Statlig program for forurensningsovervåking

Silver, Platinum, Sucralose, Bisphenol A, Tetrabrombisphenol A, Siloxanes, Phtalates (DEHP) and Phosphororganic flame retardants

SCREENING OF NEW CONTAMINANTS IN SAMPLES FROM THE NORWEGIAN ARCTIC

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Authors: Anita Evenset (project leader), Henriette Leknes, Guttorm N. Christensen, Nicholas Warner, Mikael Remberger & Geir Wing Gabrielsen

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Preface

On behalf of the Norwegian Pollution Control Authority (SFT) Akvaplan-niva, the Norwegian Polar Institute, Norwegian Institute for Air Research (NILU), and Swedish Environmental Research Institute (IVL) have analyzed selected metals and new organic contaminants in various samples collected in the Norwegian Arctic. The samples were collected on several different cruises performed as parts of other ongoing research projects.

Thanks are due to all who have participated in this project and especially to:

- ✓ Paul Renaud, Lionel Camus and Michael Carroll, Akvaplan-niva, for sampling of sediment and polar cod
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- ✓ Mikael Remberger, Swedish Environmental Research Institute (IVL) for PFR analyses
- ✓ Jon Fuglestad, project manager at Norwegian Pollution Control Authority.

Tromsø 20.02.2009

Anita Evenset

Anita Evenset

Project leader

Innhold

1. Summary

The aim of the present study was to obtain a snapshot of the occurrence of potentially hazardous substances in the marine environment in regions far from local sources. The samples included in the present study were all collected around Svalbard (including Bjørnøya) on different cruises performed as parts of other projects. Most of the samples are from the marine environment (seawater, sediment, fish and seabirds), but one freshwater fish species (Arctic char – *Salvelinus alpinus*) from an Arctic lake with high levels of POPs, Lake Ellasjøen on Bjørnøya, has been included in the study.

The project focused on the following compounds/compound groups: Silver (Ag), platinum (Pt), sucralose, bisphenol A (BPA), tetrabrombisphenol A (TBBPA), siloxanes, bis(2-ethylhexyl)phthalate (DEHP) and phosphororganic flame retardants (PFRs).

Seawater samples were collected in Kongsfjorden, Liefdefjorden and close to Moffen in July an August 2008.

Marine sediment samples were taken in Kongsfjorden (two stations), in Liefdefjorden, in Smeerenburgfjorden, on the Hopen Bank and in the Hopen Trench (April – September 2008). In addition, one sediment sample collected from Lake Ellasjøen on Bjørnøya in 2004 was analysed as part of the project. Samples of Atlantic cod were obtained from Kongsfjorden, while samples of polar cod were collected in Liefdefjorden, Billefjorden and close to Moffen. Archived samples of Arctic char from Lake Ellasjøen (from 2004) was also analysed for selected compounds. Seabirds (kittiwake and common eider) were shot in Kongsfjorden and Liefdefjorden as part of the International Polar Year project COPOL (Contaminants in Polar Regions). Liver samples from these birds were kindly allocated to the screening project.

Sampling areas

The analyses were performed by the Norwegian Institute for Air Research (NILU), Kjeller, and Swedish Environmental Research Institute (IVL).

Seawater samples (n = 3) were analysed for sucralose, but no sucralose was detected in any of the samples (< 0.5 ng/l).

The concentrations of Ag varied from 193 – 427 ng/g dry weight (dw) in the marine sediment samples (according to Molvær *et al.* (1997) levels below 300 ng/g dw can be defined as background levels). Sediment from Hopendypet and Smeerenburgfjorden has Ag-concentrations higher than 300 ng/g dw, but this can be due to natural geological conditions. In Ellasjøen the Ag-concentration was 413 ng/g dw, which is the upper range of values normally found in lake sediments from coastal areas in Northern Norway and slightly higher than Christensen *et al.* (2008) measured in sediment from this lake.

All the sediment samples had low concentrations of Pt (< 20 ng/g dw).

Neither BPA nor TBBPA were detected in any samples of sediment, fish or seabirds analysed in the present study. These compounds are being produced and used in large amounts, and a systematic mapping in a south to north transect can maybe provide better information about their potential for long-range transport.

No siloxanes or DEHP were detected in sediment samples. One or more of the cyclic siloxanes were detected in all, except one, of the fish samples, but the levels were low compared to levels measured in fish from fjords close to urbanised areas. The highest siloxane concentrations measured in the present study were measured in polar cod collected in Liefdefjorden, i.e. in an area far from any local sources. D5 was measured in highest concentrations (up to 19.1 ng/g ww), followed by D3, D6 and D4. The linear siloxane, MDM, was detected in one Atlantic cod sample. Low levels of cyclic siloxanes (D3, D4 and D5 (only in one sample)) were measured in kittiwakes from Kongsfjorden (2.6 – 3.8 ng/g ww). The levels in kittiwakes were generally lower than the levels measured in fish liver. The opposite picture occurs for lipid normalised data so this could be due to differences in lipid content.

DEHP was detected in 11 of the 16 analysed fish samples (from 99 – 293 ng/g ww). The highest concentration was measured in liver from polar cod collected in Billefjorden. DEHP was also detected in kittiwakes from remote fjords (Kongsfjorden and Liefdefjorden), and in one common eider. The concentrations varied from < 88 – 155 ng/g ww, and there were no apparent differences between the two areas (Kongsfjorden vs. Liefdefjorden) or between species. The levels in fish and birds were comparable on a wet weight basis, but when calculated on a lipid basis the levels in seabirds were significantly higher than in fish. The results from the present study thus indicates that DEPH is long-range transported to the Arctic region.

Thirteen phosphorous compounds were analysed, but only 8 were detected in the fish samples (TIBP, TBP, TCEP, TCPP, TDCP, TPhP, EHDPP and TEHP) and 7 in the liver samples from seabirds (TIBP, TBP, TCEP, TCPP, TPhP, EHDPP and TEHP). EHDPP was the dominant compound in both fish (up to 50 ng/g ww) and seabird samples (up to 28 ng/g ww). Of the chlorinated PFRs, TCEP, TCPP and TDCP were detected in the fish samples (< 0.6 – 26 ng/g ww), while only TCEP and TCPP were detected in the seabird samples (< 0.5 – 4.7 ng/g ww). On a wet weight basis the concentrations of most compounds were higher in Atlantic cod than in Arctic char from Lake Ellasjøen and polar cod. On a lipid basis the highest levels occurred in homogenate of whole Atlantic cod. The levels and patterns of phosphorous compounds were generally comparable in all the analysed birds. However, the levels of PFRs were lower in the seabird samples than in samples of fish (both on a wet weight basis and on a lipid basis). The levels of PFRs were in the same range as the siloxane levels, but considerably lower than levels of DEHP in the same samples.

2. Introduction

Many studies have investigated levels and distribution of conventional persistent organic pollutants (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 subject 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 (e.g. some brominated and phosphor containing flame retardants, siloxanes, phthalates). Many of these compounds are relatively persistent in the environment, but their potential for long-range transport and bioaccumulation is being questioned. There are few local sources for contaminants in the Arctic region, thus the occurrence of human-made substances in the Arctic environment indicates that they are being long-range transported, and if they occur in significant concentrations in Arctic organisms they bioaccumulate. In work with international conventions that aim at phasing out harmful compounds, focus is first and foremost being put on properties like persistency, volatility (potential for long-range transport) and toxicity. Compounds that are detected in the Arctic environment, and that has potential toxic effects will therefore be high on the list for chemicals that need to be phased out and substituted by less harmful compounds.

The Norwegian Pollution Control Authority has during the past few years initiated and funded several screening studies for the detection and distribution of various "new contaminants". Most of these studies have focused on areas close to urban settlements, i.e. the main source areas for the selected compounds. The aim of the present study was to obtain a snapshot of the occurrence of potentially hazardous substances in the marine environment in regions far from local sources. The samples included in the present study were all collected around Svalbard (including Bjørnøya). Most of the samples are from the marine environment (seawater, sediment, fish and seabirds), but one freshwater fish species (Arctic char – *Salvelinus alpinus*) from an Arctic lake with high levels of POPs (Evenset *et al.* 2004; 2005), Lake Ellasjøen on Bjørnøya, was included in the study.

The project focused on little known anthropogenic substances and their derivatives, which are either used in high volumes or are likely to be persistent and hazardous to humans and other organisms. Findings of significant concentrations of any of the selected compounds may result in further investigations or monitoring.

An overview of the compounds that were included in the present study is given in Table 1. A brief description of the different compounds, their environmental occurrence and potential effects are given in the following text.

Table 1. Compound that were screened for in the present study. Sample type and number of samples are given in the columns to the right.

Compound group	Compound		Medium	No. of samples
Metals	Ag	Silver	Sediment	3
	Pt	Platinum	Sediment	3
Chlorocarbon	$C_{12}H_{19}Cl_3O_8$	Sucralose	Seawater	3
Brominated compounds	TBBPA	Tetrabrombisphenol A	Sediment Fish Seabirds	7 21 14
Phenolic compounds	BPA	Bisphenol A	Sediment Fish Seabirds	7 21 14
Siloxanes	D3	Hexamethylcyclotri-siloxane	Sediment Fish Seabirds	6 16 14
	D4	Octamethylcyclotetra-siloxane	"	"
	D5	Decamethylcyclopenta-siloxane	"	"
	D6	Dodecamethylcyclohexa-siloxane	"	"
	MM	Hexamethyldi-siloxane	"	"
	MDM	Octamethyltri-siloxane	"	"
	MD2M	Decamethyltetra-siloxane	"	"
	MD3M	Dodecamethylpenta-siloxane	"	"
Fthalates	DEHP	Bis(2-ethylhexyl)phthalate	Sediment Fish Seabirds	6 16 14
Phosphororganic flame retardants	TIBP	Tri-iso-butylphosphate	Fish Seabirds	25 14
	TBP	Tri-n-butylphosphate	"	"
	TCEP	Tris(2-chloroethyl)phosphate	"	"
	TCPP	Tris(2-chloropropyl)phosphate	"	"
	DBPhP	Dibutylfenylfosfat	"	"
	DPhBP	Difenylbutylfosfat	"	"
	TDCP	Tris(1,3-dichloro-2-propyl)phosphate	"	"
	TBEP	Tris(butoxyethyl)phosphate	"	"
	TPhP	Tri-phenylphosphate	"	"
	EHDPP	2-Ethylhexyl-diphenylphosphate, octicizer	"	"
	TEHP	Tris(2-etylhexyl)fosfat	"	"
	ToCrP	Tris-o-chresylfosfat	"	"
	TCrP	Trischresylfosfat	"	"

2.1 Silver (Ag) and platinum (Pt)

2.1.1 Ag

Silver and silver salts have a wide range of applications. Silver shows the best electric conductivity of all metals, and is therefore commonly used in electrical and electronic products, including batteries. Water-soluble silver compounds, such as $AgNO_3$, are well known to have anti-bacterial properties, and are increasingly used as anti-bacterial agents. Recently this ability has been utilized in production of e.g. fridges, washing machines, cosmetics, and clothing to prevent bacterial growth. Earlier one of the most common use of silver salts was in photographic films and papers, but this use is declining (Herzke *et al.* 2007).

Silver is a heavy metal that is poorly dissolved, but that adhere to particles. Most of the silver that is released into the environment is therefore found in soil or sediment. Data on total emissions of silver are not available, but there is a risk that considerable amounts of silver enter the environment through deposited household waste and wastewater. In addition, coal burning contributes large amounts of silver to the atmosphere (Purcell and Peters 1998). Silver released into the atmosphere can adhere to small particles and be subject to long-range atmospheric transport (Krachler *et al.* 2008). It has also been shown that silver can be taken up and accumulated in organisms (Drake & Hazelwood 2005).

Silver has no known biological functions, and metallic silver and insoluble silver compounds appear to pose minimal risk to human health (Drake & Hazelwood 2005). The most prominent effect of prolonged ingestion, inhalation or dermal absorption of silver is discoloration of skin and eyes. On the other hand silver in its ionic form is highly toxic to aquatic animals and plants (WHO 2002). Some acute toxicity data on mammals is available (WHO 2002), and freshwater fish and amphibians are the most sensitive vertebrates to dissolved silver. Recent research also indicates that discharges of silver can contribute to the development of bacteria resistant to antibiotics.

Generally, background concentrations of silver are low in Norway (Steinnes *et al.* 2007). However, elevated levels have been found around some industrial sites (results from moss survey, Steinnes *et al.* 2007). No data on levels of silver in the Arctic marine environment are available.

