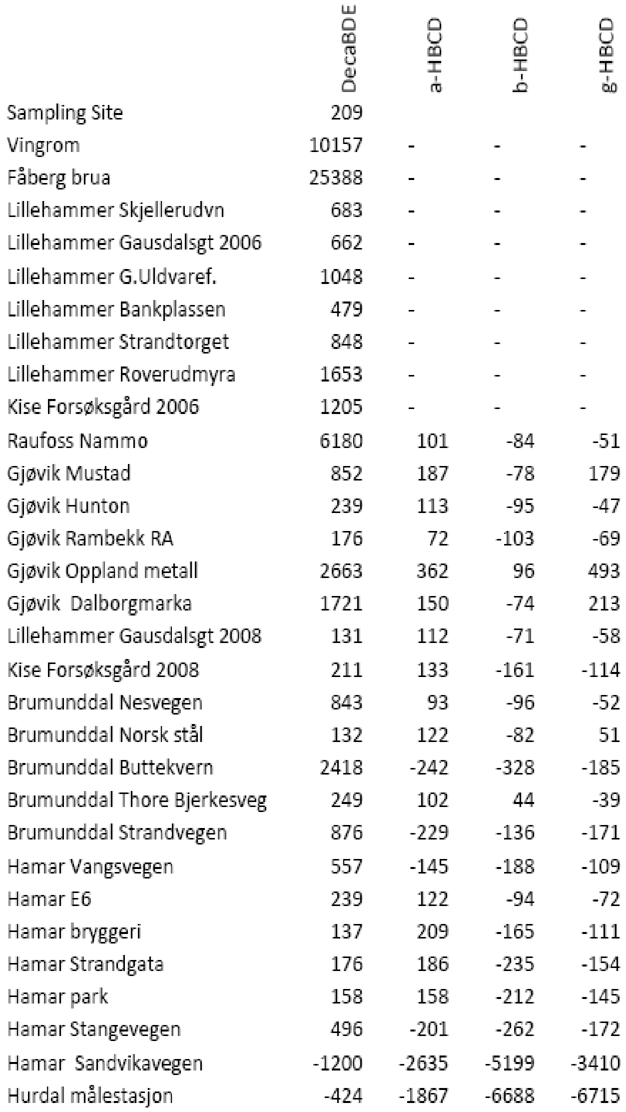
Sampling Site	2,3,3',4,4',5-HexCB 156	2,3,3',4,4',5'-HexCB 157	2,3',4,4',5,5'-HexCB 167	Sum-HexCB	2,2',3,3',4,4',5-HepCB 170	2,2',3,4,4',5,5'-HepCB 180	2,2',3,4,4',5',6-HepCB 183	2,2',3,4',5,5',6-HepCB 187	2,3,3',4,4',5,5'-HepCB 189	Sum-HepCB	2,2',3,3',4,4',5,5'-OctCB 194
Vingrom	11	-2	6	1238	24	120	28	42	-6	215	7
Fåberg brua	37	4	21	2079	72	280	53	87	3	536	24
Lillehammer Skjellerudvn	16	-1	5	1568	45	114	44	87	-1	290	-2
Lillehammer Gausdalsgt 2006	26	3	9	3234	57	166	63	135	-3	585	4
Lillehammer G.Uldvaref.	42	7	26	3744	83	221	93	172	-1	569	6
Lillehammer Bankplassen	24	2	15	3257	52	170	75	178	-1	475	16
Lillehammer Strandtorget	10	-1	-1	909	27	75	29	60	-1	192	7
Lillehammer Roverudmyra	21	-2	13	2947	53	166	50	132	-3	813	7
Kise Forsøksgård 2006	4	-2	4	1585	26	79	30	77	-2	453	4
Raufoss Nammo	-3	-3	3	693	9	51	12	59	-5	131	-5
Gjøvik Mustad	22	3	12	1686	34	121	52	123	-2	330	7
Gjøvik Hunton	30	-2	14	2601	42	148	61	154	-2	405	-3
Gjøvik Rambekk RA	13	6	5	1398	22	60	24	77	-4	670	-3
Gjøvik Oppland metall	139	31	56	8410	141	353	95	240	6	1647	36
Gjøvik Dalborgmarka	62	15	26	4299	70	188	50	136	-3	999	16
Lillehammer Gausdalsgt 2008	17	-3	10	2058	37	104	40	99	-5	784	-2
Kise Forsøksgård 2008	10	6	6	1173	17	56	20	66	-2	627	-2
Brumunddal Nesvegen	8	3	-1	492	12	38	4	33	-2	87	-2
Brumunddal Norsk stål	11	4	7	1676	16	56	26	73	-2	653	-2
Brumunddal Buttekvern	10	6	7	1173	17	46	24	47	-4	472	-6
Brumunddal Thore Bjerkesveg	28	7	14	2588	45	149	64	159	-1	418	5
Brumunddal Strandvegen	-3	-3	-3	1031	-5	47	21	49	-4	118	-4
Hamar Vangsvegen	-3	-2	-2	743	-4	47	21	37	-3	105	-4
Hamar E6	30	7	8	2005	33	126	50	104	-3	313	-4
Hamar bryggeri	23	10	11	1608	36	97	43	92	9	276	14
Hamar Strandgata	31	8	16	2409	62	160	61	122	-3	405	-4
Hamar park	23	-2	10	2086	40	124	47	108	-4	319	-6
Hamar Stangevegen	13	6	7	1527	23	61	25	65	-2	573	4
Hamar Sandvikavegen	-9	-7	-8	507	-11	-11	-9	42	-8	42	-11
Hurdal målestasjon	33	16	-7	529	-10	32	21	48	-7	101	-8



