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New brominated flame retardants in Arctic biota

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New brominated flame retardants in Arctic biota
Nye bromerte flammehemmere i Arktisk biota

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1. Preface

Brominated flame retardants (BFRs) are a group of chemicals that inhibit combustion. They are extensively used in electrical and electronic equipment, transport equipment, building materials, paint and insulation foams. However, many of the brominated flame retardants have undesirable effects on the environment and on human health. Therefore it is a national target to substantially reduce the release of five prioritized brominated flame retardants before 2010 and completely eliminate the discharge of these five substances before 2020.

To increase the knowledge of emerging "new" BFRs and their ability for long-range transport to, and accumulation in, Arctic biota, 14 emerging "new" BFRs were analyzed in various animal samples collected in the Norwegian Arctic. The Norwegian Polar Institute, the Norwegian Institute for Air Research (NILU) and Akvaplan-niva performed this screening on behalf of the Norwegian Climate and Pollution Agency (Klif).

We would like to thank all who have participated in projects that delivered samples for this screening and especially to the contaminants in polar regions (COPOL) field team, 2009, for all assistance during sampling. We would further thank Jon Fuglestad, the project manager at Klif, for his collaboration on the project. Lastly we thank Nanette Verboven for improvements of the English text.

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Summary

As part of the work related to international conventions, harmful chemicals should be removed from the market if they fulfill the following criteria; persistency, volatility (potential for long-range transport), bimagnification (accumulate in the food chain) and toxicity (show toxic effects). The main goal of the present study was to screen for ”new” brominated flame retardants (BFRs) in seven animal species from Svalbard. Detection of these BFRs in Arctic biota implies long-range transport, because local sources are not present. Contaminants that are detected in the Arctic environment, that accumulate in the food web and have toxic effects will be high on the priority list of chemicals that need to be phased out and substituted by less harmful compounds.

The study includes one fish species; capelin (*Mallotus villosus*), three seabird species; common eider (*Somateria mollissima*), Brünnich’s guillemot (*Uria lomvia*) and black-legged kittiwake (*Rissa tridactyla*) and three mammalian species; ringed seal (*Phoca hispida*), arctic fox (*Vulpes lagopus*) and polar bear (*Ursus maritimus*). The samples from these species were collected in collaboration with other research projects to optimize use of time and resources.

Two of the 14 compounds were not analyzed due to analytical problems. Seven BFRs were not detected in the biota samples. The compound 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB) was detected in all the seven species and bis(2-ethylhexyl)tetrabromophthalate (BEHTBP) was found in five of the seven species. Due to a lack of data points above detection limits no statistical analysis could be performed. The lipid normalized concentrations of TBB indicate that this compound may biomagnify in the marine food chain. BEHTBP do not show the same ability.

The results from the present study indicate that two of the 12 analyzed BFRs undergo long-range transport to the Arctic and that one compound (TBB) may undergo biomagnification in the Arctic marine food chain. Three other BFRs (1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), decabromodiphenylethane (DBDPE) and 2,4,6-tribromophenol (TBP)) are found at very low levels (mean 0.05-0.7 ng/g wet weight) and should be included in future analyses of BFRs in Arctic biota. It is recommended that TBB and BEHTBP are monitored in these and other Arctic species, or in similar species at lower latitudes to clarify their distribution and bio-accumulation capacity.

Norsk sammendrag

Som en del av det internasjonale arbeidet med å fase ut skadelige kjemikalier skal stoffer som er giftige, er motstandsdyktig mot nedbryting, har potensial for akkumulering/ biomagnifisering eller har høy flyktighet slik at det kan spres, fjernes. Hovedmålet med dette studiet var å gjøre analyser av "nye" bromerte flammehemmere (BFR) i prøver fra sju dyrearter fra Svalbard. De 14 utvalgte nye BFRene er kjemikalier som har vært vurdert til å kunne ha potensial for langtransport via atmosfære eller vann samtidig som vi har liten kjennskap til om disse forbindelsene er tilstede i Arktis. Årsaken til at prøver fra Svalbard er valgt ut til denne undersøkelsen er at deteksjon av BFRer i Arktis vil indikere langtransport av forbindelsene siden det finnes få eller ingen lokale kilder i dette området. Stoffer som blir funnet i prøver fra Arktis, samtidig som de potensielt er giftige og kan akkumulere, vil bli høyt prioritert på listen over stoffer som bør reguleres.

Det ble tatt prøver fra sju arktiske arter til dette studiet; en art fisk; lodde (*Mallotus villosus*), tre arter sjøfugl; ærfugl (*Somateria mollissima*), polarlomvi (*Uria lomvia*) og krykkje (*Rissa tridactyla*) og tre arter pattedyr; ringsel (*Phoca hispida*), fjellrev (*Vulpes lagopus*) og isbjørn (*Ursus maritimus*). Prøvene ble samlet inn gjennom andre pågående forskningsprosjekter på Svalbard både for å redusere tid og kostnader.

To av totalt 14 BFRer lot seg ikke analysere på grunn av standardenes lave løselighet eller ustabile signaler i analyseinstrumentet. Sju av stoffene ble ikke påvist i noen av prøvene. Stoffet 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB) ble påvist i alle artene og bis(2-ethylhexyl)-tetrabromophthalate (BEHTBP) ble funnet i fem av sju arter. På grunn av få datapunkter over deteksjonsgrensa var det ikke hensiktsmessig å gjøre statistiske analyser av materialet. En sammenligning av fettvektskonsentrasjonene av TBB og BEHTBP mellom artene indikerer at TBB kan biomagnifisere (høyere konsentrasjon oppover i næringskjeden), mens BEHTBP ikke ser ut til å ha denne egenskapen.

Resultatene fra dette studiet viser at to av de 12 analyserte BFRene transporteres til Arktisk og at TBB kan biomagnifisere. Tre andre BFRer (1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), decabromodiphenylethane (DBDPE) og 2,4,6-tribromophenol (TBP)) ble funnet i svært lave konsentrasjoner (gjennomsnitt 0,05-0,7 ng/g våt vekt) og bør inkluderes i nye analyser av BFR fra Arktisk biota. Det anbefales å gjøre nye analyser av TBB og BEHTBP i både arktiske og temporære arter for å kartlegge spredning og deres evne til akkumulasjon og biomagnifikasjon i næringskjedene.