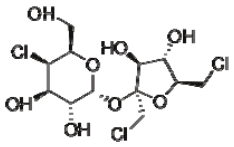
2.1.2 Pt

As silver, platinum belongs to the noble metals. Platinum is used in catalytic converters, sensors and spark plugs, as catalyst in chemical processing, in high temperature and no corrosive wires and contacts, in dental/medical equipment and reconstructives and in cytostatica (Herzke *et al.* 2007). The emission of platinum has increased markedly during the last two decades due to introduction of catalyst in vehicles. Today traffic is the main source of platinum-group elements (PGE) contamination to the environment in urban areas. Possible discharges of platinum containing compounds from medical and dental applications may be discovered in municipal wastewater. Sporadic perturbations of the atmospheric content of Platinum Group Elements (PGEs) are caused also by volcanic eruptions, as recorded in polar glacial archives (Koeberl 1989). The emission of fine PGE-containing particles and their occurrence in urban areas suggest the possibility for long-range transport to e.g. Arctic areas. Pollution of the Northern Hemisphere by Pt has been ascertained in some cases and attributed to the emission from vehicles equipped with catalytic converters (Barbante *et al.* 2001; Van de Velde *et al.* 2000).

In its metallic form Pt is regarded as non-toxic. However, halogenated Pt-salts are known as powerful sensitisers inducing allergic responses. Some platinum drugs exert considerable toxicity, especially on the peripheral nervous system and on the kidney (Hartmann *et al.* 1999; Screnci & McKeage 1999). These drugs are used as therapeutic agents and are designed to be bioactive. Human health effects of metallic platinum are primarily confined to occupational exposure as in for example platinum metal refineries and catalyst manufacture plants (WHO 1991a). According to the WHO report, platinum compounds at concentrations in the mg/l and mg/kg range affect aquatic and terrestrial plants, and several studies have shown that Platinum can bioaccumulate and is bioavailable (Ravindra *et al.* 2004; Zimmermann *et al.* 2005).

Generally, background concentration of platinum in Norway (Steinnes *et al.* 2007) is relatively low.

2.2 Sucralose

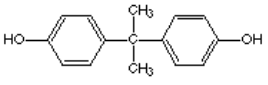


Sucralose

Sucralose (1,6-Dichlor-1,6-dideoxy- β-D-fructofuranosyl-4-chlor-4-deoxy-α-D-glucopyrano-sid ($C_{12}H_{19}Cl_3O_8$)) is a synthetic sweetener which is used as an additive in food products. In the European Union, it is also known under the E number (additive code) E955. Sucralose has been used as an artificial sweetener for nearly 30 years, and today the compound is approved as sweetener in more than 80 countries (Green *et al.* 2008). Norway approved sucralose in June 2005, and the sweetener is now used in various low-calorie food and soft drinks and can also be obtained commercially as sugar substitute (Splenda) in food stores. Sucralose is approximately 600 times sweeter than sucrose (table sugar), twice as sweet as saccharin, and four times as sweet as aspartame. Unlike aspartame, it is stable under heat and over a broad range of pH conditions and can be used in baking or in products that require a longer shelf life.

Sucralose is stable and most of it (85 %) passes unchanged through the human gastrointestinal tract. Sucralose has a low human toxicity and it does not bio-accumulate, thus sucralose itself is not toxic at the levels present in food products. However, the degradation of sucralose in the environment is very slow. The environmental lifetime in Norwegian waters is expected to be 5-10 years. A preliminary study performed by Swedish Environmental Research Institute (IVL) and the Norwegian Institute for Air Research (NILU) showed that more or less all sucralose arriving at sewage treatment plants passes through them, and is spread into the environment (Green *et al.* 2008). The level in sewage water (range from tens of ng/l to several µg/l) are below the levels immediately toxic for organisms living in water, but since the substance degrades slowly it is plausible that the levels will increase over time.

2.3 Tetrabromobisphenol A (TBBPA) and bisphenol A (BPA)

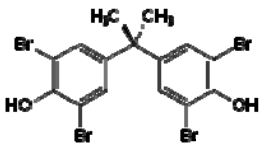


Bisphenol A

Bisphenol A (BPA) is an industrial chemical used to make a hard, clear plastic known as polycarbonate, which is used in many consumer products, including re-usable water bottles, baby bottles, sports equipment, medical and dental devices, dental composite (white) fillings and sealants, lenses, and household electronics. BPA is also found in epoxy resins, which act as a

protective lining on the inside of metal-based food and beverage cans. Products containing or made from BPA have been in commerce for more than 50 years.

BPA has been demonstrated to be weakly estrogenic, binding nuclear estrogen receptors with an affinity approximately 1/10,000 to 1/100,000 that of estradiol (E2) (Bolger *et al.*, 1998; Welshons *et al.*, 1999; Nagel *et al.*, 1997) and causing uterotrophic effects at high doses (200 to 800 mg/kg) in animals (Ashby and Odum, 2004). Despite a half-life in the soil of only 1–10 days, its ubiquity makes it an important pollutant.

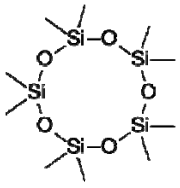


Tetrabrombisphenol A

TBBPA is a derivative of BPA and is synthesized from this substance. It is the most used brominated flame retardants both in Norway and globally. TBBPA can be used as reactive and additive flame retardant. It is used in e.g. printed circuit boards, computers and TVs. TBBPA has been proved toxic and has shown significantly thyroid hormonal activities (Meerts *et al.* 2001). The structure similarity of TBBPA to bisphenol A has suggested that TBBPA might have the ability to bind to the estrogens receptor and disrupt signalling (Meerts *et al.* 2000). TBBPA is more water-soluble than for instance polybrominated diphenyl ethers, and is found in blood and liver of animals. However it may form a metabolite, dimethyl-TBBPA, which is more lipophilic and may accumulate in fat.

Very few data are presently available for BPA and TBBPA in the Arctic environment (de Wit *et al.* 2006), but TBBPA has been detected in Arctic air samples (Xie *et al.* 2007 a), showing that this compound has the potential of long-range transport. It has also been found in marine sediments collected close to urbanised areas in Northern-Norway, in Atlantic cod liver from Lofoten and Varanger area (Fjeld *et al.* 2004) and in Norwegian peregrine falcon and golden eagle eggs (Herzke *et al.* 2005). It has also been found as the dimethylated metabolite at relatively high levels in peregrine falcons from Greenland. However, Fredriksen *et al.* (2007) did not detect TBBPA or dimethyl-TBBPA in any samples of egg, liver, or adipose tissue of marine biota from Greenland and the Faroe Islands in a screening study.

2.4 Siloxanes



Decamethylcyclopenta-siloxane, D5

Siloxanes form a large group of chemicals with molecular weights from a few hundreds to several hundred thousands, but this study is limited to cyclic and linear polydimethyl siloxanes of low molecular weight. They occur as clear viscous liquids at room temperature and have varying physical-chemical properties. Siloxanes are used in a number of industrial applications and in consumer products such as additives in fuel, car polish, cleaners, anti foamers and car waxes. Besides this, they are widely used in e.g. personal care and biomedical products (Table 2). D4, D5, and MM are chemicals of high production volume within the European Union. In the Nordic countries there is a limited use of MD2M, MDM and MM, and more extensive use of D4 and D5. Other compounds are also used, but no numbers are available (Kaj *et al.* 2005). The wide-spread use of siloxanes, their broad application as well as their high volatility has raised the concern for these compounds within various disciplines of environmental science. Norway has placed D5 on a priority list of substances whose emissions should be substantially reduced or halted.

Table 2. Areas of application of siloxanes in the Nordic countries (SPIN, 2005*).

Substance	Area of application
D3	Industry for perfume, raw material and intermediaries for cosmetic production, manufacture of chemicals and chemical products. Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
D4	Fuel additives, Cleaning/washing agents, Impregnation materials, Adhesives, Binding agents, Surface treat-ment, Construction materials, Paints, laquers, varnishes, Fillers, Reprographic agents, Process regulators, Anti-set-off, Anti adhesive agents, Cosmetics
D5	Fuel additives, surface treatment, cleaning/washing agents, filler, impregnation material, adhesives, binding agents, paints, laquers, varnishes, reprographic agents, softeners, surface active agents, process regulators
D6	Surface treatment, paint, laquer, varnishes
MDM, MD2M	Paint, laquer and varnishes

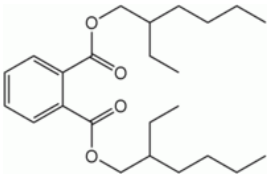
* The figures from the SPIN database only represent the registered use in the Nordic countries. For most products, importers are not obliged to register the full content of chemicals. It is therefore difficult to estimate the true use of siloxanes in the Nordic countries.

Siloxanes are resistant to chemical reactions such as oxidation, reduction, and photodegradation (HSDB, 2004). In the atmosphere, siloxanes may exist both in the vapour and particle phases. When in the particle phase, siloxanes are removed from the air mainly through wet and dry deposition whereas in the vapour phase they may also react with hydroxyl radicals (HSDB, 2004). MM, D4, and D5, have high vapour pressures and high Henry's law constants and presumably vaporize both from wet and dry soils as well as from water. Siloxanes have high Koc and are expected to be immobile in soil. They adsorb to particles in water and are likely to be enriched in sediments (HSDB, 2004). Bioconcentration factors (BCFs) calculated from the apparent octanol/water partition coefficients are generally low for siloxanes with low molecular weight and high for siloxanes with high molecular weight. Laboratory experiments have also shown a high BCF for D4 (HSDB, 2004). In practice, the bioconcentration of heavier siloxanes can be restricted because of limited absorbance through cell membrane due to their large size. High vaporisation of siloxanes from water as a result of their high volatility, combined with high sedimentation rates further reduce the actual concentrations available for uptake in biota (HSDB, 2004).

Recent studies have suggested that siloxanes may have direct or indirect toxic effects on various biological processes. MM is irritant to skin and D4 is classified as R62 "possible risk of impaired fertility" and as R53 "may cause long-term adverse effects in the aquatic environment" in the EU (KemI 2004). Some evidence exists on the potential carcinogenity of siloxane D5 (U.S. EPA 2003).

In a study by Schlabach *et al.* (2007) siloxanes were detected in sewage water, sludge, marine sediment and Atlantic cod (*Gadus morhua*) from the inner Oslofjord area. Very few data exist on siloxanes in the Arctic environment, but they have been found in samples of glaucous gull (*Larus hyperboreus*) collected on Bjørnøya in the Barents Sea (Knudsen *et al.* 2005). The levels of D5 in the gulls were higher than those found in seals along the coast of Denmark and comparable to levels measured in freshwater and marine fish from densely populated areas of Scandinavia (Knudsen *et al.* 2007).

2.5 Phtalates



Bis(2-ethylhexyl)-phthalate, DEHP

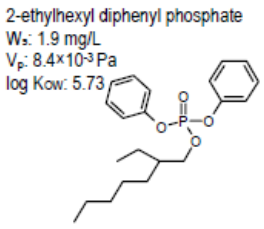
Bis(2-ethylhexyl)phthalate ($C_6H_4(CO_2C_8H_{17})_2$), commonly abbreviated DEHP, is the most commonly used phthalate. Only this phthalate was included in the present study. Phthalates were first produced during the 1920s, and have been produced in large quantities since the 1950s, when polyvinyl chloride (PVC) was introduced. Due to its suitable properties and the low cost, DEHP is widely used as a plasticizer in manufacturing of articles made of PVC. Plastics may contain 1% to 40% of DEHP. It is also used as a hydraulic fluid and as a dielectric fluid in capacitors. DEHP also finds use as a solvent in lightsticks. It has also been used as a plasticiser in medical devices such as intravenous tubing and bags, catheters, nasogastric tubes, dialysis bags and tubing, and blood bags and transfusion tubing, and air tubes.

Multiple recent studies conclude DEHP to be a reproductive and developmental toxicant in animals with a special concern for critically ill male infants. DEHP is thought to be a "gender-bender" chemical that may mimic the estrogen hormone and demasculate boys by altering the anogenital index (Swan *et al.* 2005). However, according to a new risk assessment performed by the European Union in 2008 "DEHP poses no risk to the general population and no further measures need to be taken to manage the substance in any of its key end-use applications" (Commission Communication C/2008 34/1 and Commission Recommendation L 33/8).

DEHP is a semi-volatile compound that has the potential for atmospheric transport (Xie *et al.* 2005; 2007 b). Based on physio-chemical properties it is expected that DEHP in the atmosphere will occur partly associated with particles and partly in gas phase. Xie *et al.* (2007) found that there was an overall deposition from air to sea of DEHP in the Norwegian Sea, the Greenland Sea and in the high Arctic. This suggests that atmospheric transport and deposition of phthlates is a significant process for their occurrence in the remote Atlantic and Arctic Ocean. It is lipid soluble and will therefore adhere to particle and accumulate in lipids once released into the aquatic environment.

In Norway elevated concentrations of DEHP has been found in marine sediments close to sewage outlets (Bakke *et al.* 2007). DEHP has also been detected in samples of sediment and fish from lakes in southern Norway, and in sediment, mussel and fish collected in the marine environment along the coast of Norway (north to Varangerfjorden) (Bakke *et al.* 2007). The results from screening studies performed so far indicates that DEHP are subject to atmospheric transport and deposition and that it biomagnifies in food webs (Bakke *et al.* 2007).