	2,2',3,3',4,4',5,5',6-NonCB	DecaCB	Sum 7 PCB	Sum PCB	TBA	4,4'-DiBB	2,2',4,4',5,5'-HexBB	2,4,4'-TriBDE	2,2',4,4'-TetBDE	2,3',4,4'-TetBDE	2,2',4,5' + 2,3',4',6-TetBDE
Sampling Site	206	209				15	153	28	47	66	49 + 71
Vingrom	3	2	2099	15430	1438	2	-1	21	249	13	24
Fåberg brua	10	2	3512	22334	1531	1	2	39	687	38	54
Lillehammer Skjellerudvn	-1	-1	5243	31739	2340	-17	-18	153	3563	154	244
Lillehammer Gausdalsgt 2006	2	1	6764	35792	1635	3	-1	343	8133	364	508
Lillehammer G.Uldvaref.	5	5	9861	35973	1710	2	-1	3002	41287	1406	2991
Lillehammer Bankplassen	6	-1	9470	49555	2466	-1	-2	280	6143	255	402
Lillehammer Strandtorget	-1	-1	3250	26418	2445	-1	-2	26	295	13	22
Lillehammer Roverudmyra	3	-1	5720	29244	2522	2	-1	89	904	45	78
Kise Forsøksgård 2006	3	2	3041	17913	2438	-1	-1	14	118	8	10
Raufoss Nammo	-4	-2	2397	23617	990	-	-	15	103	-4	10
Gjøvik Mustad	14	-1	6580	35357	1165	-	-	27	181	12	24
Gjøvik Hunton	-3	-1	11295	42943	1822	-	-	18	146	5	14
Gjøvik Rambekk RA	-2	2	3711	24398	1111	-	-	51	134	-6	25
Gjøvik Oppland metall	16	5	36248	212547	1258	-	-	55	424	47	45
Gjøvik Dalborgmarka	7	4	16217	92692	1073	-	-	66	454	43	67
Lillehammer Gausdalsgt 2008	-2	1	3670	24300	1056	-	-	100	1691	61	107
Kise Forsøksgård 2008	3	3	2234	16917	1401	-	-	14	115	11	16
Brumunddal Nesvegen	-2	-1	1249	12092	837	-	-	8	71	4	8
Brumunddal Norsk stål	-2	2	3327	22891	832	-	-	16	120	-3	9
Brumunddal Buttekvern	-9	-4	2203	16363	723	-	-	21	157	-5	9
Brumunddal Thore Bjerkesveg	-1	-1	11458	42979	1276	-	-	14	90	10	19
Brumunddal Strandvegen	-5	-3	4226	23430	1115	-	-	-6	70	-4	5
Hamar Vangsvegen	-5	-2	2847	26250	1144	-	-	8	90	-2	7
Hamar E6	-5	-2	5874	27327	1212	-	-	7	69	-3	6
Hamar bryggeri	-3	-2	4765	24990	1136	-	-	14	96	-3	10
Hamar Strandgata	-4	-2	7251	32821	1186	-	-	22	129	-3	6
Hamar park	-5	-2	5952	28419	1119	-	-	16	136	-4	10
Hamar Stangevegen	-4	-3	2542	16595	1092	-	-	19	130	-6	7
Hamar Sandvikavegen	-14	-5	1615	24503	1042	-	-	9	56	-9	6
Hurdal målestasjon	-6	-4	1179	12269	1364	-	-	-7	45	-8	8