2. Background

Persistent organic pollutants (POPs) are chemicals resistant to environmental degradation and can therefore remain intact for exceptionally long periods of time. They can further become widely distributed throughout the environment and accumulate in the fatty tissue of living organisms. POPs are found at higher concentrations at higher levels in the food chain and can be toxic to both humans and wildlife. Many studies have investigated levels and distribution of conventional POPs in the Arctic environment (MacDonald et al., 2000; AMAP, 2004). However, many other compounds with some of the same properties as POPs have been subjected to relatively limited investigation with respect to their environmental fate and distribution in Arctic areas. These include compounds that are being used in large amounts today, like some brominated flame retardants. Many of these compounds are relatively persistent in the environment, but their potential for long-range transport and bioaccumulation is being questioned.

The Arctic Monitoring and Assessment program (AMAP) has reviewed the occurrence and effects of POPs in the Arctic environment in three reports from 1998, 2002 and 2009 (AMAP, 1998; 2004; 2009). The general conclusions from times series reviewed in these reports is that the levels of many "legacy" POPs have declined due to bans and regulations. The newer POPs, like some of the brominated flame retardants (BFRs) and perfluorinated compounds (PFC), are still increasing, while some of the first regulated BFRs, the penta- and octa-brominated diphenyl ethers (BDEs), have leveled out or started to decrease (AMAP, 2009; Helgason et al., 2009).

As part of the governmental work to reduce and eliminate some of the new brominated compounds a screening program was established by the Climate and Pollution Agency in order to confirm the presence of these substances in the Arctic biota. The goal of the present study was to screen selected samples from Arctic organisms for the occurrence of 14 "new" brominated compounds. The 14 BFRs included in the present study were chose from a priority list proposed from a thorough review on "new" BFRs and their potential as environmental pollutant in the Climate and Pollution Agency (former Norwegian Pollution Control Authority) report number 2462-2009 (Harju et al., 2009).

2.1 Brominated compounds

Flame retardant chemicals are present in various products in businesses and homes throughout the word. Unfortunately, limited information on the global production and use of BFRs is available (Fisk et al., 2003; de Wit et al., "In press"). However, Harju et al. (2009) reviewed the production volume and found the best estimated global production volume of BFRs was about 311.000 metric tonnes per year, including 150.000 tonnes TBBP-A, 30.000 tonnes deca-BDE and about 130.000 tonnes "new" BFR. The BFRs are applied to the products to make them less flammable and are very effective in electronics, plastics and textile applications. This means that they are very useful chemicals with a widely dispersed pattern of use. They can however be lost through abrasion, leaching and volatilization. Through their extensive use, high persistency to degradation and disposal to landfills, the BFRs have the potential to spread in the environment. The BFRs are fat-soluble and Arctic animals are particular rely on fat reserves for energy and insulation. The Arctic animal's accumulation of fat at productive parts of the year, increases the potential for bio-accumulation of fat soluble compounds.

During the last decade some BFRs have been shown to accumulate in biota (Darnerud, 2003). The long-range spreading capacity and bio-accumulating potential are characteristics that define some of the BFRs as POPs (www.pops.int/). In this context, the remote arctic areas

have been important reference areas to prove both long-range transport and bio-accumulating capacity. The early documentation of congeners of the technical mixtures penta- and octa-BDE in Arctic was an argument to ban production, import, export, sale and use of products with more than 0.1 % (by weight) of penta-, octa- and deca-BDE in Norway. The regulation and ban of the poly-BDEs (PBDEs), and most probably a better waste handling, have resulted in a temporal decrease in most PBDEs (AMAP, 2009; Helgason et al., 2009). The hexabromocyclododecane (HBCD) on the other hand is not regulated. Only few temporal trend data for HBCD exist and they indicate no changes or an increased concentration in biota (Helgason et al., 2009; de Wit et al., "In press"). The remote Arctic areas are thereby important for documentation of chemicals long-range transport capacity and their temporal trends.

Toxicological and ecotoxicological studies have mainly been performed on polybrominated biphenyls (PBBs) and PBDEs, as reviewed by de Wit (2002) and Darnerud (2003). The general findings are that some congeners seem to be more toxic than others. The penta-BDEs seem to be more toxic at than the deca-BDE. The toxic effects are related to endocrine changes that can influence growth, immune system, reproduction and development. The PBBs and PBDEs are also known to be mutagenic.

In the report by Harju et al. (2009) the studied effects of these BFRs were reviewed. None of the present BFRs were reported to be genotoxic (mutagenic), a few were found to be slightly eye irritant and about half of these could bind to the AhR receptor and could thereby influence the endocrine system. By feeding these “new” BFRs to mice, a general toxicity, for example the LD_{50}, could be reported. The LD_{50}s were reported for 6 of the present 14 BFRs and varied from 2 mg/kg (TBP) to >20 g/kg (PBT) (Harju et al., 2009). Toxicological studies on the “new” emerging BFRs analyzed in present study are generally limited.

The names, CAS-numbers, abbreviations and formulas of the 14 “new” BFRs included in the study are presented in Table 1.

Table 1: Names, CAS-numbers, abbreviations and formulas of the included BFRs.

Name	CAS-number	Abbreviation	Formula
Pentabromotoluene	87-83-2	PBT	$C_7H_3Br_5$
Pentabromoethylbenzene	85-22-3	PBEB	$C_8H_5Br_5$
Hexabromobenzene	87-82-1	HBB	C_6Br_6
2,3-dibromopropyl-2,4,6-tribromophenyl ether	35109-60-5	DPTE	$C_9H_7Br_5O$
tetrabromophthalic anhydride	632-79-1	TBPA	$C_8Br_4O_3$
1,2-bis(2,4,6-tribromophenoxy)ethane	37853-59-1	BTBPE	$C_{14}H_8Br_6O_2$
2-ethylhexyl-2,3,4,5-tetrabromobenzoate	183658-27-7	TBB	$C_{15}H_{18}Br_4O_2$
Tetrabromobisphenol-bis(2,3-dibromopropylether)	21850-44-2	TBBPA-DBPE	$C_{21}H_{20}Br_8O_2$
decabromodiphenylethane	84852-53-9	DBDPE	$C_{14}H_4Br_{10}$
2,4,6-tribromophenyl allyl ether	3278-89-5	ATE	$C_9H_7Br_3O$
bis(2-ethylhexyl) tetrabromophthalate	26040-51-7	BEHTBP	$C_{24}H_{34}Br_4O_4$
2,4,6-tribromophenol	118-79-6	TBP	$C_6H_3Br_3O$
ethylene bis(tetrabromophthalimide)	32588-76-4	BTBPI	$C_{18}H_4Br_8N_2O_4$
Tetrabromobisphenol-diallylether	25327-89-3	TBBPA-DAE	$C_{21}H_{20}Br_4O_2$