2.6 Phosphororganic flame retardants



Phosphor containing flame retardants (PFR) are not used in the same variety of applications as their brominated counter parts (BFR). Many of the compounds contain halogens. Because of their physical-chemical characteristics they function as plasticisers, broadening their field of application, especially in the production of polyurethane foam. The

chlorinated organophosphate esters tris-(chloro*iso*propyl) phosphate (TCPP), tris-(dichloro*iso*propyl) phosphate (TDCP) and tris-(chloroethyl) phosphate (TCEP) are predominantly used as flame retardants in polyurethane foams. As TCEP was found to be carcinogen in animal experiments the production was phased out around 1990 in Europe (Andresen 2006). It was substituted by TCPP. Although TDCP is carcinogen as well, it is still used as flame retardant for special applications. The market share is in comparison to TCPP small, though. The non-chlorinated alkylphosphates tri-*n*-butylphosphate (T*n*BP), tri-*iso*-butylphosphate (T*i*BP), triphenylphosphate (TPP), ethylhexyldiphenylphosphate (EHDPP) and tris-(butoxyethyl) phosphate (TBEP) are predominantly used as plasticisers. Other applications are as additives to hydraulic fluids, in floor polishes and as flame retardants (Andresen 2006).

A wide range of biological effects of organophosphate esters has been reported, indicating substantial differences between the various organic phosphates. The acute oral toxicity (LC_{50}rats) for the chlorinated and non-chlorinated flame retardants and plasticisers is moderate. It ranges from 1 to 6 g/kg bodyweight for the different substances. For aquatic organism the 96h-LC_{50} values, e.g., in rainbow trout, ranged from 0.36 mg/L to 250 mg/l (WHO 1991 b; c; WHO 1998 a;b). Almost nothing is known on the effect on humans. TBP has been reported to have a slight inhibitory effect on human plasma cholinesterase in an *in vitro* study and for TPP a significant reduction of in red blood cell cholinesterase has been observed.

The octanol-water partition coefficient (K_{ow}) of a substance can be used to predict its potential to bioconcentrate – the higher the log K_{ow} value, the higher its ability to bioconcentrate. Log K_{ow} values for PFRs range from -0.65 to 9.49, indicating that there are significant differences in bioconcentration potential among PFRs The potential for biodegradation decreases with the chain length for alkyl phosphates, and similarly, with the number and size of alkyl substituents for aryl phosphates (Saeger *et al.* 1979). In addition, the chlorinated OPs are more resistant to degradation than alkyl and aryl phosphates (WHO 1991 a; b; 1998).

In the Norwegian environment phosphororganic flame retardants have been found in freshwater and marine sediment collected close to urbanized areas, and in blue mussels from Oslofjorden (only detected in one sample) (Green *et al.* 2008).

3. Material and methods

3.1 Fieldwork

The samples analysed in the present screening were collected on different cruises performed as parts of various projects. The samples from Ellasjøen on Bjørnøya were collected in 2004 and stored at -20° C until analyses. However, most samples were collected in 2008.

Several persons were involved in the sampling performed in 2008. All persons involved in sampling received oral and written instructions about sampling procedures, sampling handling and storage prior to the cruises.

3.1.1 Sampling areas

The marine samples were collected in the Barents Sea (Hopenbanken, Hopenrenna) or in fjords on the west-coast of Spitsbergen. Samples of lake sediment and Arctic char were collected from Lake Ellasjøen, located on the south-western part of Bjørnøya (Figure 1).

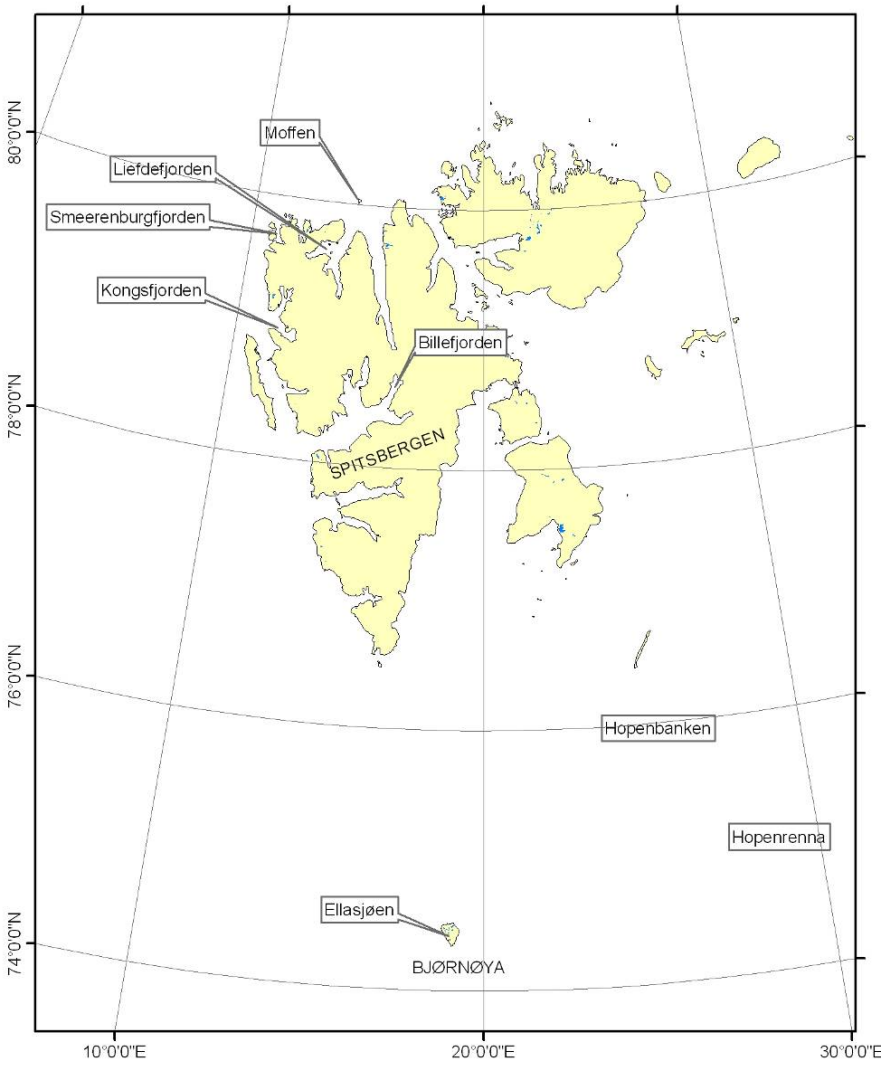


Figure 1. Map showing areas where samples for the screening were collected. Positions for sampling stations are given in chapter 3.1.3 - 3.1.6.

3.1.2 Sampling procedures/QA/QC

All sampling was carried out by personnel that had long experience in sampling for contaminant analyses. All equipment used for sampling were cleaned before use (acetone and hexane) and special storage containers for different sample types were provided by the laboratory (NILU).

Siloxanes are used in many different personal care products, so special precautions had to be taken during sampling for analyses of these compounds. Nitrile gloves were used for all sampling and the personnel involved had to avoid use of personal care products and to shower in clean hot water prior to sampling (no shampoo, deodorant, perfume etc.). Also DEHP occurs in many of the products used in everyday life, so the same precautions were taken for samples for this analysis.

3.1.3 Seawater

Seawater for sucralose analyses were collected on three different sites (Table 3). The samples were collected in water samplers mounted to a CTD- rosette (Figure 2). The water bottles were opened at the required depth, allowed to fill with water, and then closed. Water was tapped directly from the water sampler and into 2 l plastic bottles that were prepared by NILU. The water bottles were labelled and frozen to -20° C immediately after sampling. The samples were stored frozen until analyses.

Table 3. Stations were seawater samples for sucralose analyses were collected.

Location	Station	Date	Latitude °N	Longitude °E	Depth (m)
Kongsfjorden	Kb. 3	20.07.2008	78°57.60'N	11°56.40'E	15
Liefdefjorden	COPOL 2	24.07.2008	79°37.10'N	12°57.94'E	15
Moffen		22.08.008	80°48.00'N	16°20.00'E	15

Figure 2. CTD-rosette used for water sampling. Photo: Guttorm N. Christensen, Akvaplan-niva.

3.1.4 Sediment

The marine sampling was carried out from two different vessels: RV Jan Mayen (Hopen area, Smeerenburgfjorden) and RV Lance (Kongsfjorden and Liefdefjorden). Sampling positions and depths are given in Table 4. The marine sediment samples were collected with a 0.1 m^2 Van Veen grab. Only grabs where the sediment/water interface was undisturbed was used for contaminant samples. The surface sediment (0 – 2 cm) was collected with a steel spoon rinsed with acetone and hexane (3 times) and transferred to pre-cleaned glass-jars for contaminant analyses, acid-treated plastic containers for Ag and Pt-analyses and plastic containers for analyses of total organic carbon (TOC). Blank samples were taken in Kongsfjorden, Liefdefjorden and Smeerenburgfjorden. All samples were frozen on board to -20 °C and kept frozen until analyses.

Figure 3. Sediment sampling in Kongsfjorden, July 2008. Photos: Guttorm N. Christensen, Akvaplan-niva.

The sediment sample from Ellasjøen was collected from a small rubber boat using a gravity corer with diameter 45 mm. Only cores with undisturbed water – sediment interface were used for contaminant analyses. The cores were brought to shore where they were sliced in 0.5 cm intervals. The sediment was transferred to pre-cleaned glass jars and stored frozen at -20° C until analyses. In order to get enough material for screening of new contaminants the upper four segments (0 – 0.5, 0.5 – 1, 1 – 1.5 and 1.5 – 2 cm) were pooled prior to analyses.

Table 4. Information about sampling sites for sediment samples.

Location		Date	Latitude	Longitude	Depth (m)
Kongsfjorden	Kb.3	20.07.2008	78°57.60'N	11°56.40'E	242
Kongsfjorden	COPOL 1	19.07.2008	78°57.30'N	09°34.80'E	329
Liefdefjorden	COPOL 2	23.07.2008	79°37.10'N	12°57.94'E	146
Smeerenburgfjorden		03.09.2008	79°41.57'N	11°07.58'E	205
Hopen Bank	St. 12	29.04.2008	75°55.12'N	25°20.88'E	111
Hopen Trench	St. 18	28.04.2008	75°03.40'N	30°28.23'E	382
Ellasjøen	St. 3	03.07.2004	74°23.19'N	19°01.54'E	20

3.1.5 Fish

In Kongsfjorden and Liefdefjorden Atlantic cod (*Gadus morhua*) and polar cod (*Boreogadus saida*) were caught using multi gill nets. The nets were left in sea for approximately 12 hours before the fish were harvested and sampled. The fish were wrapped in several layers of aluminum foil (at least three) as soon as it was removed from the net, and then put into labelled zip-lock bags. In order to avoid any contamination during sampling the fish were frozen whole (-20° C). Therefore no measurements of length, weight etc. were carried out. However, all the polar cod were in the range 12 – 20 cm, while the Atlantic cod were approximately 30 – 50 cm. In the laboratory the liver were dissected out in a clean room just before analyses. Some of the fish were small and in order to get enough material some analyses had to be carried out on homogenates of whole fish.

Also Arctic char (*Salvelinus alpinus*) from Lake Ellasjøen were caught with gill nets. Length, weight and sex were recorded (Table 6) and the fish were dissected immediately after sampling. A piece of the dorso-lateral muscle was dissected out, wrapped in aluminium foil and put into labelled zip-lock bags. The samples were frozen to -20° C and stored frozen at Akvaplan-niva until analyses. No special precaution to avoid siloxane or DEPH-contamination of the samples from Ellasjøen were taken, so these samples were only analyses for BPA, TBBPA and phosphororganic compounds.

Table 5. Fish sampling stations.

Location	Species	Date	Latitude	Longitude	Depth (m)
Kongsfjorden	Atlantic cod	28.04.2008	78°55.79'N	11°54.80'E	5 - 20
Liefdefjorden	Polar cod	29.04.2008	79°34.71'N	12°48.11'E	10 - 30
Billefjorden	Polar cod	03.09.2008	78°39.40'N	11°07.58'E	75\
Moffen	Polar cod	22.08.2008	80°48.00'N	16°20.00'E	75
Ellasjøen	Arctic char	04.07.2004	74°23.19'N	19°01.54'E	5 – 20

Table 6. Information about fish caught in Ellasjøen, July 2004.

Fish no.	Length (cm)	Weight (g)	Sex
2-04	52.5	1 542	M
4-04	54.0	1 841	M
17-04	34.5	500	M
19-04	43.0	840	M
21-04	41.8	715	M

3.1.6 Seabirds

Kittiwakes (*Rissa tridactyla*) and common eiders (*Somateria mollissima*) were shot in Kongsfjorden and Liefdefjorden in July 2008. Different morphometric measurements (Table 7) were taken in the field. In order to avoid contamination from personnel or equipment in the laboratory the birds were dissected in the field (Figure 4). All equipment used for dissection was rinsed in acetone and hexane (three times) before use and between samples. Liver was removed and sectioned into pieces for different analyses. A piece for analyses of siloxanes and DEPHs was put into pre-cleaned glass jars provided by the laboratory. For analyses of BPA, TBBPA and PFRs a section was wrapped in aluminum foil and put into labelled zip-lock bags. All samples were frozen to -20° C and kept frozen until analyses. Blank samples were taken on both sites.