	3,3',4,4'-TetBDE	2,2',3,4,4'-PenBDE	2,2',4,4',5-PenBDE	2,2',4,4',6-PenBDE	2,3',4,4',6-PenBDE	2,2',3,4,4',5'-HexBDE	2,2',4,4',5,5'-HexBDE	2,2',4,4',5,6'-HexBDE	2,2',3,4,4',5',6-HepBDE	2,2',3,3',4,4',5,6'-OctBDE	2,2',3,3',4,4',5,5',6-NonBDE
Sampling Site	77	85	99	100	119	138	153	154	183	196	206
Vingrom	-1	6	159	35	2	-2	11	11	20	-14	392
Fåberg brua	-2	9	294	82	4	-2	22	15	46	36	648
Lillehammer Skjellerudvn	-13	90	2321	609	-17	-52	-43	-28	-17	-76	-210
Lillehammer Gausdalsgt 2006	5	179	5698	1446	41	14	161	239	29	14	49
Lillehammer G.Uldvaref.	-15	890	22913	5420	159	108	1242	1318	32	-12	50
Lillehammer Bankplassen	-7	132	3820	972	31	11	148	191	10	-10	47
Lillehammer Strandtorget	-1	5	146	36	2	4	20	11	114	-15	87
Lillehammer Roverudmyra	-1	29	834	163	4	4	56	45	36	22	149
Kise Forsøksgård 2006	2	4	87	16	2	-3	10	7	23	20	85
Raufoss Nammo	-3	7	96	19	-2	-18	13	15	22	-84	383
Gjøvik Mustad	-1	4	65	17	-2	4	12	6	18	-20	122
Gjøvik Hunton	-2	2	60	14	-2	-8	8	4	11	-12	30
Gjøvik Rambekk RA	-4	-4	53	12	-3	-16	-11	6	10	16	-46
Gjøvik Oppland metall	-6	20	365	65	4	16	137	47	427	191	263
Gjøvik Dalborgmarka	-1	22	557	61	-3	9	94	37	107	65	185
Lillehammer Gausdalsgt 2008	-1	23	795	241	-2	-9	27	36	5	-15	-22
Kise Forsøksgård 2008	5	5	48	12	3	14	14	7	19	50	124
Brumunddal Nesvegen	3	3	56	14	-2	-11	11	7	-5	96	201
Brumunddal Norsk stål	-2	5	53	12	-1	-7	13	3	7	10	44
Brumunddal Buttekvern	-4	-9	57	17	-5	-29	-18	-9	9	-106	262
Brumunddal Thore Bjerkesveg	7	-11	55	19	-8	-25	24	11	26	-47	-50
Brumunddal Strandvegen	-2	-1	50	11	-2	-16	7	-3	9	-41	115
Hamar Vangsvegen	-2	-3	50	11	-2	-12	8	5	8	-22	91
Hamar E6	-2	3	38	8	-2	-12	9	-5	5	-12	-25
Hamar bryggeri	-2	-3	52	11	-2	-19	-14	5	9	-17	-34
Hamar Strandgata	-2	3	50	11	-2	-12	12	3	-6	-29	-47
Hamar park	-3	4	68	13	-2	-11	10	9	8	-32	-34
Hamar Stangevegen	-5	-8	57	17	-5	-35	-22	-11	16	-52	-89
Hamar Sandvikavegen	-6	-9	41	9	-7	-23	-16	-9	12	-804	-1081
Hurdal målestasjon	4	-6	24	6	-2	-25	-18	7	-13	-238	-379