There are principally two ways of including flame retardants to polymer products, the additive or reactive inclusion. In case of additive flame retardants the substance is dispersed in the final product. The chemicals are not bound to the polymer chain and this makes them more likely to be lost during the products lifetime. The reactive flame retardants are chemically bound to the polymer structure. This reduces the chances of leakage from the product. The compounds included in this study have been evaluated as substances where more information is needed. The chosen compounds have been evaluated as potential environmental pollutant on the basis of production volume, usage (additive or reactive), theoretically long-range transport potential, risk to the aquatic environment, bioaccumulation potential or they have been found to be present in the environment (Fisk et al., 2003; Harju et al., 2009; de Wit et al., "In press").

The main goal of the present project was to study the occurrence of these 14 new brominated flame retardants in biological samples from the Norwegian remote Arctic area, Svalbard.

3. Materials and methods

The purpose of this project was to screen samples from remote Arctic areas for new BFRs. Samples for this screening were delivered from other scientific projects to optimize the use of resources.

3.1 Selected species

Seven species from Svalbard were included. The collection details are given in Table 2. More information about the species is given below.

Table 2. Overview of species and samples in the present study.

Species	Scientific name	Location	Sampling year	Age (year)	Sex	N	Sample matrix
Capelin	*Mallotus villosus*	Kongsfjorden	2009	–	F+M	10	Whole fish
Common eider	*Somateria mollissima*	Kongsfjorden	2009	Adult	F	10	Liver
Black-legged kittiwake	*Rissa tridactyla*	Kongsfjorden	2009	Adult	F+M	10	Liver
Brünnich's guillemot	*Uria lomvia*	Kongsfjorden	2008	–	–	5	Egg
		Bjørnøya	2008	–	–	5	Egg
Ringed seal	*Phoca hispida*	Tempelfjorden	2007	Adult (5-19)	F+M	10	Liver
Arctic fox	*Vulpes lagopus*	Van Mijenfjorden	2007/ 2008	Adult (3-14)	F+M	10	Liver
Polar bear	*Ursus maritimus*	Hornsund / Storfjorden	2008	Adult (5-23)	M	10	Plasma

The fish fauna of the Barents- and Arctic Seas is characterized by relatively few species (Gjøsæter, 2009). Food web studies have identified capelin (*Mallotus villosus*) as important food for other fish, sea mammals and seabirds (Barrett, 2007; Gjøsæter, 2009). The capelin is a small forage fish of the smelt family found in the Atlantic and Arctic oceans. It forages along the Polar front and at the edge of the ice shelf. In autumn it migrates to the coast of Northern Norway and Kola Peninsula for spawning. Capelin spawn on sandy beaches and sandy bottom at the age of 2-6 years, and most capelins die after spawning. The capelins' wintering area is south of the ice-covered parts of the Barents Sea. Capelin is a fatty fish species that transfers energy from the lower trophic to higher trophic level in the Barents Sea ecosystem.

The Barents Sea is a productive ecosystem (Sakshaug et al., 2009). The high primary production generates energy for the secondary production and the large fish and seabird stocks. The estimated numbers of breeding birds in the Barents Sea is about 4 million pairs (Gabrielsen, 2009). The three seabird species common eider (*Somateria mollissima*), black-legged kittiwake (*Rissa tridactyla*) and Brünnich's guillemot (*Uria lomvia*) represent avian predators that forage at different levels of the marine food web. The common eider is a benthic feeder eating moluscs, polychaetes and other bottom organisms. The black-legged kittiwake cannot dive, therefore it forages in the upper water masses. The kittiwake's diet consists mainly of small fish, such as capelin and polar cod (*Boreogadus saida*), and different pelagic amphipods. The Brünnich's guillemot dives and eats mainly small fish and squid.

The common eider is a large diving duck. It has a circumpolar distribution and breeds in the Arctic and boreal zones of the northern hemisphere. It winters largely within the breeding range, leaving only the most northern regions. The eider normally lays 4-6 eggs and only the female incubates for 24-26 days. They do not feed during the incubation period and can therefore lose up to 40 % of their body weight during incubation. The breeding population at Svalbard is estimated to be somewhere between 13.500 and 27.500 pairs (Strøm, 2006).

The blacked-legged kittiwake is a medium-sized gull that has a circumpolar distribution. It is a cliff breeder in the Arctic and boreal zone throughout much of the northern hemisphere. The kittiwake is the most numerous gull species, but, due to large reductions of the breeding populations around the northern hemisphere, it is classified in the Norwegian red list as vulnerable in mainland Norway and close to endangered at Svalbard. Black-legged kittiwakes are not considered true migrants, but outside the breeding season they disperse widely over most of the North-Atlantic Ocean. The black-legged kittiwake lays 1-3 eggs and both parents' incubate for about 27 days. The breeding population at Svalbard is estimated to be 270,000 pairs, of which ca. 90,000 pairs breed on Bjørnøya (Strøm, 2006).

The Brünnich's guillemot is a stout built auk with a high latitude circumpolar distribution in Arctic and sub-Arctic seas. It is one of the most numerous seabirds in the northern hemisphere with an estimated breeding population in Svalbard of 850,000 pairs. The Brünnich's guillemot breeds on narrow cliff ledges, lays only one egg that both parents incubate for about 32 days (Strøm, 2006).