Table 7. Morphometric data for seabirds that were included in the present screening. All birds were collected in July 2008.

Species	Sample ID	Location	Sex	Wing (cm)	Tars (mm)	Beak (mm)	Head (mm)	Weight (g)
Kittiwake	K41	Kongsfjorden	Female	30.90	39.64	9.97	91.20	344
Kittiwake	K42	Kongsfjorden	Male	33.20	40.95	11.35	94.80	426
Kittiwake	K43	Kongsfjorden	Male	32.10	10.27	10.97	91.75	412
Kittiwake	K44	Kongsfjorden	Male	32.60	39.73	-	-	432
Kittiwake	K45	Kongsfjorden	Male	32.70	41.21	11.74	93.04	388
Kittiwake	K51	Liefdefjorden	Male	32.50	39.80	11.90	92.30	*
Kittiwake	K52	Liefdefjorden	Male	32.90	41.50	11.30	95.00	*
Kittiwake	K54	Liefdefjorden	Female	30.80	39.80	10.10	90.60	*
Kittiwake	K55	Liefdefjorden	Male	32.50	40.20	10.60	92.70	*
Common eider	E41	Kongsfjorden	Female	29.10	62.40	11.93	122.70	1486
Common eider	E42	Kongsfjorden	Female	30.00	61.40	11.50	123.40	1560
Common eider	E43	Kongsfjorden	Female	29.60	65.00	12.68	118.70	1440
Common eider	E44	Kongsfjorden	Female	30.00	65.50	12.40	119.40	1364
Common eider	E45	Kongsfjorden	Female	28.90	60.50	12.20	116.80	1812

* dissection was carried out on Lance, unreliable weight due to boat vibrations

Figure 4. Dissection of common eiders in the field (Kongsfjorden), July 2008. Photo: Guttorm N. Christensen, Akvaplan-niva.

3.2 Chemical analyses

3.2.1 Ag and Pt in sediments

Sample preparation: Dried sediments were extracted in aqua regia using microwave oven. ^{185}Re was added to all standards and samples as internal standard.

Analytical determination: The concentration of silver and platinum were determined using a high resolution plasma mass spectrometer (ELEMENT2, Thermo Inc, Germany).The plasma generator was operated at 1250 W. The silver isotope ^{107}Ag was determined in low resolution mode (R~300) and the platinum isotope ^{195}Pt was determined in high resolution mode (R~11000). The flow rate of plasma gas and auxiliary gas used were 15 l min^{-1} and 1 l min^{-1}, respectively. Nebulizer gas flow was around 0.9 l min^{-1} and optimised daily. The spraychamber assembly consisted of a Meinhard concentric nebulizer and a glass spray chamber of type Scott. Nickel-tipped cones were used for both sampler and skimmer. The data processing and instrument control were performed by the ELEMENT software.

3.2.2 Sucralose in water

Sucralose was analysed in water samples using SPE extraction and clean-up and high pressure liquid chromatography-high resolution mass spectrometry (HPLC-HRMS) detection.

Sample preparation: Samples of sea water (1000 ml) were added D6-labelled sucralose as an internal standard. Sample extractions were performed using reversed phase SPE columns. Sucralose was eluted from the columns with acetone: methanol. To remove matrix compounds the extract was cleaned by passing through two different mixed-mode ion exchange SPE-cartridges with subsequent extract volume reduction.

Instrumental analysis: Liquid chromatography was performed with an Agilent 1100 liquid chromatography system equipped with an autosampler, a quaternary pump and an on-line degassing system. The compound separation was performed with a reversed phase C18 column using water and acetonitrile as mobile phase. The analytical detector was a Micromass LCT orthogonal-acceleration time-of-flight (TOF) mass spectrometer (MS) operated in negative electrospray ionisation mode.

3.2.3 TBA/TBBPA in sediment and biota

TBBPA and BPA were analysed in the sediment and biota samples using solvent extraction, solid phase extraction (SPE) clean-up and ultra pressure liquid chromatography-high resolution mass spectrometry (UPLC-HRMS) detection.

Sample preparation: Biota and wet sediment samples were homogenised with a drying agent, added internal standards and extracted with methyl-tert-butyl ether (MTBE). For sediments, the extracts were cleaned by SPE using ion exchange and polymeric solid phase extraction columns. For biota samples, the phenolic compounds were extracted from the MTBE phase using aqueous sodium hydroxide. The aqueous phase was acidified and subjected to clean-up by reversed phase SPE followed by silica columns.

Instrumental analysis: TBBPA and BPA compounds were analysed by UPLC-HRMS. Reversed phase separation was performed on a Waters Acquity UPLC using a C18 column and acetonitrile and purified water as the mobile phase. The analytes were detected in high resolution on a Waters LCT Premier Time-of-Flight mass spectrometer (TOF-MS) using atmospheric pressure chemical ionisation in negative mode. Quantification was performed using ^{13}C-labelled internal standards.

3.2.4 Siloxanes and DEPH in sediment and biota

Siloxanes and DEHP were analysed in the sediment and biota samples using solvent extraction and gas chromatography-high resolution mass spectrometry (GC-HRMS) detection.

Sample preparation: To avoid sample contamination, all handling and sample preparation was carried out in a clean room laboratory. The clean room is built according to international standards (US Federal Standard 209e) for class 10000 and 100000 particles per ft^3. All glassware was heated to 450°C overnight before use. Other equipment was rinsed thoroughly with hexane to minimize contamination.

Siloxanes and DEHP were extracted from biota and wet sediment by vortex mixing with hexane. For the cyclic polysiloxanes D3, D4, D5 and D6 and the linear polysiloxanes MM, MDM, MD2M and MD3M, a branched siloxane analogue was added as an internal standard prior to extraction. After extraction, the samples were centrifuged and transferred to vials for chromatographic analysis. A second branched siloxane analogue was added before analysis as a recovery control standard. For DEHP, isotope labeled ^{13}C-hexachlorobenzene was used as internal standard and 1,2,3,4-tetrachloronaphtalene as recovery standard.

Instrumental analysis: The chromatographic analysis was performed on an Agilent 5890N gas chromatograph (GC) with Agilent 7683B autosampler. The isomer identification was performed by high-resolution mass spectrometry (HRMS) on a Waters Autospec-V Ultima in positive electron ionisation mode (EI+, 35 eV). Two masses were monitored for each compound.

3.2.5 Organic phosphate esters in biota

Sample preparation: The freeze dried samples (4-44 g ww) were grinded using mortar and pestle and weighted in a test tube. Recovery standard was added (tripentylphosphate; TPA) and mixed well. The samples were extracted with MTBE on a shaking machine for 30 minutes. The extracts were withdrawn and the samples were extracted one more time with MTBE for 30 min. The extracts were combined and concentrated under N_2.

The lipid in the extracts was separated by means of gel permeation chromatography (GPC) or partition extraction of the extract (hexane) and acetonitril. Finally, the sample extracts were fractionated on a solid phase column (PSA Isolute). Prior to GC analysis a volumetric standard was added.

Instrumental analysis: The organic phosphate esters were analysed on a 6890N gas chromatograph coupled to a 5973N mass selective detector (Agilent Technologies, Inc. Santa Clara, CA USA). The samples were injected (1 µl) in split-less mode (240°C). The fused silica capillary column (VF-5MS 30 m x 0.25 mm i.d. x 0.25 µm film thickness, Varian) was held at 45°C for 2 min., ramped 12°C/min to 290°C, and isothermal at 290°C for 2 min. Helium was used as carrier gas. The detector was used in selected ion monitoring mode (SIM) with electron ionisation at energy of 70 eV. The analytes were identified by their characteristic retention times and one target ion (Rrg-ion) used for quantification. In most cases two qualifier ions (Q-ion) were recorded to increase specificity (Table 8). Quantification was based on comparison of peak abundance to the known response of the internal standard (biphenyl). The reported analyte concentrations were corrected according to the determined surrogate (TAP) standard losses.

Table 8.. Summary of target- and qualifier ions used to identify and quantify the target analytes.

Compound	Tgt-ion*	Q1-ion*	Q2-ion*
Tris-*iso*-butylphosphate	99	155	-
Trisbutylphosphate	99	155	-
Trischloroethylphosphate	249	251	205
Tris-chloropropylphosphate	277	279	201
Trisamylphosphate, recoverystandard	99	239	-
Tris-(1,3-dichloropropyl) phosphate	191	209	381
Trisbutoxyphosphate	125	299	-
Trisphenylphosphate	326	235	215
2-ethylhexyl-di-phenylphosphate	251	250	-
Tetrekis(2-chlorethyl)dichloroisopentyldiphosphate (V6)	-	-	-

(*) Explanations: Target ion (T-ion). Qualifier ion (Q_1 och Q_2-ion). Injection standard (IS).

4. Results and discussion

4.1 Ag and Pt

The concentrations of Ag varied from 193 – 427 ng/g dry weight (dw) in the marine sediment samples. The lowest concentrations were found in sediment from Kongsfjorden, followed by Hopenbanken, Liefdefjorden, Hopendypet and Smeerenburgfjorden (Table 9). These concentrations are relatively low. In the Norwegian classification system for fjords and coastal areas developed by SFT, Ag-concentrations below 300 ng/g dw are defined as background levels (Molvær *et al.* 1997). Sediment from Hopendypet and Smeerenburgfjorden has Ag-concentrations higher than 300 ng/g dw, but this can be due to natural geological conditions.

In Ellasjøen the Ag-concentration was 413 ng/g dw, which is the upper range of values normally found in lake sediments from coastal areas in Northern Norway (Rognerud *et al.* 2008). The Ag-concentration measured in the present study is also somewhat higher than previously measured in sediment from Lake Ellasjøen (220 – 230 ng/g dw, Christensen *et al.* 2008).

All the sediment samples had low concentrations of Pt (< 20 ng/g dw) (Table 9).

Table 9. Levels of silver (Ag) and platinum (Pt) in sediment samples (0 – 2 cm) collected around Svalbard, 2008, and in Lake Ellasjøen on Bjørnøya, 2004. Concentrations are given as ng/g dw.

Location	Station	Ag	Pt
Kongsfjorden	Kb3	223.9	<20
Kongsfjorden	COPOL 1	192.6	<20
Liefdefjorden	COPOL 2	262.1	<20
Hopen Bank	St. 12	254.9	<20
Hopen Trench	St. 18	402.9	<20
Smeerenburgfjorden		426.6	<20
Ellasjøen	St. 3	412.5	<20

4.2 Sucralose in water samples

No sucralose was detected in any of the three water samples (concentrations < 0.5 ng/l).

Sucralose has been measured in relatively high concentrations in sewage water and in areas that receives urban sewage (Brorström-Lundén *et al.* 2008; Green *et al.* 2008). In a Swedish screening study where water from reference lakes, i.e. lakes receiving no directs sewage effluent or from sites upstream of sewage outlets, no sucralose was found (Brorström-Lundén *et al.* 2008). Two of the water samples analysed in the present study (Liefdefjorden and Moffen) was collected far from any sewage outlets. The water sample in Kongsfjorden was taken relatively close to Ny-Ålesund. This small settlement is the permanent home to around 35 persons serving the Ny-Ålesund research station all year round. During the summer the population number is significantly higher due to visiting scientists. The sewage outlet from Ny-Ålesund is in Kolhamna, and some sucralose will be released from this site. However, due to the low population number and the large dilution in the fjord system no sucralose could be detected in seawater.

4.3 TBA/TBBPA

4.3.1 Sediment

Concentration of BPA and TBBPA were below the limit of detection for all sediment samples (Table 10).

Table 10. BPA and TBBPA in sediment samples (0 – 2 cm) collected around Svalbard, 2008, and in Lake Ellasjøen on Bjørnøya, 2004. Concentrations are given as ng/g dw.

Location	Station	BPA	TBBPA
Kongsfjorden	Kb3	<0.47	<0.36
Kongsfjorden	COPOL 1	<0.56	<0.20
Liefdefjorden	COPOL 2	<0.50	<0.26
Smeerenburgfjorden		<3.10	<0.62
Hopen Bank	St. 12	<0.39	<0.17
Hopen Trench	St. 18	<0.55	<0.23
Ellasjøen	St. 3	<0.65	<0.38

The results on TBBPA (but not on BPA) from the present study agree well with results published by Bakke *et al.* (2008). Bakke *et al.* (2008) did not detect TBBPA in marine sediment samples (n = 11) collected in the southern and eastern Barents Sea. However, they found BPA-levels varying from 2.32 – 10.20 ng/g dw in the same sediment samples. The highest levels were measured in sediment samples from Tromsøflaket. Fjeld *et al.* (2004) found levels of BPA ranging from 0.01 to 7.40 µg/kg dw in sediments from presumably uncontaminated sites, and equaling 57.5 ng/g dw in a sediment sample collected in Tromsø harbour. TBBPA-levels in sediment from Tromsø harbour was 1.24 ng/g dw. Thus, the levels of TBBPA in sediment analysed in the present study were comparable to those measured in other screening studies in northern regions, while BPA-levels were significantly lower. However, the sediment samples analysed as part of the present study were collected further north than the samples analysed by Fjeld *et al.* (2004) and Bakke *et al.* (2008), i.e. in larger distance from potential source areas. This could be the reason for the differences in BPA-levels, but this should be investigated further by analysing sediment samples collected in a transect from the Norwegian coast and north to Spitsbergen.