Sampling Site	DecaBDE 209	a-HBCD	b-HBCD	g-HBCD
Vingrom	10157	-	-	-
Fåberg brua	25388	-	-	-
Lillehammer Skjellerudvn	683	-	-	-
Lillehammer Gausdalsgt 2006	662	-	-	-
Lillehammer G.Uldvaref.	1048	-	-	-
Lillehammer Bankplassen	479	-	-	-
Lillehammer Strandtorget	848	-	-	-
Lillehammer Roverudmyra	1653	-	-	-
Kise Forsøksgård 2006	1205	-	-	-
Raufoss Nammo	6180	101	-84	-51
Gjøvik Mustad	852	187	-78	179
Gjøvik Hunton	239	113	-95	-47
Gjøvik Rambekk RA	176	72	-103	-69
Gjøvik Oppland metall	2663	362	96	493
Gjøvik Dalborgmarka	1721	150	-74	213
Lillehammer Gausdalsgt 2008	131	112	-71	-58
Kise Forsøksgård 2008	211	133	-161	-114
Brumunddal Nesvegen	843	93	-96	-52
Brumunddal Norsk stål	132	122	-82	51
Brumunddal Buttekvern	2418	-242	-328	-185
Brumunddal Thore Bjerkesveg	249	102	44	-39
Brumunddal Strandvegen	876	-229	-136	-171
Hamar Vangsvegen	557	-145	-188	-109
Hamar E6	239	122	-94	-72
Hamar bryggeri	137	209	-165	-111
Hamar Strandgata	176	186	-235	-154
Hamar park	158	158	-212	-145
Hamar Stangevegen	496	-201	-262	-172
Hamar Sandvikavegen	-1200	-2635	-5199	-3410
Hurdal målestasjon	-424	-1867	-6688	-6715

9. Appendix B - Hg measurement data

Table 13: Statistical summary of GEM data. Data are listed pr month

	Average, ng/m^3	STD, ng/m^3	Median, ng/m^3	Max, ng/m^3	Min, ng/m^3	Count, #
March 07*	1.47	± 0.18	1.49	1.90	1.17	192*
April 07	1.45	± 0.21	1.49	2.35	0.84	676
May 07	1.65	± 0.14	1.63	2.66	1.40	714
June 07	1.65	± 0.24	1.58	3.14	1.27	680
July07	1.68	± 0.17	1.66	2.75	1.30	685
August 07	1.54	± 0.19	1.52	3.15	1.20	684
September 07	1.54	± 0.21	1.48	2.53	1.23	188**
October 07	1.70	± 0.25	1.62	2.34	1.35	225**
Novoember 07	1.67	± 0.21	1.63	3.11	1.34	707
December 07	1.63	± 0.13	1.61	2.54	1.39	743
January 08	1.60	± 0.10	1.59	2.43	1.42	685
February 08	1.56	± 0.11	1.56	1.92	1.26	616
March 08	1.75	± 0.29	1.66	3.72	1.44	670
April 08	1.56	± 0.13	1.53	2.18	1.30	684
May 08	1.63	± 0.21	1.60	2.33	0.92	665
June 08	1.61	± 0.21	1.55	2.60	1.30	661
July 08	1.67	± 0.21	1.65	2.29	0.99	593
August 08	1.69	± 0.21	1.64	2.88	1.35	693
September 08	1.64	± 0.17	1.60	2.78	1.29	653
October 08	1.72	± 0.23	1.67	3.22	1.29	648
November 08	1.61	± 0.21	1.54	2.58	1.24	666
December 08	1.52	± 0.09	1.50	1.93	1.37	738
January 09	1.60	± 0.09	1.59	2.75	1.45	741
February 09	1.63	± 0.12	1.63	2.94	1.44	667
March 09	1.58	± 0.09	1.57	2.02	1.30	738
April 09	1.58	± 0.18	1.56	3.88	1.11	713
May 09	1.56	± 0.15	1.56	2.34	1.18	716
June 09	1.63	± 0.26	1.55	2.87	1.27	703

* Measurements started on March 23.