Three mammalian species were included in this screening. The ringed seal (*Phoca hispida*), the arctic fox (*Vulpes lagopus*) and the polar bear (*Ursus maritimus*). The ringed seal was chosen since it links the marine lower tropic level with the higher trophic level. It does this by foraging on fish and crustaceans, and by being the most important food for the polar bear. Ringed seal leftovers from polar bear hunts are also eaten by arctic foxes. Both arctic fox and polar bear were chosen as top predators in the marine environment. The arctic fox also represents the terrestrial food chain of Arctic.

The ringed seals are small phocid seals with a circumpolar distribution. They are the only northern seal that can maintain breathing holes in thick sea ice and this special ability allows them to have an extensive distribution in the Arctic and sub-Arctic. Ringed seals give birth in the early spring to their single pup inside a snow lair in fjord or sea ice. Ringed seals are a long-lived species that can reach 45 years of age. Ringed seals are the most abundant arctic seal and the Svalbard-Barents Sea population is thought to number in the hundreds of thousands (Kovacs and Lydersen, 2006).

The arctic fox is the only mammalian terrestrial predator at the Svalbard archipelago. It has a circumpolar distribution and lives in two main tundra habitats, inland and coast, depending on the availability of food resources. In Svalbard they belong to the coastal ecotype feeding from both the marine and terrestrial food web. In Svalbard arctic foxes mate from February until mid April and a litter of five or six cubs is born in a den in May or early June. Average longevity is about three to four years, but a 13 year old individual has been recorded from Svalbard (Fuglei, 2006).

The polar bear is the largest species of bear in the world. They are markedly sexually dimorphic, with males being larger than females. The polar bear has a circumpolar distribution. There are approximately 20 different populations of polar bears in the Arctic. Together these populations estimate approximately 25,000 bears. The Barents Sea population of polar bears numbers about 2,500 polar bears and includes animals that den in both Svalbard and Franz Josef Land. Only pregnant female polar bears den during the winter to give birth to

1-3 cubs. The female leaves the den with her cubs in late March or early April. Survival of juveniles to the age of two years is only about 30 %. Adult survival is high and polar bears typically live 15-25 years (Aars, 2006).

The species selected represent the medium and upper part of the Arctic food web. They have different food preferences and their capacity to metabolize pollutants differs.

Figure 1: Pictures of the species included in this screening. From upper left corner; Capelin (©Fredrik Broms, NPI), Black-legged kittiwake (©Rob Barrett), Ringed seal (©Bjørn Frantzen, NPI), Common eider (©Bildearkiv, NPI), arctic fox (©Tore Nordstad), Brünnich's guillemot (©Hallvard Strøm, NPI), Polar bear (©Tor Ivan Karlsen, NPI).

3.2 Species, sampling procedures and areas

The samples were analyzed individually and the sample matrixes were whole fish, egg, liver or blood plasma (Table 2). The capelin were trawled, sorted into the two sexes and frozen (-20 °C) in ziplock bags. Common eider and black-legged kittiwake were shot, brought to the laboratory and dissected. A liver sample for contaminant analyzes was placed in aluminum foil and frozen (-20 °C). Brünnich's guillemot eggs were collected, wrapped individually in aluminum foil and frozen (-20 °C). Ringed seals were shot on the sea ice and directly dissected. A liver sample for contaminants analyzes was paced in aluminum foil and frozen (-20 °C) upon return to the lab. The maximum time from packing to freezing was one day, but, because of low air temperatures, the samples were maintained below zero for most of this time. The Arctic fox samples were obtained from trapped foxes, brought to the Governor of Svalbard. They were stored frozen from 6 to 9 mounts after which they were brought to the laboratory for dissection. A liver sample was individually packed in aluminum foil and stored frozen (-20 °C) until analyzes. Blood from polar bears was centrifuged in the field. Plasma was transferred to cryogenic vials and immediately frozen (-20 °C). Only new and clean equipments and material were used to handle the samples. All samples were stored frozen at -20°C or lower until analyses.

The geographical areas of sample collection are given in Figure 2, while the location of each sample is given in Table 2.

Figure 2: Map of Svalbard including the locations from which the samples were collected. Detailed information of sampling locations is given in Table 2.

Permission to collect samples was obtained for each project that collected samples for this screening. All sampling was done in accordance to current regulations of the Norwegian Animal Welfare Act and all sampling was approved by the Governor of Svalbard.

3.3 Chemical analysis

The analyses of the BFRs, the substances included in table 1, were performed at the Norwegian Institute for Air Research (NILU), Tromsø.

Tissue samples were extracted and prepared as previously described by Herzke et al (2002) with some adaptations to ensure extraction of more polar compounds. Briefly, whole fish, egg and liver samples were homogenized and dried in a 10 fold amount of dry sodium sulfate. The homogenate was transferred to a glass column, the internal standards were added and extracted three times with cyclohexane/acetone (3:1) and once with dichlormetan/n-hexan (1:1). The amount of lipids was determined gravimetrically. Lipid was removed in a two step process, first on a gel permeation chromatography (GPC) and secondly on a florisil column.

A recovery standard (octachloronaphthalene, 10 µL of a 1 ng/µL solution in isooctane) was added to all samples prior to quantification. For quantification of all compounds, reference material was obtained from Cambridge Isotope Laboratories (Woburn, MA,USA). Solvents of pesticide grade were employed (E. Merck, Darmstadt, Germany). ^{13}C-labelled compounds were used as internal standards presenting each group of analytes, containing between 77 and 500 pg/µL ^{13}C-labelled PBDE-28, -47, -99, -153, -183, -209 as well as ^{13}C labeled DBDPE, TBP, HBB and BTBPE.

The detection limit (DL) varied from 0.5 to 292 pg/g wet weight (wet wt). Generally, the DL was quite good for most BFRs while some "large" BFRs gave higher DLs which is in agreement with earlier published results (such as PBDE 209). Recoveries were acceptable and varied between 67 and 120% for the labeled PBDEs. Standard reference material (SRM) of whale blubber (National institute of standards and technology - NIST 1945) was used as a control sample. One SRM and one laboratory blank were analyzed along with every 10th sample. No blank contamination was detected. NILUs quality insurance system for analyses of organic compounds in biological matrixes was followed. These new compounds are not included as accredited analyses since the methods are just established. Further research and inter-calibrations between laboratories are needed before these compounds can be included as accredited analyzes.