4.3.2 Fish

BPA or TBBPA were not detected in any of the analysed fish species (Table 11).

Fjeld *et al.* (2004) detected low levels of TBBPA in liver samples from cod collected in Lofoten and Varangerfjorden, but the concentration of BPA was below the detection limit in the same samples. As far as we know there are no data available on levels of BPA or TBBPA in fish from high Arctic regions.

Table 11. BPA and TBBPA in fish collected around Svalbard, 2008, and in Lake Ellasjøen on Bjørnøya, 2004. Concentrations are given as ng/g wet weight (ww).

Species	Location	Tissue	BPA	TBBPA
Atlantic cod	Kongsfjorden	Liver	<2.2	<3.3
Atlantic cod	Kongsfjorden	Liver	<2.1	<2.9
Atlantic cod	Kongsfjorden	Liver	<1.8	<1.1
Atlantic cod	Kongsfjorden	Liver	<2.5	<2.5
Atlantic cod	Kongsfjorden	Liver	<2.2	<3.1
Polar cod	Levdifjorden	Liver	<0.70	<0.34
Polar cod	Levdifjorden	Liver	<1.2	<0.67
Polar cod	Billefjorden	Liver	<1.0	<1.6
Polar cod	Billefjorden	Liver	<1.6	<1.9
Polar cod	Billefjorden	Liver	<1.1	<0.66
Polar cod	Billefjorden	Liver	<2.1	<1.3
Polar cod	Moffen	Whole fish	<1.7	<0.20
Polar cod	Moffen	Whole fish	<3.6	<0.19
Polar cod	Moffen	Whole fish	<3.0	<0.20
Polar cod	Moffen	Whole fish	<4.0	<0.30
Polar cod	Moffen	Whole fish	<1.0	<0.47
Arctic char	Ellasjøen	Muscle	<0.13	<0.43
Arctic char	Ellasjøen	Muscle	<0.31	<0.40
Arctic char	Ellasjøen	Muscle	<0.32	<0.45
Arctic char	Ellasjøen	Muscle	<0.48	<0.25
Arctic char	Ellasjøen	Muscle	<0.32	<0.38

4.3.3 Seabirds

None of the phenolic compounds were detected in liver samples from kittiwake or common eider (Table 12). As far as we know these compounds have not been analysed in these seabird species before.

The results are in agreement with those published by Frederiksen *et al.* (2007). They did not detect TBBPA or dimethyl-TBBPA in any samples of fish (shorthorn sculpin (*Myoxocephalus scorpius*), seabirds (Fulmar (*Fulmarus glacialis*), black guillemots (*Cepphus grylle*), or marine mammals (ringed seal (*Phoca hispida*), minke whale (*Balaenoptera acutorostrata*), pilot whale (*Globicephala melas*), polar bear (*Ursus maritimus*)) from Greenland or the Faroe Islands in a screening study performed in 2006.

Table 12. BPA and TBBPA in liver from seabirds from Kongsfjorden and Liefdefjorden on Svalbard, July 2008. Concentrations are given as ng/g ww.

Species	Location	Individual no.	BPA	TBBPA
Kittiwake	Kongsfjorden	K41	<1.4	<0.18
Kittiwake	Kongsfjorden	K42	<1.5	<0.11
Kittiwake	Kongsfjorden	K43	<1.7	<0.21
Kittiwake	Kongsfjorden	K44	<2.4	<0.19
Kittiwake	Kongsfjorden	K45	<0.78	<0.16
Kittiwake	Liefdefjorden	K51	<0.94	<0.20
Kittiwake	Liefdefjorden	K52	<0.76	<0.15
Kittiwake	Liefdefjorden	K54	<1.1	<0.18
Kittiwake	Liefdefjorden	K55	<1.4	<0.19
Eider	Kongsfjorden	E41	<0.93	<0.17
Eider	Kongsfjorden	E42	<2.9	<0.21
Eider	Kongsfjorden	E43	<1.8	<0.15
Eider	Kongsfjorden	E44	<1.5	<0.41
Eider	Kongsfjorden	E45	<1.5	<0.29

4.3.4 Conclusions, BPA and TBBPA

Neither BPA nor TBBPA were detected in any samples of sediment, fish or seabirds analysed in the present study. However, BPA has previously been detected in sediment samples collected in the southern and eastern Barents Sea (Bakke *et al.* (2008). These compounds are being produced and used in large amounts, and a systematic mapping in a south to north transect can maybe provide better information about their potential for long-range transport.

4.4 Siloxanes and DEHP

4.4.1 Sediment

No siloxane-compounds were detected in the sediment samples collected on the west-coast of Spitsbergen (Table 13). Also DEHP was below the detection limit in all the samples (Table 13).

In order to check for possible contamination during sampling field blanks from all three samples sites were analysed for the same compounds as the sediment samples. MM was found in low concentrations in one of the blank samples, but not in any of the samples (Table 13).

Table 13. Siloxanes in sediment samples (0 – 2 cm) collected around Svalbard, 2008, and in Lake Ellasjøen on Bjørnøya, 2004. Concentrations in samples are given as ng/g dw. Concentrations in blank samples are given as ng/sample.

Location	Station	MM	MDM	MD2M	MD3M	D3	D4	D5	D6	DEHP
Kongsfjorden	Blank, Kb3	<0.31	<0.19	<0.28	<0.29	<6.0	<4.8	<4.5	<15	n.a.
Kongsfjorden	Blank, COPOL 1	<1.0	<0.30	<0.52	<0.45	<4.9	<4.0	<5.5	<17	<60
Liefdefjorden	Blank	0,51	<0.19	<0.28	<0.29	<0.94	<1.1	6,8	<0.79	<60
Kongsfjorden	Kb3	<0.33	<0.23	<0.31	<0.29	<5.1	<4.0	<3.8	<13	<60
COPOL 1	COPOL 1	<0.71	<0.21	<0.42	<0.33	<3.3	<2.7	<3.7	<11	<60
Liefdefjorden	COPOL 2	<0.88	<0.27	<0.55	<0.44	<4.2	<3.3	<4.6	<14	<60

Bakke *et al.* (2008) analysed 11 sediment samples collected in the southern and eastern Barents Sea for cyclic siloxanes and DEHP. They found measurable concentrations of D4 in one sediment sample (40 ng/g dw) and of D5 in two (11 and 13 ng/g dw). In all other sediment samples the siloxane concentrations were below detection limits. DEHP-concentrations in the same sediment samples varied from 1 160 – 57 690 ng/g dw. Thus, the results on siloxanes from the present study were in good agreement with those from Bakke *et al.* (2008). However, the DEHP-levels measured by Bakke *et al.* (2008) were very much higher than those measured in sediment from the Svalbard fjords. The DEHP-levels reported by Bakke *et al.* are also considerable higher than those previously measured in sediment samples collected in contaminated Norwegian fjords (e.g. inner Oslofjord, Frierfjorden and Kristiansandsfjorden). Thus, it is likely that the samples from the Barents Sea have been contaminated during sampling or storage (Bakke *et al.* 2008).

4.4.2 Fish

The linear siloxane, MDM, was detected in one liver sample from Atlantic cod (Kongsfjorden) and one liver sample from polar cod (Billefjorden) (Table 14). The levels measured in these samples were comparable or slightly higher than those previously measured in liver from Atlantic cod caught in Oslofjorden (Schlabach *et al.* 2007). Based on molecular weight one would expect a relatively low bioaccumulation of this compound, so its occurrence in Atlantic cod from Kongsfjorden is unexpected.

One or more of the cyclic siloxanes were detected in all, except one, of the fish samples. D3 was detected in 12 of 16 analysed samples (3.6 – 10.4 ng/g ww), D4 in 15 of 16 samples (2.6 – 9.2 ng/g ww), D5 in 15 of 16 samples (2.2 – 19.1 ng/g ww) and D6 in 7 of 16 samples (2.2 – 10.7 ng/g ww). D3, D4 and D5 were detected in all the Atlantic cod samples, but no D6 was found in liver from this species. In polar cod from Liefdefjorden D3, D4, D5 and D6 were found. No D3 was found in polar cod from Billefjorden. On a lipid weight basis the levels of cyclic siloxanes were highest in whole polar cod from the Moffen area (Appendix 1). This is probably due to the low lipid content in these samples. Bioconcentration factors calculated from the apparent octanol/water partition coefficients are generally low for siloxanes with low molecular weight and high for siloxanes with high molecular weight, thus a high bioconcentration could be expected for e.g. D6 and D5. Laboratory experiments have also shown high BCF for D4 (HSDB, 2004). In the present study levels of the cyclic siloxanes were comparable in all the fish samples. However, since no data on siloxane levels in water or prey items for the species investigated in the present study are available it is difficult to say anything about bioconcentration or bioaccumulation potential for the different compounds.

The siloxane concentrations measured in the Arctic fish samples were low compared to concentrations measured in e.g. Atlantic cod from industrialised areas, like the Oslofjord area where up to 2 200 ng/g ww of D5 was measured in in cod liver (Schlabach *et al.* 2007).

DEHP was detected in 11 of the 16 analysed fish samples, in considerable higher concentrations that the siloxanes. The highest concentration (293 ng/g ww) was measured in liver from polar cod collected in Billefjorden. Measurable concentration of DEHP was also found in liver from 3 of the Atlantic cod sampled in Kongsfjorden and in liver from polar cod sampled in Liefdefjorden (Table 14). On a lipid weight basis the DEHP-levels in liver from Atlantic cod and polar cod were comparable (Appendix 1). No DEHP was found in polar cod (whole fish) from Moffen.

Table 14. Siloxanes and DEHP in fish collected around Svalbard, 2008. Concentrations are given as ng/g ww. AC = Atlantic cod, PC = polar cod, Wf = whole fish.

Species	Location	Tissue	Lipid %	MM	MDM	MD2M	MD3M	D3	D4	D5	D6	DEHP
AC	Kongsfjorden	Liver	38	<0.22	0,33	<0.18	<0.23	5.0	3.9	3.9	<9.7	156
AC	Kongsfjorden	Liver	42	<0.17	<0.12	<0.19	<0.17	4.3	2.9	2.8	<8.1	<88
AC	Kongsfjorden	Liver	43	<0.15	<0.13	<0.21	<0.16	4.4	3.9	4.0	<9.3	125
AC	Kongsfjorden	Liver	31	<0.10	<0.09	<0.15	<0.12	5.3	3.7	2.7	<8.3	<88
AC	Kongsfjorden	Liver	30	<0.19	<0.13	<0.22	<0.21	7.1	3.9	4.6	<9.5	203
PC	Liefdefjorden	Liver	35	<0.20	<0.15	<0.21	<0.20	10.4	9.2	19.1	10.7	142
PC	Liefdefjorden	Liver	39*	<0.21	<0.16	<0.23	<0.22	5.8	6.3	18.6	10.7	126
PC	Billefjorden	Liver	39*	<0.16	0,17	<0.20	<0.17	<3.3	2.6	6.9	<8.2	99
PC	Billefjorden	Liver	39*	<0.13	<0.12	<0.18	<0.15	<3.2	3.2	8.6	<8.1	<60
PC	Billefjorden	Liver	37	<0.18	<0.15	<0.20	<0.25	<4.3	<3.4	9.4	<11	<60
PC	Billefjorden	Liver	46	<0.33	<0.18	<0.27	<0.25	<4.3	3.9	11.9	<11	293
PC	Moffen	Wf	3.4	<0.30	<0.21	<0.52	<0.75	9.9	7.8	<2.5	3.2	<60
PC	Moffen	Wf	3.5	<0.34	<0.19	<0.59	<0.71	7.2	6.5	4.3	2.9	<60
PC	Moffen	Wf	2.9	<0.31	<0.18	<0.42	<0.66	7.5	6.7	3.7	3.8	<60
PC	Moffen	Wf	2.71	<0.18	<0.09	<0.27	<0.30	3.6	3.6	2.2	2.2	<60
PC	Moffen	Wf	5.73	<0.30	<0.13	<0.44	<0.58	7.6	7.4	5.1	2.9	<60

* estimated

4.4.3 Seabirds

No linear siloxanes were detected in seabird livers. D3 and D4 were detected in liver from 4 of the 5 kittiwakes collected in Kongsfjorden (2.6 – 3.8 ng/g ww), while D5 was detected in liver from one of the Kongsfjorden birds (1.5 ng/g ww). However, D5 was also detected in the field blank from Kongsfjorden (Table 15), so contamination of the sample during field processing cannot be excluded. No siloxanes were detected in kittiwakes shot in Liefdefjorden (Table 15). It is possible that the kittiwakes in Kongsfjorden have been exposed to siloxanes originating from the small research community in Ny-Ålesund. However, no siloxanes were detected in common eiders from Kongsfjorden. The two bird species have different diets and different trophic levels, and this could possibly explain differences in siloxane levels. Kittiwakes feed mainly in the pelagic zone, on crustaceans and small fish, while eiders have a benthic diet (molluscs, polychaets, benthic crustaceans etc.). Another explanation could be that these species have differences in metabolic capacity.