** Instrument repair and maintenance from Sept 10 to October 22.

Table 14: Summary of total-Hg in wet deposition. Values are listed pr month

Sample date, start	Sample date, end	Concentration, ng Hg / l	Precipitation, mm	Deposition, µg Hg / m^2	Deposition of Hg to Mjøsa, g
15.07.2006	01.08.2006	14.5	38.10	0.55	202
01.08.2006	01.09.2006	9.2	104.9	0.96	352
01.09.2006	02.10.2006	12.0	38.1	0.46	167
02.10.2006	01.11.2006	9.9	120.8	1.20	436
01.11.2006	01.12.2006	5.3	60.8	0.32	118
01.12.2006	01.01.2007	4.5	30.9	0.14	50.8
01.01.2007	01.02.2007	5.8	37.5	0.40	145
01.02.2007	01.03.2007	6.6	30.5	0.50	186
01.03.2007	01.04.2007	6.6	11.5	0.32	118
01.04.2007	01.05.2007	11.2	16.1	0.33	122
01.05.2007	01.06.2007	26.0	49.7	0.40	147
01.06.2007	01.07.2007	18.9	73.3	1.25	456
01.07.2007	01.08.2007	9.2	110.5	0.66	240
01.08.2007	01.09.2007	8.0	104.9	0.75	276
01.09.2007	01.10.2007	7.2	42.0	0.83	303
01.10.2007	01.11.2007	2.4	14.7	0.13	47.5
01.11.2007	01.12.2007	2.0	51.1	0.05	18.6
01.12.2007	01.01.2008	3.1	47.7	0.15	55.1
01.01.2008	01.02.2008	5.8	53.7	0.13	114
01.02.2008	01.03.2008	6.9	31.8	0.22	80.0
01.03.2008	01.04.2008	12.3	43.2	0.53	194
01.04.2008	01.05.2008	26.0	35.2	0.91	334
01.05.2008	01.06.2008	47.2	74.0	3.50	1280
01.06.2008	01.07.2008	21.5	31.8	0.68	249
01.07.2008	01.08.2008	27.9	69.3	1.93	705
01.08.2008	01.09.2008	6.7	132.3	0.89	323
01.09.2008	01.10.2008	4.8	27.2	0.13	47.8
01.10.2008	01.11.2008	3.4	57.6	0.20	71.5
01.11.2008	01.12.2008	3.7	57.0	0.21	76.2
01.12.2008	01.01.2009	4.4	29.2	0.13	46.6
01.01.2009	01.02.2009	12.3	41.9.	0.51	188
01.02.2009	01.03.2009	8.6	54.2	0.47	170
01.03.2009	01.04.2009	15.7	26.2	0.41	150
01.04.2009	01.05.2009	15.8	47.5	0.75	274
01.05.2009	01.06.2009	19.4	38.9	0.75	275
01.06.2009	01.07.2009	14.4	34.8	0.50	183

Table 15: Summary of MeHg in wet deposition. Values are listed pr month

Sample date, start	Sample date, end	Concentration, ng MeHg / l	Precipitation, mm	Deposition, ng MeHg / m^2	Deposition of MeHg to Mjøsa, g
15.07.2006	01.08.2006	0.17	38.10	6.5	2.4
01.08.2006	01.09.2006	0.03	104.9	6.3	2.3
01.09.2006	02.10.2006	0.19	38.1	7.2	2.6
02.10.2006	01.11.2006	0.03	120.8	7.2	2.6
01.11.2006	01.12.2006	0.12	60.8	7.0	2.6
01.12.2006	01.01.2007	0.07	30.9	2.2	0.8
01.01.2007	01.02.2007	0.03	37.5	3.0	1.1
01.02.2007	01.03.2007	0.03	30.5	1.8	0.7
01.03.2007	01.04.2007	0.03	11.5	0.9	0.3
01.04.2007	01.05.2007	0.23	16.1	15.2	5.6
01.05.2007	01.06.2007	0.03	49.7	4.3	1.6
01.06.2007	01.07.2007	0.03	73.3	5.7	2.1
01.07.2007	01.08.2007	0.165	110.5	18.9	6.9
01.08.2007	01.09.2007	0.03	104.9	3.2	1.2
01.09.2007	01.10.2007	0.03	42.0	1.5	0.6
01.10.2007	01.11.2007	0.03	14.7	2.9	1.1
01.11.2007	01.12.2007	0.03	51.1	4.1	1.5
01.12.2007	01.01.2008	0.03	47.7	5.7	2.1
01.01.2008	01.02.2008	0.17	53.7	9.1	3.3
01.02.2008	01.03.2008	0.19	31.8	5.9	2.1
01.03.2008	01.04.2008	0.27	43.2	11.4	4.2
01.04.2008	01.05.2008	1.55	35.2	54.6	19.9
01.05.2008	01.06.2008	0.73	74.0	53.7	19.6
01.06.2008	01.07.2008	0.81	31.8	25.6	9.3