3.4 Statistical analysis

Due to low sample size and a large number of the samples being below DL, no statistics could be done. The results are therefore presented as numbers of samples above DL (%), mean concentration and standard deviation.

4. Results and discussions

Of all the new BFRs analyzed in the present study the BTBPI could not be detected since the standard compound could not be dissolved in any of the used organic solvents (Table 3). The production volume of this compound is high and is evaluated to have low potential for long-range transport. It will probably not bio-accumulate and has to our knowledge not been found in any environmental sample (Harju et al., 2009). At the moment, there are no indications that BTBPI is of environmental concern. Further, the TBBPA-DAE could not be quantified in this study since the standard compound was unstable in the mass spectrometer (Table 3). As for the BTBPI, the TBBPA-DAE has low potential for long-range transport, bio-accumulation and has not been found in any environmental samples (Harju et al., 2009). The production volume of TBBPA-DAE is low (Harju et al., 2009).

Table 3: The percentage of samples above detection limit (DL), mean and (standard deviation) pg/g wet wt of the "new" brominated flame retardants (BFRs) in seven species from the Norwegian Arctic. N.D. = not detected (below DL), n = 10 for all species.

BFR	**Capelin**	**Common eider**	**Brünnich's guillemot**	**Kittiwake**	**Ringed seal**	**Arctic fox**	**Polar bear**
Organ	Whole	Liver	Egg	Liver	Liver	Liver	Plasma
Lipid %	2.6	3.7	11.0	5.5	3.5	7.1	0.9
PBT	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PBEB	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
HBB	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
DPTE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
TBPA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
BTBPE	N.D.	N.D.	40% 664 (367)	N.D.	N.D.	N.D.	N.D.
TBB	100% 378 (240)	100% 862 (1243)	90% 1213 (984)	90% 732 (261)	100% 435 (292)	90% 975 (608)	90% 3460 (2481)
TBBPA-DBPE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
DBDPE	N.D.	N.D.	10% 581 (-)	N.D.	N.D.	N.D.	N.D.
ATE	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
BEHTBP	90% (719) (292)	60% 1652 (1396)	70% 1799 (1358)	50% 800 (356)	60% 573 (198)	N.D.	N.D.
TBP	N.D.	90% 90 (95)	N.D.	N.D.	50% 50 (26)	N.D.	N.D.
BTBPI	No analyses possible because dissolution of crystalline standard compound was not possible.						
TBBPA-DAE	No quantitative data because unstable in mass spectrometer.						

A total of seven of the 12 BFRs analyzed, were not detected above DL in any samples (Table 3). Of these seven, the TBPA has to our knowledge not previously been detected in any environmental samples (Harju et al., 2009). The other (PBT, PBEB, HBB, DPTE, TBBPA-DBPE and ATE) have been measured at least once in abiotic or biotic samples around the world (Harju et al., 2009; Lam et al., 2009; Vetter et al., 2010).

The PBT, PBEB and HBB, that not were detected in present study (Table 3), have earlier been detected in glaucous gull (*Larus hyperboreus*) from Bjørnøya, the Barents Sea (Verreault et al., 2007). The BTBPE on the other hand was only detected in 40% of the Brünnich's guillemot eggs (Table 3). There may be several reasons why these first three BFR compounds were not detected in the present study. First, the detected levels in the glaucous gulls were low (<DL – 2.6 ng/g wet wt for HBB in egg yolk) (Verreault et al., 2007). Secondly, the HBB, PBEB, BTBPE and PBT detected in the glaucous gull study had a higher percentage of detection in egg yolk than in adult's blood plasma (Verreault et al., 2007). This might indicate

that these BFRs are metabolized or excreted in the adult glaucous gulls, and might be a part of the explanation why BTBPE was found in the Brünnich's guillemot egg and not in the tissue of the other birds. Further, the short estimated half-life in fish, also indicate a rapid excretion or metabolizing of these four BFRs, reviewed by Harju et al. (2009).

Only TBB was found in all species in the present study, while the BEHTBP was detected in five of the seven species (Table 3). Since percentage extractable lipids varied between organs and species (Table 3), lipid weight (lipid wt) levels were calculated to compare the concentration between species. The polar bear had much higher concentration of TBB (414.8 ng/g lipid wt) than the other species analyzed (Figure 3). The mean levels of TBB were 19, 11, 13, 15 and 18 ng/g lipid wt in capelin, Brünnich's guillemot, ringed seal, kittiwake and arctic fox respectively. The polar bear's mean concentration of TBB was about 30 times higher than in its most important prey, the ringed seal (Figure 3). It is difficult to explain this large increase in TBB level from ringed seal to polar bear, especially since there is no indication of biomagnification from capelin to its predatory species of Brünnich's guillemot, kittiwake and ringed seal. The high TBB concentration found in polar bears may be a result of biomagnification, but further research is needed before a conclusion can be made. In the present study, measurements were made on different organs for the different species and that might explain some of the variation. The TBB was not detected in sediment, sludge waste water, waste or seepage water, biological material or air in Norway (Møskeland, 2010). TBB was neither detected in Norwegian terrestrial mammals (Polder et al., 2009), but has been found in blubber samples of Indo-Pacific humpback dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) from Hong Kong, South China (Lam et al., 2009).