In a study by Knudsen *et al.* (2007) D5 (the only siloxane compound measured in their study) was detected in liver samples from dead glaucous gulls (*Larus hyperboreus*) found on Bjørnøya. Levels of this compound varied from 32.2 – 68.8 ng/g ww. This is much higher than the levels measured in kittiwakes in the present study (1.5 ng/g ww in one kittiwake from Kongsfjorden). Kittiwake and glaucous gulls have different diets (glaucous gull is omnivorous) and glaucous gulls generally have much higher levels of persistent organic contaminants than kittiwakes.

DEHP was detected in 6 of the kittiwakes (4 from Kongsfjorden and 2 from Liefdefjorden), and in one common eider (Table 15). The concentrations varied from < 88 – 155 ng/g ww, and there were no apparent differences between the two areas (Kongsfjorden vs. Liefdefjorden) or between species.

Table 15. Siloxanes and DEHP in liver from seabirds from Kongsfjorden and Liefdefjorden on Svalbard, July 2008. Concentrations in samples are given as ng/g ww. Concentration in blank sample is given as ng/sample.

Species	Location	Ind. no.	Lipid %	MM	MDM	MD2M	MD3M	D3	D4	D5	D6	DEHP
Field blank	Kongsfjorden			0,48	<0.30	<0.84	<1.1	<0.94	<1.1	5,2	<0.79	<88
Kittiwake	Kongsfjorden	K41	3	<0.21	<0.09	<0.34	<0.38	3,8	3,2	<1.7	<1.7	<88
Kittiwake	Kongsfjorden	K42	2.5	<0.22	<0.08	<0.24	<0.38	2,9	2,6	1,5	<1.8	105
Kittiwake	Kongsfjorden	K43	2.22	<0.26	<0.11	<0.42	<0.42	3,0	2,7	<2.1	<2.0	105
Kittiwake	Kongsfjorden	K44	2.17	<0.26	<0.13	<0.38	<0.44	<2.5	<3.0	<2.2	<2.1	111
Kittiwake	Kongsfjorden	K45	2.8	<0.27	<0.14	<0.43	<0.50	3,7	3,5	<2.3	<2.1	94
Kittiwake	Liefdefjorden	K51	4.3	<0.31	<0.15	<0.49	<0.56	<3.0	<3.6	<2.6	<2.5	155
Kittiwake	Liefdefjorden	K52	4.21	<0.26	<0.13	<0.39	<0.43	<2.4	<2.9	<2.1	<2.0	<88
Kittiwake	Liefdefjorden	K54	5.81	<0.25	<0.12	<0.42	<0.45	<2.4	<2.9	<2.1	<2.0	<88
Kittiwake	Liefdefjorden	K55	2.44	<0.26	<0.15	<0.46	<0.58	<2.4	<2.9	<2.1	<2.0	105
Eider	Kongsfjorden	E41	1.5	<0.27	<0.11	<0.47	<0.51	<2.6	<3.1	<2.3	<2.1	100
Eider	Kongsfjorden	E42	1.94	<0.23	<0.13	<0.36	<0.48	<2.1	<2.6	<1.9	<1.8	<88
Eider	Kongsfjorden	E43	1.67	<0.33	<0.18	<0.46	<0.68	<3.1	<3.8	<2.8	<2.6	<88
Eider	Kongsfjorden	E44	2.61	<0.28	<0.17	<0.44	<0.59	<2.6	<3.2	<2.3	<2.2	<88
Eider	Kongsfjorden	E45	1.7	<0.23	<0.16	<0.36	<0.47	<2.1	<2.6	<1.9	<1.8	<88

4.4.4 Conclusions, siloxanes and DEHP

No siloxanes or DEHP were detected in sediment samples.

One or more of the cyclic siloxanes were detected in all, except one, of the fish samples, but the levels were low compared to levels measured in fish from fjords close to urbanised areas. The highest concentrations measured in the present study were measured in polar cod from Liefdefjorden, i.e. in an area far from any local sources. D5 was measured in highest concentrations (up to 19.1 ng/g ww), followed by D3, D6 and D4. The linear siloxane, MDM, was detected in one Atlantic cod sample. Based on molecular weight one would expect a relatively low biocaccumulation of this compound, so its occurrence in Atlantic cod from Kongsfjorden is unexpected.

Low levels of cyclic siloxanes (D3, D4 and D5 (only in one sample)) were measured in kittiwakes from Kongsfjorden (2.6 – 3.8 ng/g ww). The levels in kittiwakes were generally lower than the levels measured in fish liver. The opposite picture occurred for lipid

normalised data (see Appendix 1) so this could be due to differences in lipid content. Differences in exposure in air and water, or loss through respiration may also be a reason for differences in siloxane levels in fish and birds. Since seabirds are air breathing organisms and the siloxanes highly volatile compounds, loss of siloxanes through expiration may also occur.

DEHP was detected in 11 of the 16 analysed fish samples (from 99 – 293 ng/g ww). The highest concentration was measured in liver from polar cod collected in Billefjorden. DEHP was thus detected in samples collected in Kongsfjorden and in the other Arctic fjords where there are no local sources for phthalates. DEHP was also detected in kittiwakes from remote fjords (Kongsfjorden and Liefdefjorden), and in one common eider (Table 15). The concentrations varied from < 88 – 155 ng/g ww, and there were no apparent differences between the two areas (Kongsfjorden vs. Liefdefjorden) or between species. The levels in fish and birds were comparable on a wet weight basis, but when calculated on a lipid basis the levels in seabirds were significantly higher than in fish (see Appendix 1).

4.5 Phosphororganic compounds

4.5.1 Fish

Due to lack of liver material most of the analyses of phosphororganic compounds were performed on homogenates of whole fish.

Thirteen phosphorous compounds were analysed, but only 8 were detected in the fish samples (TIBP, TBP, TCEP, TCPP, TDCP, TPhP, EHDPP and TEHP). TIBP and TDCP have previously been detected in low concentrations in air samples from Ny-Ålesund (Green *et al.* 2008), indicating long-range transport for these compounds. DBPhP, DPhBP, TBEP, ToCrP or TCrP were not detected in any of the samples analysed in the present study. TEHP was only detected in one sample (liver from Atlantic cod) (Table 16). TPhP was the only phosphororganic compound that was detected in all the analysed fish samples, but the levels were relatively low (from 0.5 – 2.4 ng/g ww in whole fish and from 5.7 – 13 ng/g lw in liver from Atlantic cod).

EHDPP was detected in all but one sample, and had the highest levels (from 1.3 – 52 ng/g ww or from 83 – 3200 ng/g lw). This compound has been shown to occur in relatively high concentrations in sewage sludge (Marklund 2005), and to bioaccumulate in organisms (Muir *et al.* 1985). However, little data on environmental occurrence and bioaccumulation of this compound is available.

The chlorinated PFRs, TCEP and TCPP, were detected in most of the fish samples, while TDCP was detected in 9 of the 25 analysed fish samples (Table 16). These compounds can be classified as persistent organic pollutants (Andresen 2005), but due to relatively low log Kow-values they are expected to have a low potential for bioconcentration and bioaccumulation. In an exposure study performed by Sasaki *et al.* (1981) no bioconcentration of TCEP occurred in goldfish or killifish, while relatively high bioconcentration factors were estimated for TDCP. In the present study TCEP was detected in more samples than TDCP, but in samples where both compounds were detected the levels were generally comparable. Since we have no information about water concentrations of these compounds in Arctic region, no conclusions about bioconcentration factors can be drawn.

On a wet weight basis the concentrations of most compounds were highest in Atlantic cod, followed by Arctic char from Lake Ellasjøen and polar cod (Figure 5). On a lipid basis the highest levels occurred in homogenate of whole Atlantic cod (Appendix 1).

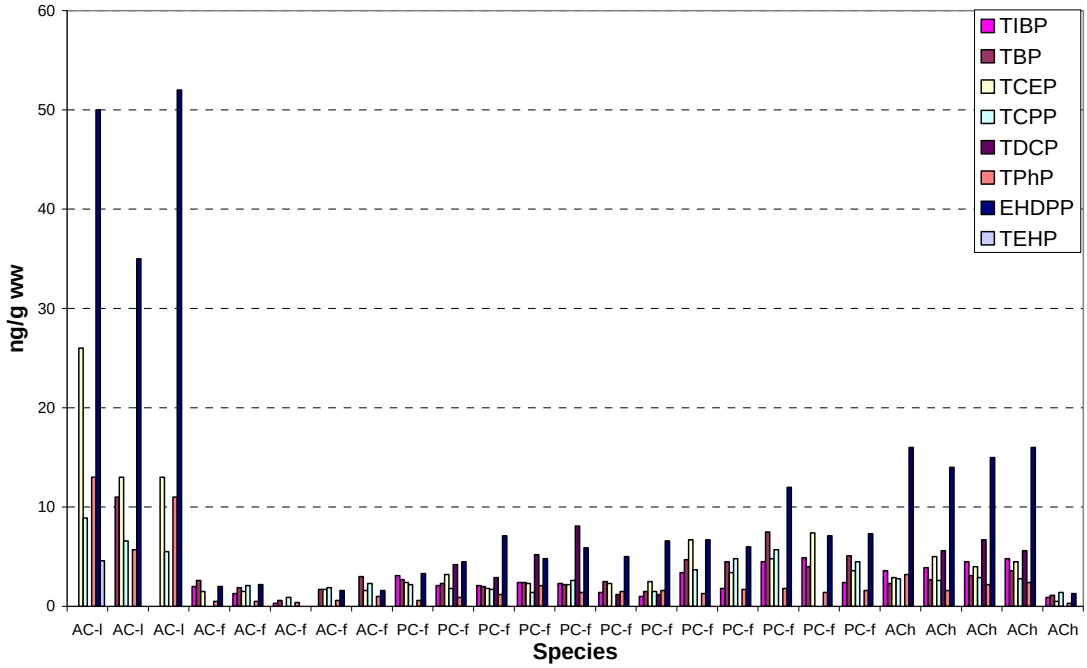


Figure 5. Phosphororganic compounds in fish samples. Only compounds that were detected in the seabird samples are included in the figure. AC-l = Atlantic cod, liver, AC-f= Atlantic cod, whole fish, PC-f = polar cod, whole fish, ACh = Arctic char, muscle.

4.5.2 Seabirds

DPhBP, TDCP, TBEP, TEHP, ToCrP or TCrP were not detected in any of the analysed seabird samples. DBPhP was only detected in low concentrations (0.33 ng/g ww) in liver from one kittiwake from Kongsfjorden (Table 17). TPhP and EHDPP were detected in all the seabird samples in concentrations ranging from 0.6 – 3.3 ng/g ww and 6.0 – 28 ng/g ww, respectively.

The chlorinated PFRs, TCEP and TCPP, occurred in 8 and 11 seabird samples (< 0.5 – 4.7 ng/g ww), respectively. The concentrations of these compounds were generally lower than the concentrations of EHDPP (6.0 – 28.0 ng/g ww), but in the same range or somewhat higher than the concentrations of TPhP (0.9 – 3.3 ng/g ww) (Table 17).

The levels and patterns of phosphorous compounds were generally comparable in all the analysed birds (Figure 6). Generally the levels of PFRs were lower in the seabird samples than in samples of fish (both on a wet weight basis (Table 16; Table 17) and on a lipid basis (Appendix 1). This may be due to differences in diet or metabolic degradation and excretion. Differences in accumulation pattern (e.g. muscle vs. liver) may also be the reason for different concentrations.