Table 16: Summary of results from DGM measurements

Dato	Tid	Flux, ng/m2*time	Cw	Ca	R	Tluft, C	Tluft, K	Tvann, C	Tvann, K	H, Pa*m3/mol	K, m/h	vind, u2 (m/s)	vind, u10 (m/s)	Sc(Hg)	Sc(CO2)	v, cm2/s	H'	D, cm2/s	Global rad	nw(t)	V
17.07.08	10:20	0.37	57.8	1.7	8.314472	15.4	288.55	19	292.15	718.277	0.0070	1	1.18	402.23	567.4	0.011	0.2957	2.62839E-05		0.00102707	14.82
17.07.08	10:20	0.35	56.0	1.7	8.314472	15.4	288.55	19	292.15	718.277	0.0070	1	1.18	402.23	567.4	0.011	0.2957	2.62839E-05		0.00102707	14.82
17.07.08	10:20	0.91	58.2	1.7	8.314472	15.4	288.55	20	293.15	738.772	0.0172	2	2.01	381.40	565.5	0.010	0.3031	2.70349E-05		0.001002	14.82
17.07.08	10:20	0.95	60.4	1.7	8.314472	15.4	288.55	20	293.15	738.772	0.0172	2	2.01	381.40	565.5	0.010	0.3031	2.70349E-05		0.001002	14.82
12.11.08	10:15	1.74	52.7	1.7	8.314472	-1	272.15	2	275.15	388.685	0.0406	4	4.49	1073.57	632.8	0.016	0.1699	1.50628E-05		0.001673756	14.82
12.11.08	11:20	2.84	98.0	1.7	8.314472	-1	272.15	2	275.15	388.685	0.0322	3	3.90	1073.57	632.8	0.016	0.1699	1.50628E-05		0.001673756	14.82
12.11.08	12:30	1.36	92.0	1.7	8.314472	-1	272.15	2	275.15	388.685	0.0166	2	2.60	1073.57	632.8	0.016	0.1699	1.50628E-05		0.001673756	14.82
08.05.09	08:25	0.17	19.4	1.7	8.314472	5	278.15	0	273.15	352.247	0.0207	3	3.08	1219.32	644.7	0.017	0.1551	1.39422E-05		0.001791199	14.82
08.05.09	09:55	0.07	14.5	1.7	8.314472	5	278.15	0	273.15	352.247	0.0220	3	3.19	1219.32	644.7	0.017	0.1551	1.39422E-05		0.001791199	14.82
08.05.09	11:00	0.26	17.1	1.7	8.314472	5	278.15	0	273.15	352.247	0.0436	4	4.85	1219.32	644.7	0.017	0.1551	1.39422E-05		0.001791199	14.82
01.07.09	08:30	0.22	61.7	1.7	8.314472	22	295.15	19	292.15	718.277	0.0039	1	0.83	402.23	567.4	0.011	0.2957	2.62839E-05		0.00102707	14.82
01.07.09	09:30	0.35	64.5	1.7	8.314472	23	296.15	19	292.15	718.277	0.0059	1	1.06	402.23	567.4	0.011	0.2957	2.62839E-05		0.00102707	14.82
01.07.09	10:45	0.60	68.9	1.7	8.314472	24	297.15	19	292.15	718.277	0.0095	1	1.42	402.23	567.4	0.011	0.2957	2.62839E-05		0.00102707	14.82