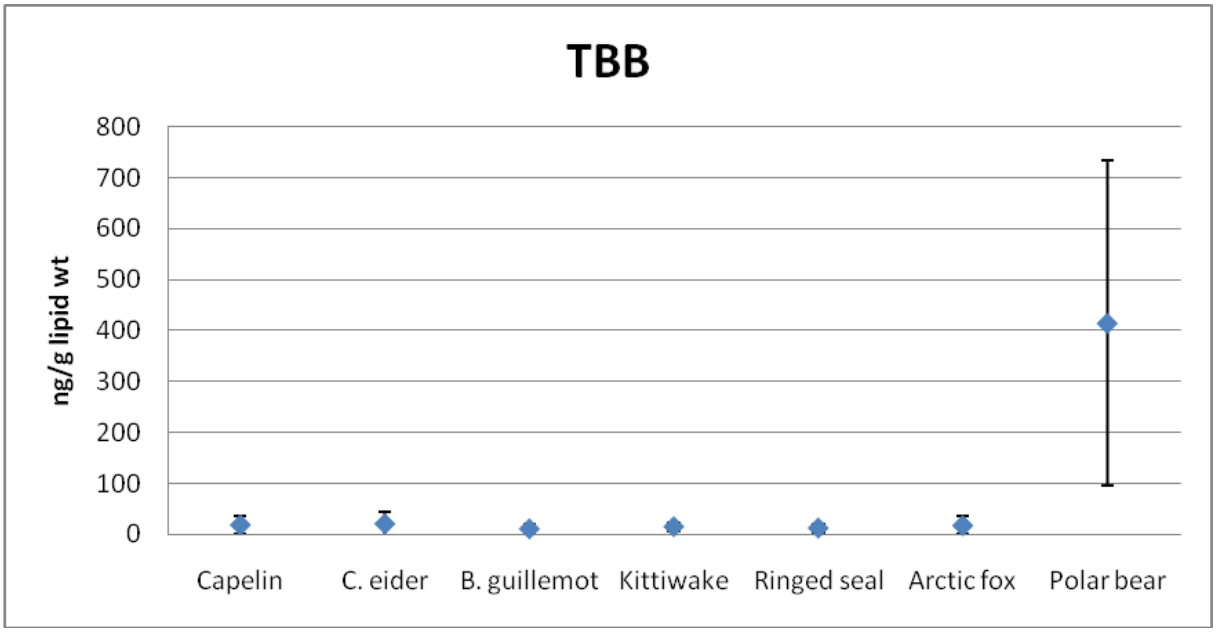

Figure 3: The mean 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (TBB) (ng/g lipid wt) distribution with ± standard deviation.

The BEHTBP was detected in capelins, eiders, guillemots, kittiwakes and ringed seal (Table 3 and Figure 4). The concentrations do not seem to differ between species, although there might be a slight decrease towards the higher trophic levels. Based on the literature BEHTBP has only been detected in indoor dust, biosolids from waste water treatment plants and recently in fish from the Great Lake system (US) (Harju et al., 2009; Zhou et al., 2010). This compound

was neither found in Norwegian screening of either abiotic samples or terrestrial mammals (Polder et al., 2009; Møskeland, 2010).

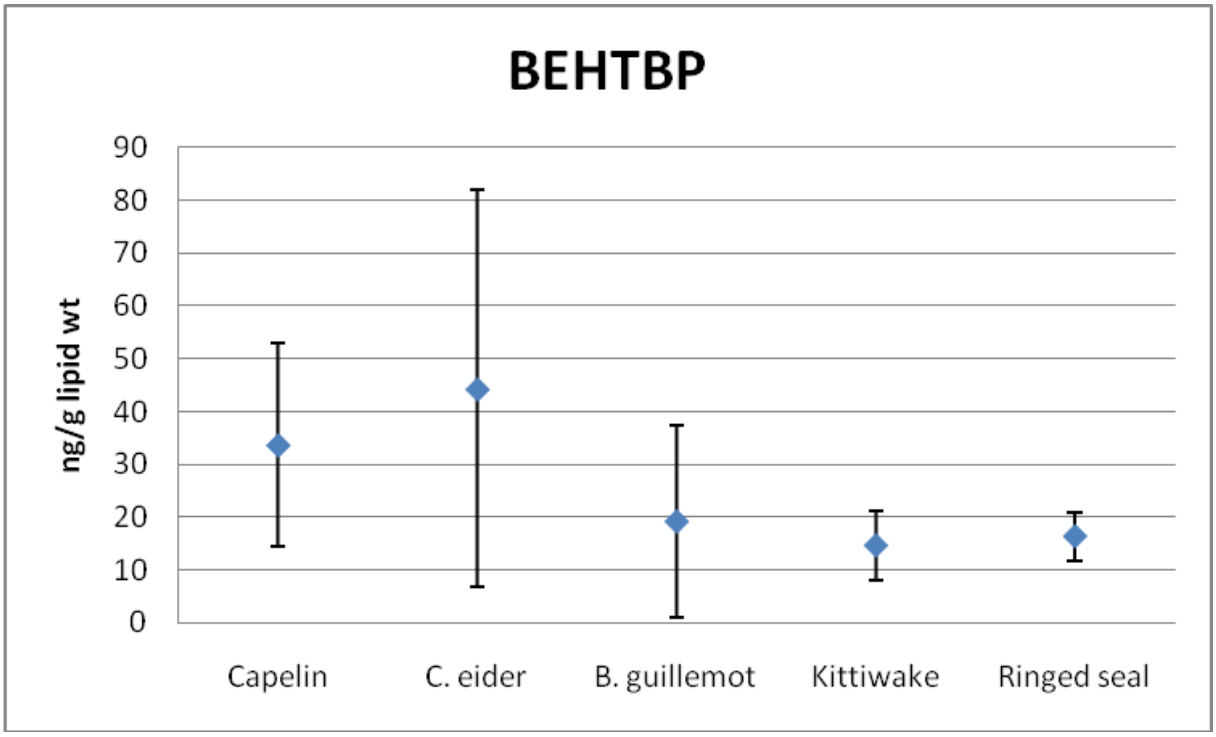

Figure 4: The mean bis(2-ethylhexyl)tetrabromophthalate (BEHTBP) (ng/g lipid wt) distribution with ± standard deviation.

The DBDPE was only detected in one guillemot egg (10% of the samples). DBDPE has been found at very low levels in a Canadian fresh water food web, in house dust from US and Sweden. There is no information on production volume of this compound and, according to the review by Harju et al. (2009), the potential for bio-accumulation and long-range transport is low.