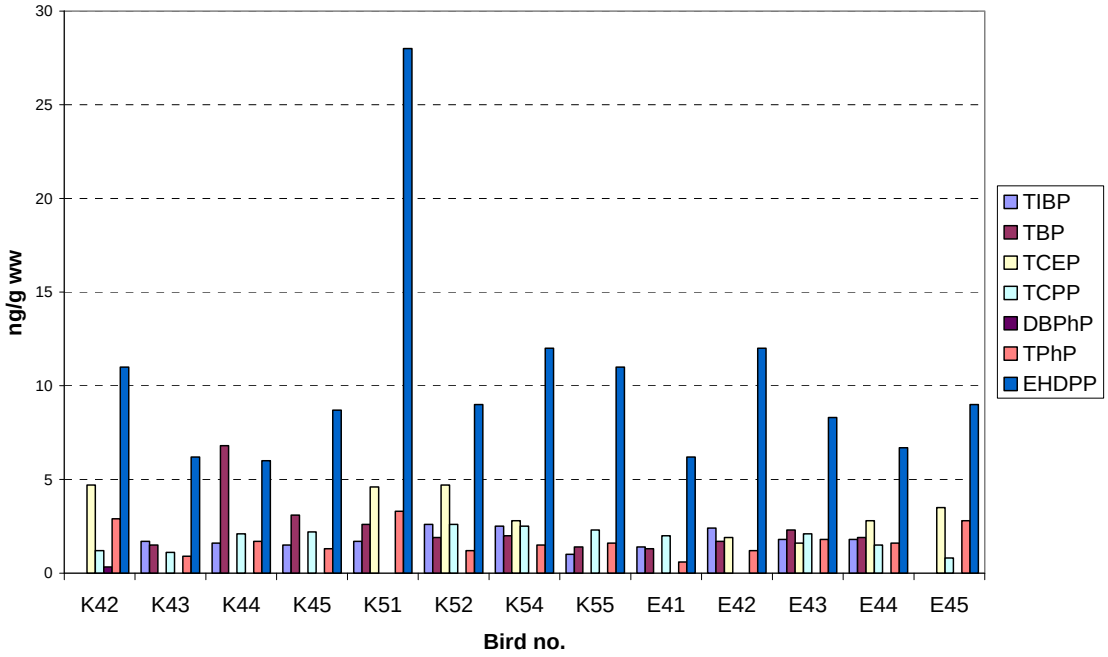


Figure 6. Phosphororganic compounds in liver samples from seabirds from Kongsfjorden and Liefdefjorden, July 2008. Only compounds that were detected in the seabird samples are included in the figure. K = kittiwake, E = common eider.

4.5.3 Conclusions, Phosphororganic compounds

Thirteen phosphorous compounds were analysed, but only 8 were detected in the fish samples (TIBP, TBP, TCEP, TCPP, TDCP, TPhP, EHDPP and TEHP) and 7 in the liver samples from seabirds (TIBP, TBP, TCEP, TCPP, TPhP, EHDPP and TEHP).

EHDPP was the dominant compound in both fish (up to 50 ng/g ww) and seabird samples (up to 28 ng/g ww). Of the chlorinated PFRs, TCEP, TCPP and TDCP were detected in the fish samples (< 0.6 – 26 ng/g ww), while only TCEP and TCPP were detected in the seabird samples (< 0.5 – 4.7 ng/g ww). On a wet weight basis the concentrations of most compounds were higher in Atlantic cod than in Arctic char from Lake Ellasjøen and polar cod (Figure 5). On a lipid basis the highest levels occurred in homogenate of whole Atlantic cod (Appendix 1). The levels and patterns of phosphorous compounds were generally comparable in all the analysed birds (Figure 6). However the levels of PFRs were lower in the seabird samples than in samples of fish (both on a wet weight basis (Table 16; Table 17) and on a lipid basis) (Appendix 1).

The levels of PFRs were in the same range as the siloxane levels, but considerably lower than levels of DEHP in the same samples.

Table 16. Phosphororganic compounds in fish collected around Svalbard, 2008. Concentrations are given as ng/g ww.

Sample type	Location	Tissue	Lipid content	TIBP	TBP	TCEP	TCPP	DBPhP	DPhBP	TDCP	TBEP	TPhP	EHDPP	TEHP	ToCrP	TCrP
AC	Kongsfjorden	Liver	38.0 %	<2	<2	26	8.9	<1	<1	<6	<6	13	50	4.6	<2	<2
AC	Kongsfjorden	Liver	42.0 %	<2	11.0	13	6.6	<1	<1	<6	<6	5.7	35	<1	<2	<2
AC	Kongsfjorden	Liver	31.0 %	<2	<2	13	5.5	<1	<1	<6	<6	11	52	<1	<2	<2
AC	Kongsfjorden	Whole fish*	0.14 %	2.0	2.6	1.5	<0.1	<0.05	<0.1	<0.3	<0.2	0.5	2.0	<0.04	<0.08	<0.08
AC	Kongsfjorden	Whole fish*	0.15 %	1.3	1.9	1.5	2.1	<0.05	<0.1	<0.3	<0.2	0.5	2.2	<0.04	<0.08	<0.08
AC	Kongsfjorden	Whole fish*	0.11 %	0.3	0.6	<1.5	0.9	<0.05	<0.1	<0.3	<0.2	0.4	<2	<0.04	<0.08	<0.08
AC	Kongsfjorden	Whole fish*	0.13 %	<0.3	1.7	1.7	1.9	<0.1	<0.2	<0.6	<0.6	0.6	1.6	<0.1	<0.2	<0.2
AC	Kongsfjorden	Whole fish*	0.05 %	<0.3	3.0	1.6	2.3	<0.1	<0.2	<0.6	<0.6	1.0	1.6	<0.1	<0.2	<0.2
PC	Moffen	Whole fish	3.39 %	3.1	2.7	2.4	2.2	<0.1	<0.2	<0.6	<0.6	0.6	3.3	<0.1	<0.2	<0.2
PC	Moffen	Whole fish	3.45 %	2.1	2.3	3.2	1.8	<0.1	<0.2	4.2	<0.6	0.9	4.5	<0.1	<0.2	<0.2
PC	Moffen	Whole fish	2.90 %	2.1	2.0	1.8	1.7	<0.1	<0.2	2.9	<0.6	1.2	7.1	<0.1	<0.2	<0.2
PC	Moffen	Whole fish	2.71 %	2.4	2.4	2.3	1.4	<0.1	<0.6	5.2	<0.6	2.1	4.8	<0.1	<0.2	<0.2
PC	Moffen	Whole fish	5.73 %	2.3	2.2	2.2	2.6	<0.1	<0.2	8.1	<0.6	1.4	5.9	<0.1	<0.2	<0.2
PC	Liefdefjorden	Whole fish*	1.11 %	1.4	2.5	2.3	<0.5	<0.1	<0.6	1.2	<0.6	1.5	5.0	<0.1	<0.2	<0.2
PC	Liefdefjorden	Whole fish*	1.39 %	1.0	1.5	2.5	1.5	<0.1	<0.6	1.2	<0.6	1.6	6.6	<0.1	<0.2	<0.2
PC	Billefjorden	Whole fish*	2.32 %	3.4	4.7	6.7	3.7	<0.2	<0.2	<1.5	<0.6	1.3	6.7	<0.2	<0.6	<0.6
PC	Billefjorden	Whole fish*	1.39 %	1.8	4.5	3.4	4.8	<0.2	<0.2	<1.5	<0.6	1.7	6.0	<0.2	<0.6	<0.6
PC	Billefjorden	Whole fish*	1.34 %	4.5	7.5	4.8	5.7	<0.2	<0.2	<1.5	<0.6	1.8	12	<0.2	<0.6	<0.6
PC	Billefjorden	Whole fish*	1.55 %	4.9	4.0	7.4	<0.5	<0.2	<0.2	<1.5	<0.6	1.4	7.1	<0.2	<0.6	<0.6
PC	Billefjorden	Whole fish*	1.24 %	2.4	5.1	3.6	4.5	<0.2	<0.2	<1.5	<0.6	1.6	7.3	<0.2	<0.6	<0.6
ACh	Ellasjøen	Muscle	4.11 %	3.6	2.3	2.9	2.8	<0.05	<0.1	<0.3	<0.2	3.2	16	<0.04	<0.08	<0.08
ACh	Ellasjøen	Muscle	6.51 %	3.9	2.7	5.0	2.6	<0.05	<0.1	5.6	<0.2	1.6	14	<0.04	<0.08	<0.08
ACh	Ellasjøen	Muscle	5.79 %	4.5	3.1	4.0	2.9	<0.1	<0.2	6.7	<0.6	2.2	15	<0.1	<0.2	<0.2
ACh	Ellasjøen	Muscle	6.47 %	4.8	3.6	4.5	2.8	<0.1	<0.2	5.6	<0.6	2.4	16	<0.1	<0.2	<0.2
ACh	Ellasjøen	Muscle	1.14 %	0.9	1.1	0.5	1.4	<0.1	<0.2	<0.6	<0.6	0.3	1.3	<0.1	<0.2	<0.2

*whole fish – liver

Table 17. Phosphororganic compounds in liver from seabirds from Kongsfjorden and Liefdefjorden on Svalbard, July 2008. Concentrations are given as ng/g dw.

Species	Location	Ind. no.	Lipid content	TIBP	TBP	TCEP	TCPP	DBPhP	DPhBP	TDCP	TBEP	TPhP	EHDPP	TEHP	ToCrP	TCrP
Kittiwake	Kongsfjorden	K42	2.50 %	<0.5	<1	4.7	1.2	0.33	<0.6	<1.5	<1.5	2.9	11	<0.2	<0.6	<0.6
Kittiwake	Kongsfjorden	K43	2.22 %	1.7	1.5	<0.6	1.1	<0.2	<0.6	<1.5	<1.5	0.9	6.2	<0.2	<0.6	<0.6
Kittiwake	Kongsfjorden	K44	2.17 %	1.6	6.8	<0.6	2.1	<0.2	<0.6	<1.5	<1.5	1.7	6.0	<0.2	<0.6	<0.6
Kittiwake	Kongsfjorden	K45	2.80 %	1.5	3.1	<0.6	2.2	<0.2	<0.6	<1.5	<1.5	1.3	8.7	<0.2	<0.6	<0.6
Kittiwake	Liefdefjorden	K51	4.30 %	1.7	2.6	4.6	<0.5	<0.2	<0.6	<1.5	<1.5	3.3	28	<0.2	<0.6	<0.6
Kittiwake	Liefdefjorden	K52	4.21 %	2.6	1.9	4.7	2.6	<0.2	<0.6	<1.5	<1.5	1.2	9.0	<0.2	<0.6	<0.6
Kittiwake	Liefdefjorden	K54	5.81 %	2.5	2.0	2.8	2.5	<0.2	<0.6	<1.5	<1.5	1.5	12	<0.2	<0.6	<0.6
Kittiwake	Liefdefjorden	K55	2.44 %	1.0	1.4	<1.5	2.3	<0.2	<0.6	<1.5	<1.5	1.6	11	<0.2	<0.6	<0.6
Eider	Kongsfjorden	E41	1.50 %	1.4	1.3	<1.5	2.0	<0.2	<0.6	<1.5	<1.5	0.6	6.2	<0.2	<0.6	<0.6
Eider	Kongsfjorden	E42	1.94 %	2.4	1.7	1.9	<0.5	<0.2	<0.6	<1.5	<1.5	1.2	12	<0.2	<0.6	<0.6
Eider	Kongsfjorden	E43	1.67 %	1.8	2.3	1.6	2.1	<0.2	<0.6	<1.5	<1.5	1.8	8.3	<0.2	<0.6	<0.6
Eider	Kongsfjorden	E44	2.61 %	1.8	1.9	2.8	1.5	<0.2	<0.6	<1.5	<1.5	1.6	6.7	<0.2	<0.6	<0.6
Eider	Kongsfjorden	E45	1.70 %	<0.5	<1	3.5	0.8	<0.2	<0.6	<1.5	<1.5	2.8	9.0	<0.2	<0.6	<0.6

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6. Appendix 1

Lipid normalised concentrations of siloxanes and DEHP in fish collected around Svalbard, 2008. Concentrations are given as ng/g lw. AC = Atlantic cod, PC = polar cod, Wf = whole fish.

Species	Location	Tissue	MM	MDM	MD2M	MD3M	D3	D4	D5	D6	DEHP
AC	Kongsfjorden	Liver	<0.58	0.87	<0.47	<0.61	13.2	10.3	10.3	<25.5	411
AC	Kongsfjorden	Liver	<0.40	<0.29	<0.45	<0.40	10.2	6.90	6.67	<19.3	<210
AC	Kongsfjorden	Liver	<0.35	<0.30	<0.49	<0.37	10.2	9.07	9.30	<21.6	291
AC	Kongsfjorden	Liver	<0.32	<0.29	<0.48	<0.39	17.1	11.9	8.71	<26.8	<284
AC	Kongsfjorden	Liver	<0.63	<0.43	<0.73	<0.70	23.7	13.0	15.3	<31.7	677
PC	Liefdefjorden	Liver	<0.57	<0.43	<0.60	<0.57	29.8	26.3	54.6	30.6	406
PC	Liefdefjorden	Liver	<0.54	<0.41	<0.59	<0.56	14.8	16.2	47.7	27.4	323
PC	Billefjorden	Liver	<0.41	0.44	<0.51	<0.44	<8.46	6.67	17.7	<21.0	254
PC	Billefjorden	Liver	<0.33	<0.31	<0.46	<0.38	<8.21	8.21	22.1	<20.8	<154
PC	Billefjorden	Liver	<0.49	<0.41	<0.54	<0.68	<11.6	<9.19	25.4	<29.7	<162
PC	Billefjorden	Liver	<0.72	<0.39	<0.59	<0.54	<9.35	8.48	25.9	<23.9	637
PC	Moffen	Wf	<8.85	<6.19	<15.3	<22.1	292	230	<73.8	94.4	<1770
PC	Moffen	Wf	<9.86	<5.51	<17.1	<20.6	209	188	124.6	84.1	<1739
PC	Moffen	Wf	<10.69	<6.21	<14.5	<22.8	259	231	128	131	<2069
PC	Moffen	Wf	<6.64	<3.32	<9.96	<11.1	133	133	81.2	81.2	<2214
PC	Moffen	Wf	<5.24	<2.27	<7.68	<10.1	133	129	89.0	50.6	<1047

Lipid normalized concentrations of siloxanes and DEHP in liver from seabirds from Kongsfjorden and Liefdefjorden on Svalbard, July 2008. Only compounds that were detected in one or more samples are included in the table. Concentrations are given as ng/g lw.