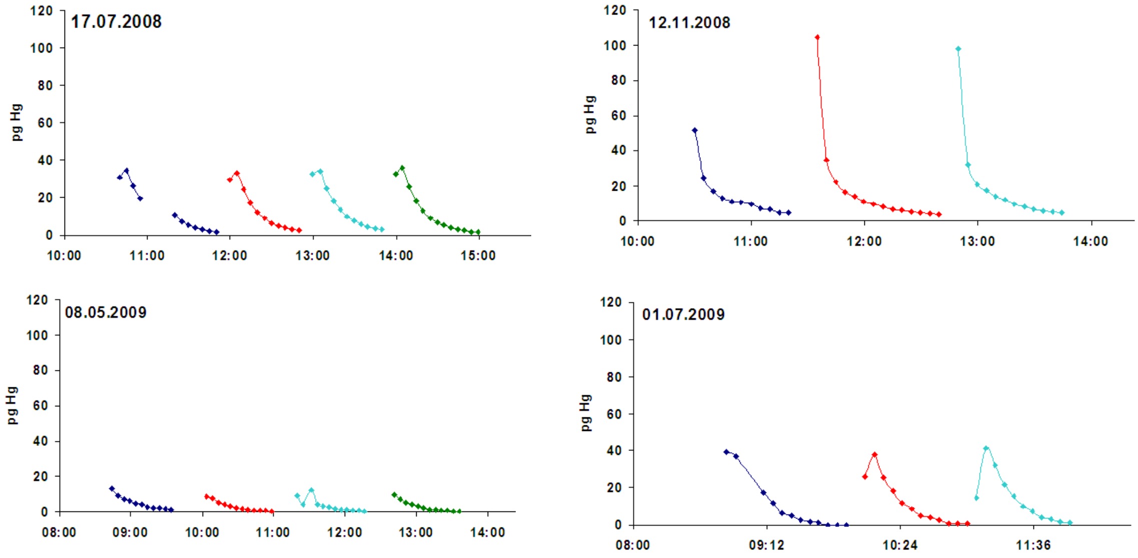


Figure 33: Purge curves from the four different days of measurements of DGM concentration.

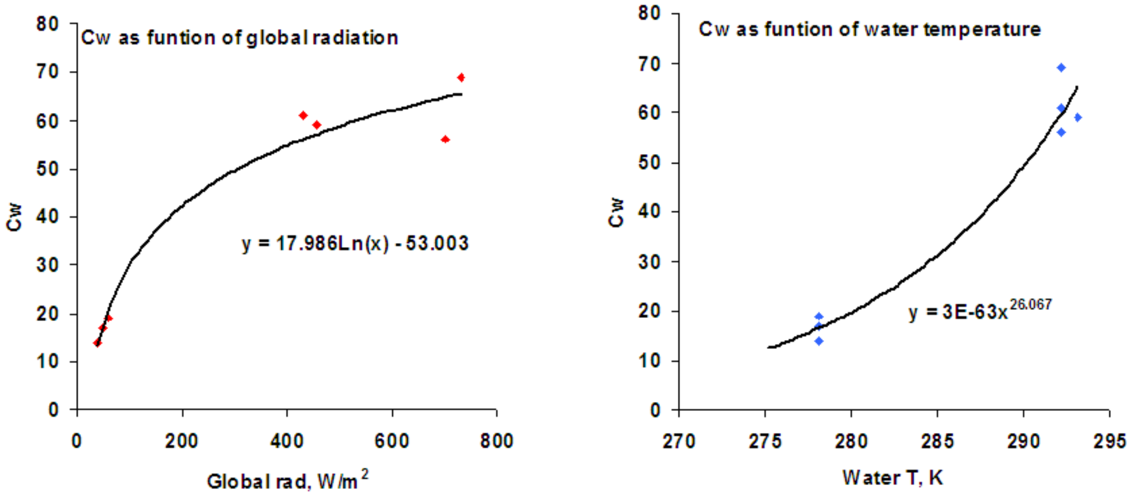


Figure 34: C_w (DGM) as function of global radiation and water temperature.

A simple method validation of the water-air gas exchange measurement technique

A quick quantitative validation of the method was performed. MilliQ water, 2 l Milliq water spiked with 50 ng/l Hg2+ and tap water were each purged with mercury free air and the purged air was collected and recorded using a Tekran 2537A mercury monitor. Purge curves as a function of time is shown in Figure 1. A summary of the results is given in table xx. As seen from the table, the deviation between measured and spiked Milli-Q water was less than 15%, which is considered satisfactory for such a non-routine analytical method.