TBP was found in liver samples from common eider and ringed seal in a high percentage (90 and 50 respectively) of the samples, but at low levels (Table 3, Figure 5). TBP has a high production volume and has been estimated to have high potential for bio-accumulation and long-range transport (Harju et al., 2009). It has been detected in a wide range of environmental samples in Australia, Asia, Pacific Ocean, Great Lake System (US), Europe and in the North and Baltic Seas (Harju et al., 2009). Furthermore, it was the only "new" BFR found in terrestrial mammalian species (Polder et al., 2009) and in biological material, although the latter study focused mostly on abiotic samples (Møskeland, 2010). It was found in comparable concentration in the eight terrestrial animas (0.01 – 0.15 ng/g wet wt) (Polder et al., 2009) as in the presents study's ringed seal and common eider (0.05 and 0.09 ng/g wet wt) (Table 3), but the detected concentrations in edible crab (*Cancer pagurus*) from Drammensfjorden (3.0 – 8.2 ng/g wet wt) and crabs of the genus *Hyas* (spider crab and lyre crab) from Sannesundet (Tromsø) (42.1 – 131 ng/g wet wt) were much higher (Møskeland, 2010). This compound is rapidly absorbed and excreted in rats (Simonsen et al., 2000). Further research on bio-accumulation and biomagnification potential and measurements in biological samples from Arctic and temporal areas are recommended for BFR 2,6,4-TBP.

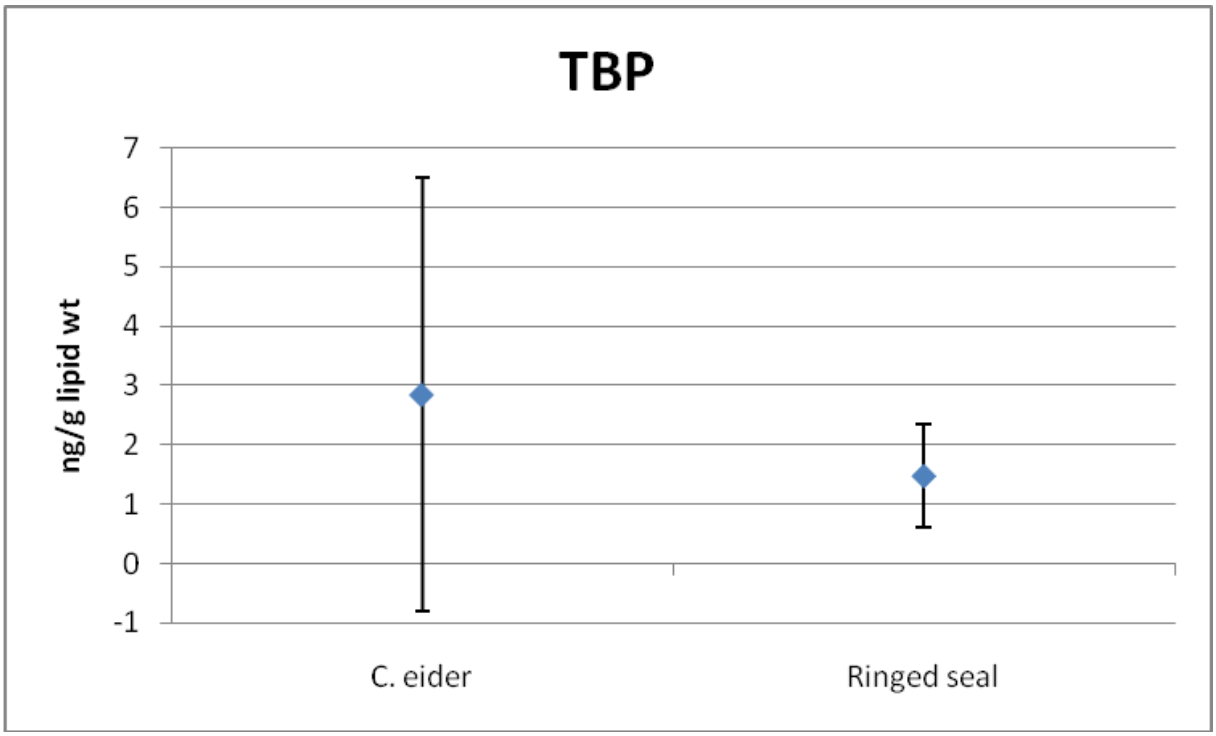

Figure 5: The mean 2,4,6-tribromophenol (TBP) (ng/g lipid wt) distribution with ± standard deviation.

5. Concluding remarks

The present study detected five "new" emerging BFRs in animals from the Svalbard area. Since these five components are present in biological material in the remote Svalbard area, and that this might be evidence for the occurrence of long-range transport, they should be of environmental concern. The levels are however low compared to PBDE and much lower than polychlorinated biphenyls (PCBs) and pesticides such as dichlorodiphenyltrichloroethane (DDT) and its metabolites.

Table 4: The detection of the "new" brominated flame retardants (BFRs) in seven species from the Norwegian Arctic. The number referred to the numbers of species the BFR was detected. The detailed results are given in Table 3.

Name	**CAS-number**	**Abbreviation**	**Present in # of 7 species**
Pentabromotoluene	87-83-2	PBT	-
Pentabromoethylbenzene	85-22-3	PBEB	-
Hexabromobenzene	87-82-1	HBB	-
2,3-dibromopropyl-2,4,6-tribromophenyl ether	35109-60-5	DPTE	-
tetrabromophthalic anhydride	632-79-1	TBPA	-
1,2-bis(2,4,6-tribromophenoxy)ethane	37853-59-1	BTBPE	1
2-ethylhexyl-2,3,4,5-tetrabromobenzoate	183658-27-7	TBB	7
Tetrabromobisphenol-bis(2,3-dibromopropylether)	21850-44-2	TBBPA-DBPE	-
decabromodiphenylethane	84852-53-9	DBDPE	1
2,4,6-tribromophenyl allyl ether	3278-89-5	ATE	-
bis(2-ethylhexyl) tetrabromophthalate	26040-51-7	BEHTBP	5
2,4,6-tribromophenol	118-79-6	TBP	2
ethylene bis(tetrabromophthalimide)	32588-76-4	BTBPI	Not analyzed
Tetrabromobisphenol-diallylether	25327-89-3	TBBPA-DAE	Not analyzed

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7. Appendix 1 – Tabulated results