Species	Location	Ind. no.	MM	MDM	MD2M	MD3M	D3	D4	D5	D6	DEHP
Kittiwake	Kongsfjorden	K41	<7	<3.00	<11.3	<12.7	127	107	<56.7	<56. 7	<2933
Kittiwake	Kongsfjorden	K42	<8.8	<3.20	<9.60	<15.2	116	104	60.0	<72.0	4200
Kittiwake	Kongsfjorden	K43	<12.0	<5.99	<17.5	<20.3	<115	<139	<101	<96.8	5115
Kittiwake	Kongsfjorden	K44	<9.6	<5.00	<15.4	<17.9	132	125	<82.1	<75.0	3357
Kittiwake	Kongsfjorden	K45	<11.7	<4.95	<18.9	<18.9	135	122	<94.6	<90.1	4730
Kittiwake	Liefdefjorden	K51	<7.21	<3.49	<11.4	<13.0	<69.8	<83.7	<60.5	<58.1	3605
Kittiwake	Liefdefjorden	K52	<6.18	<3.09	<9.26	<10.2	<57.0	<68.9	<49.9	<47.5	<2090
Kittiwake	Liefdefjorden	K54	<4.30	<2.07	<7.23	<7.75	<41.3	<49.9	<36.1	<34.4	<1515
Kittiwake	Liefdefjorden	K55	<10.7	<6.15	<18.9	<23.8	<98.4	<119	<86.1	<82.0	4303
Eider	Kongsfjorden	E41	<18.0	<7.33	<31.3	<34.0	<173	<207	<153	<140	6667
Eider	Kongsfjorden	E42	<11.9	<6.70	<18.6	<24.7	<108	<134	<97.9	<92. 8	<4536
Eider	Kongsfjorden	E43	<19.8	<10.8	<27.5	<40.7	<186	<228	<168	<156	<5269
Eider	Kongsfjorden	E44	<10.7	<6.51	<16.9	<22.6	<99.6	<123	<88.1	<84.3	<3372
Eider	Kongsfjorden	E45	<13.5	<9.41	<21.2	<27.7	<124	<153	<112	<106	<5176

Lipid normalized concentrations of phosphororganic compounds in fish collected around Svalbard, 2008. Only compounds that were detected in one or more samples are shown in the table. Concentrations are given as ng/g lw.

	Location	Tissue	TIBP	TBP	TCEP	TCPP	DBPhP	DPhBP	TDCP	TBEP	TPhP	EHDPP	TEHP	ToCrP	TCrP
AC	Kongsfjorden	Liver	<5.26	<5.26	68.4	23.4	<2.63	<2.63	<15.8	<15.8	34.2	132	12.1	<5.26	<5.26
AC	Kongsfjorden	Liver	<4.76	26.2	31.0	15.7	<2.38	<2.38	<14.3	<14.3	13.6	83.3	<2.38	<4.76	<4.76
AC	Kongsfjorden	Liver	<6.45	<6.45	41.9	17.7	<3.23	<3.23	<19.4	<19.4	35.5	168	<3.23	<6.45	<6.45
AC	Kongsfjorden	Wf*	1429	1857	1071	<71.4	<35.7	<71.4	<214	<143	357	1429	<28.6	<57.1	<57.1
AC	Kongsfjorden	Wf*	867	1267	1000	1400	<33.3	<66.7	<200	<133	333	1467	<26.7	<53.3	<53.3
AC	Kongsfjorden	Wf*	273	545	<1364	818	<45.5	<90.9	<273	<182	364	<18187	<36.4	<72.7	<72.7
AC	Kongsfjorden	Wf*	<231	1308	1308	1462	<76.9	<154	<462	<462	462	1231	<76.9	<154	<154
AC	Kongsfjorden	Wf*	<600	6000	3200	460	<200	<400	<1200	<1200	2000	3200	<200	<400	<400
PC	Moffen	Wf	91.5	80.0	70.8	64.9	<2.95	<5.90	<17.7	<17.7	17.7	97.4	<3.00	<5.90	<5.90
PC	Moffen	Wf	60.9	66.7	92.8	52.2	<2.90	<5.80	122	<17.4	26.1	130	<2.90	<5.80	<5.80
PC	Moffen	Wf	72.4	69.0	62.1	58.6	<3.45	<6.90	100	<20.7	41.4	245	<3.45	<6.90	<6.90
PC	Moffen	Wf	88.6	89.0	84.9	51.7	<3.69	<22.1	192	<22.1	77.5	177	<3.69	<7.38	<7.38
PC	Moffen	Wf	40.1	38.4	38.4	45.4	<1.75	<3.49	141	<10.5	24.4	103	<1.75	<3.49	<3.49
PC	Liefdefjorden	Wf*	126	225	207	<45.1	<9.01	<54.1	108	<54.1	135	450	<9.01	<18.0	<18.0
PC	Liefdefjorden	Wf*	71.9	108	180	108	<7.19	<43.2	86.3	<43.2	115	475	<7.19	<14.4	<14.4
PC	Billefjorden	Wf*	147	203	289	159	<8.62	<8.62	<64.7	<25.9	56.0	289	<8.62	<25.9	<25.9
PC	Billefjorden	Wf*	130	324	245	345	<14.4	<14.4	<108	<43.2	122	432	<14.4	<43.2	<43.2
PC	Billefjorden	Wf*	336	560	358	425	<14.9	<14.9	<112	<44.8	134	896	<14.9	<44.8	<44.8
PC	Billefjorden	Wf*	316	258	477	<32.3	<12.9	<12.9	<96.8	<38.7	90.3	458	<12.9	<38.7	<38.7
PC	Billefjorden	Wf*	194	411	290	363	<16.1	<16.1	<121	<48.4	129	589	<16.1	<48.4	<48.4
ACh	Ellasjøen	Muscle	87.6	56.0	70.6	68.1	<1.22	<2.43	<7.30	<4.87	77.9	389	<0.97	<1.95	<1.95
ACh	Ellasjøen	Muscle	59.9	41.5	76.8	39.9	<0.77	<1.54	86.0	<3.07	24.6	215	<0.61	<1.23	<1.23
ACh	Ellasjøen	Muscle	77.7	53.5	69.1	50.1	<1.73	<3.45	116	<10.4	38.0	259	<1.73	<3.45	<3.45
ACh	Ellasjøen	Muscle	74.2	55.6	69.6	43.3	<1.55	<3.09	86.6	<9.27	37.1	247	<1.55	<3.09	<3.09
ACh	Ellasjøen	Muscle	79.0	96.5	43.9	123	<8.77	<17.5	<52.7	<52.7	26.3	114	<8.77	<17.5	<17.5

Lipid normalised concentrations of phosphororganic compounds in liver from seabirds from Kongsfjorden and Liefdefjorden on Svalbard, July 2008. Only compounds that were detected in one or more samples are shown in the table. Concentrations are given as ng/g dw.

Species	Location	Ind. no	TIBP	TBP	TCEP	TCPP	DBPhP	DPhBP	TDCP	TBEP	TPhP	EHDPP	TEHP	ToCrP	TCrP
Kittiwake	Kongsfjorden	K42	<20.0	<40.0	188	48	<13.2	<24.0	<60	<60.0	116	440	<8.00	<24.0	<24.0
Kittiwake	Kongsfjorden	K43	76.6	67.6	<27.0	49.6	<9.01	<27.0	<67.6	<67.6	40.5	279	<9.01	<27.0	<27.0
Kittiwake	Kongsfjorden	K44	73.7	313	<27.7	96.8	<9.22	<27.7	<69.1	<69.1	78.3	277	<9.22	<27.7	<27.7
Kittiwake	Kongsfjorden	K45	53.6	111	<21.4	78.6	<7.14	<21.4	<53.6	<53.6	46.4	311	<7.14	<21.4	<21.4
Kittiwake	Liefdefjorden	K51	39.5	60.5	107	<11.6	<4.65	<14.0	<34.9	<34.9	76.7	651	<4.65	<14.0	<14.0
Kittiwake	Liefdefjorden	K52	61.8	45.1	112	61.8	<4.75	<14.3	<35.6	<35.6	28.5	214	<4.75	<14.3	<14.3
Kittiwake	Liefdefjorden	K54	43.0	34.4	48.2	43.0	<3.44	<10.3	<25.8	<25.8	25.8	207	<3.44	<10.3	<10.3
Kittiwake	Liefdefjorden	K55	41.0	57.4	<61.5	94.3	<8.20	<24.6	<61.5	<61.5	65.6	451	<8.20	<24.6	<24.6
Eider	Kongsfjorden	E41	93.3	86. 7	<100	133	<13.3	<40.0	<100	<100	40.0	413	<13.3	<40.0	<40.0
Eider	Kongsfjorden	E42	124	87.6	97.9	<25.8	<10.3	<30.9	<77.3	<77.3	61.9	619	<10.3	<30.9	<30.9
Eider	Kongsfjorden	E43	108	138	95.8	126	<12.0	<35.9	<89.8	<89.8	107.8	497	<12.0	<35.9	<35.9
Eider	Kongsfjorden	E44	69.0	72.8	107	57.5	<7.66	<23.0	<57.5	<57.5	61.3	257	<7.66	<23.0	<23.0
Eider	Kongsfjorden	E45	<29.4	<58.8	206	47.1	<11.8	<35.3	<88.2	<88.2	164.7	529	<11.8	<35.3	<35.3

Statlig program for forurensningsovervåking

Statens forurensningstilsyn (SFT)
Postboks 8100 Dep, 0032 Oslo - Besøksadresse: Strømsveien 96
Telefon: 22 57 34 00 - Telefaks: 22 67 67 06
E-post: postmottak@sft.no - Internett: www.sft.no

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Anita Evenset, Henriette Leknes, Guttorm. N. Christensen, Nicholas Warner, Mikael Remberger & Geir Wing Gabrielsen

Tittel - norsk og engelsk

Screening of new contaminants in samples from the Norwegian Arctic

Screening for nye miljøgifter i prøver fra norsk arktis

Sammendrag – summary
Samples of water, sediment, fish (polar cod, Atlantic cod and Arctic char) and seabirds (kittiwake and common eider) collected in different parts of the Norwegian Arctic were screened for silver, platinum, sucralose, bisphenol A, tetrabrombisphenol A, siloxanes, phtalates (DEHP) and phosphororganic flame retardants. Seawater samples (n = 3) were analysed for sucralose, but no sucralose was detected in any of the samples (< 0.5 ng/l). The concentrations of Ag varied from 193 – 427 ng/g dry weight (dw) in the marine sediment samples. In Ellasjøen the Ag-concentration was 413 ng/g dw. All the sediment samples had low concentrations of Pt (< 20 ng/g dw). Neither BPA nor TBBPA were detected in any samples of sediment, fish or seabirds analysed in the present study. No siloxanes or DEHP were detected in sediment samples. One or more of the cyclic siloxanes were detected in all, except one, of the fish samples, but the levels were low compared to levels measured in fish from fjords close to urbanised areas. Low levels of cyclic siloxanes (D3, D4 and D5 (only in one sample)) were measured in kittiwakes from Kongsfjorden (2.6 – 3.8 ng/g ww). The levels in kittiwakes were generally lower than the levels measured in fish liver. DEHP was detected in 11 of the 16 analysed fish samples (from 99 – 293 ng/g ww). DEHP was also detected in kittiwakes from remote fjords (Kongsfjorden and Liefdefjorden), and in one common eider. The concentrations varied from < 88 – 155 ng/g ww. Thirteen phosphorous compounds were analysed, but only 8 were detected in the fish samples (TIBP, TBP, TCEP, TCPP, TDCP, TPhP, EHDPP and TEHP) and 7 in the liver samples from seabirds (TIBP, TBP, TCEP, TCPP, TPhP, EHDPP and TEHP). EHDPP was the dominant compound in both fish (up to 50 ng/g ww) and seabird samples (up to 28 ng/g ww).

4 emneord Arktis, flammehemmere, siloxaner, ftalater	4 subject words Arktic, flame retardants, siloxanes, phthalates

Statens forurensningstilsyn
Postboks 8100 Dep,
0032 Oslo
Besøksadresse: Strømsveien 96

Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@sft.no
www.sft.no

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

Overvåkingsprogrammmet 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 overvåkningsprogrammet.

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