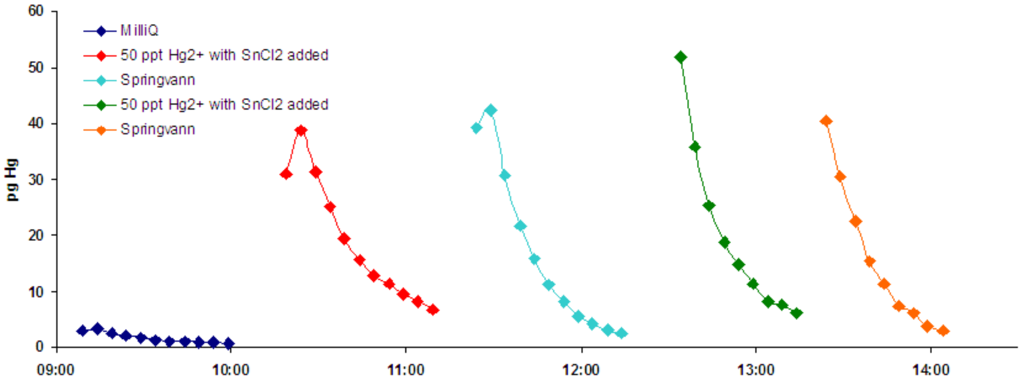


Figure 35: Purge curves for DGM.

Table 17: Validation results of the water-air gas exchange

Matrix	Result, pg/l	Spiked	Deviation, %
MilliQ-water	5.1	-	-
Spiked 50 pg Hg2+ /l	54.2	50	7%
Tap water	74.1	-	-
Spiked 50 pg Hg2+ /l	58.9	50	14%
Tap water	57.5	-	-

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Tittel - norsk og engelsk Atmosfærisk transport av miljøgifter til Mjøsa Atmospheric transport of environmental pollutants to Lake Mjøsa

Sammendrag – summary

This report describes the results of a study to reveal the sources that control levels of selected contaminants in Lake Mjøsa. The project focused on sources to air, airborne transport and deposition of PCBs, PBDEs, HBCDDs, and Hg. The following activities have been conducted from summer 2006 to summer 2009: Active air measurements of selected POPs at Kise, passive air measurements of selected POPs, and Hg-measurements and field campaigns. Based on these and earlier measurements air transport modeling and mass balance calculations were performed.The atmospheric PCB levels for the Mjøs region, measured at Kise, reflects typical Norwegian background levels and no time trend could be identified. Two passive sampling sites close to Gjøvik show elevated PCB concentrations. River water inflow is dominating inflow of ΣPCB_7 to the lake (53%), followed by atmospheric deposition (32%) and STPs (15%). PBDE measured at Kise reflects background level and no time trend could be identified. The passive air samples show a significant local source of PBDEs located in Lillehammer. Elemental mercury in air at Kise was comparable to the northern hemispheric background mean. Episodes with high concentrations of atmospheric mercury were observed year round, mainly associated with transport of polluted air from Europe. The main contributor of Hg to the water seems to be the inflow from rivers and the sediment-water exchange.

4 emneord Mjøsa, luft, organiske miljøgifter, kvikksølv	4 subject words Mjøsa, air contamination, POP, mercury

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Om SPFO

Statlig program for forurensningsovervåking omfatter overvåking av forurensningsforholdene i luft og nedbør, skog, vassdrag, fjorder og havområder. Overvåkingsprogrammet dekker langsiktige undersøkelser av:

- overgjødsling
- forsuring (sur nedbør)
- ozon (ved bakken og i stratosfæren)
- klimagasser
- miljøgifter

Overvåkingsprogrammet skal gi informasjon om tilstanden og utviklingen av forurensningssituasjonen, og påvise eventuell uheldig utvikling på et tidlig tidspunkt. Programmet skal dekke myndighetenes informasjonsbehov om forurensningsforholdene, registrere virkningen av iverksatte tiltak for å redusere forurensningen, og danne grunnlag for vurdering av nye tiltak. SFT er ansvarlig for gjennomføringen av overvåkingsprogrammet.

SPFO-rapport 1059/2009
TA-2563/2009