Nye bromerte flammehemmere analyse resultater

UL = Polarlomvi, C = Lodde, SM = Ærfugl, RT = Krykkje, RS = Ringsel, AF = Fjellrev

pg/ g ww UL = Polarlomvi,

Compound name	Sample name	UL1E	UL2E	UL3E	UL4E	UL5E	UL6E	UL7E	UL8E	UL9E	UL10E
pentabromotoluene	PBT	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
pentabromoethylbenzene	PBEB	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
hexabromobenzene	HBB	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6
2.3-dibromopropyl-2.4.6-tribromophenyl ether	DPTE	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6	< 5.6
tetrabromophthalic anhydride	TBPA ANHRD	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8	< 80.8
1.2-bis(2.4.6-tribromophenoxy)ethane	BTBPE	< 0.5	< 0.5	< 0.5	< 0.5	1125	729	< 0.5	< 0.5	556	244
2-ethylhexyl-2.3.4.5-tetrabromobenzoate	EHTBB	< 31.6	186	169	184	1000	2286	2451	898	1222	2520
TBBPA-bis(2.3-dibromopropylether)	TBBPA-DBPE	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4	< 21.4
decabromodiphenylethane	DBDPE	< 1.6	< 1.6	< 1.6	581	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6
2.4.6-tribromophenyl allyl ether	ATE	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03	< 1.03
bis(2-ethylhexyl)tetrabromophthalate	BEHTBP	479	< 106	2863	3414	3215	1661	289.4	670	< 106	< 106
2.4.6-tribromophenol	246-TBP	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6
ethylene bis(tetrabromophthalimide)	BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DIALLYLETHER	TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Lower than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

C = Lodde,

Sample name	CW1	CW2	CW3	CW4	CW5	CW6	CW7	CW8	CW9	CW10
PBT	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PBEB	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
HBB	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7
DPTE	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
TBPA ANHRD	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1	< 86.1
BTBPE	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
EHTBB	321	522	158	510	475	177	351	174	920	171
TBBPA-DBPE	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8	< 22.8
DBDPE	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7	< 1.7
ATE	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1	< 1.1
BEHTBP	1002	638	507	< 119.8	823	572	767	442	1306	410
246-TBP	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6
BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Low er than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

SM = Ærfugl

Sample name	SM62L	SM68L	SM61L	SM64L	SM65L	SM70L	SM63L	SM66L	SM67L	SM69L
PBT	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
PBEB	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
HBB	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
DPTE	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5
TBPA ANHRD	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8
BTBPE	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
EHTBB	501	574	4348	670	396	931	255	284	246	417
TBBPA-DBPE	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9
DBDPE	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9
ATE	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
BEHTBP	3083	3754	< 142	861	< 142	934	843	< 142	< 142	435
246-TBP	< 12.6	37.4	102	332	46.6	25.9	54.1	31.9	69.4	107
BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Lower than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

RT = Krykkje

Sample name	RT63L	RT L67	RT L65	RT L68	RT L69	RT L66	RT L62	RT L61	RT L64	RT L70
PBT	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
PBEB	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
HBB	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
DPTE	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2	< 7.2
TBPA ANHRD	< 103	< 103	< 103	< 103	< 103	< 103	< 103	< 103	< 103	< 103
BTBPE	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
EHTBB	< 40.3	814	737	748	407	979	477	748	466	1215
TBBPA-DBPE	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3	< 27.3
DBDPE	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1
ATE	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3
BEHTBP	< 171	< 171	819	< 171	< 171	475	671	1398	635	< 171
246-TBP	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6
BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Lower than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

RS = Ringsel

Sample name	RS L 14	RS L 15	RS L 19	RS L 8	RS L 17	RS L 9	RS L 16	RS L 21	RS L 13	RS L 12
PBT	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
PBEB	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
HBB	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
DPTE	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4
TBPA ANHRD	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3	< 92.3
BTBPE	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
EHTBB	105.9	248	160	466	320	579	452	399	475	1150
TBBPA-DBPE	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5	< 24.5
DBDPE	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9
ATE	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
BEHTBP	< 138	557	< 138	< 138	353.6	876	477	738	436	< 138
246-TBP	< 12.6	38.0	35.3	< 12.6	< 12.6	24.8	90.8	59.3	< 12.6	< 12.6
BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Lower than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

AF= Fjellrev

Sample name	AF75L	AF71L	AF89L	AF86L	AF94L	AF92L	AF101L	AF107L	AF87L	AF98L
PBT	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
PBEB	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
HBB	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
DPTE	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5	< 6.5
TBPA ANHRD	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8	< 93.8
BTBPE	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6
EHTBB	1488	628	< 36.7	500	889	505	965	2375	820	604
TBBPA-DBPE	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9	< 24.9
DBDPE	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9
ATE	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
BEHTBP	< 142	< 142	< 142	< 142	< 142	< 142	< 142	< 142	< 142	< 142
246-TBP	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6
BTBPI	no analyses possible because solvation of cristalline standard compound was not possible									
TBBPA-DAE	no quantitative data because unstable in mass spectrometer									

<: Lower than LOD (signal:noise 3:1)

Nye bromerte flammehemmere analyse resultater

pg/ g ww

ISBJ= isbjørn

Sample name	ISB 23798	ISB 23971	ISB 23969	ISB 23899	ISB 23741	ISB 23816	ISB 23976	ISB 23672	ISB 7976	ISB 7796
PBT	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< 1.2
PBEB	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3
HBB	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8	< 3.8
DPTE	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7	< 13.7
TBPA ANHRD	< 197	< 197	< 197	< 197	< 197	< 197	< 197	< 197	< 197	< 197
BTBPE	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3
EHTBB	2079	512	6401	< 77.3	1131	6094	2972	1974	2696	7281
TBBPA-DBPE	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3	< 52.3
DBDPE	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
ATE	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
BEHTBP	< 292	< 292	< 292	< 292	< 292	< 292	< 292	< 292	< 292	< 292
246-TBP	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6	< 12.6

BTBPI: no analyses possible because solvation of cristalline standard compound was not possible

TBBPA-DAE: no quantitative data because unstable in mass spectrometer

<: Lower than LOD (signal:noise 3:1)

Statlig program for forurensningsovervåking

Klima- og forurensningsdirektoratet
Postboks 8100 Dep,
0032 Oslo
Besøksadresse: Strømsveien 96

Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@klif.no
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Om Statlig program for forurensningsovervåking

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. Klima- og forurensningsdirektoratet er ansvarlig for gjennomføringen av overvåkingsprogrammet.

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