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MOSJ status report for environmental pollutants in 2011

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Norsk Polarinstitutt er Norges sentralinstitusjon for kartlegging, miljøovervåkning og forvaltningsrettet forskning i Arktis og Antarktis. Instituttet er faglig og strategisk rådgiver i miljøvernsaker i disse områdene og har forvaltningsmyndighet i norsk del av Antarktis.

The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in Norwegian polar regions. The Institute also advises Norwegian authorities on matters concerning polar environmental management.

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Foreword

Environmental monitoring of Svalbard and Jan Mayen (MOSJ) is a system for monitoring the environment of these arctic islands and the surrounding waters. It compiles the results from several monitoring programmes in a standardised manner with the objective of making them readily available and building up a means of evaluating the overall state of the environment in the region based on each individual programme. This is achieved by preparing regular reports on the state of the environment. The topics vary, and earlier assessments have dealt with terrestrial and marine environments, climate change and traffic. This report assesses pollutants for the first time.

MOSJ status reports summarise changes in the environment and discuss their causes and effects. The result is then assessed against the national environmental targets. When the state is unsatisfactory, the assessments must point out where action needs to be taken. MOSJ sends such recommendations to the authorities which are responsible for setting the actions in motion. The need to improve the monitoring is also evaluated.

Pressure on the polar regions is increasing as a consequence of the greater opportunity people have to visit them and the desire to exploit arctic resources. The ongoing changes in climate mean that the extent of sea ice is decreasing in summer and new areas are becoming interesting for transport, fishing, and oil and gas activity. Since the Industrial Revolution, long-range transboundary pollution has become a challenge for people and wildlife in the Arctic. International regulations and bans of certain environmental pollutants have given good results and there is cause for optimism in relation to the environmental pollution problem in the Arctic. Nevertheless, new chemicals are continually being produced and used. There is therefore good reason to follow their development as regards regulations, recording, and national and international efforts to achieve a pollution-free environment. The monitoring of, and research on, environmental pollutants in the northern regions is thus an important field if we are to improve the natural environment in the High North.

MOSJ is run by the Norwegian Polar Institute (NPI) in cooperation with several other institutions which supply information from their monitoring. Some of these also have seats on a scientific board along with representatives from environmental management agencies. The MOSJ secretariat at the Institute drew up a proposal for a mandate for this evaluation, and this was discussed with the board before being finally adopted. A group of scientists was then commissioned to deliver an independent evaluation in line with this mandate. This report is our response to this assignment.

The authors of the report have been:

- Kjetil Sagerup, Ingeborg Gammelsæter Hallanger, Heli Routti and Geir Wing Gabrielsen, Norwegian Polar Institute
- Anita Evenset, Akvaplan-niva
- Sylvia Frantzen, National Institute of Nutrition and Seafood Research
- Justin Gwynn, Norwegian Radiation Protection Authority
- Roland Kallenborn, Norwegian University of Life Sciences
- Katrine Aspmo Pfaffhuber, Norwegian Institute for Air Research

The various institutions taking part have performed scientific quality control of the report and it has been reviewed and commented upon by Cynthia de Wit at the University of Stockholm.

Our mandate required the report to be written in a form that would be readily understood by everyone. This is difficult when the subject concerned calls for numerous chemical formulae and biological terms. Gunnar Sander from the MOSJ secretariat has helped us to simplify our presentation on several occasions.

The report rests on the great effort made by many people and institutions in monitoring and performing research on environmental pollutants in the Arctic. We are very grateful to the many laboratories in Norway and other countries which have provided analyses of pollutants in the atmosphere, sediments and biota. We also wish to thank the technical staff at the Zeppelin and Sverdrup stations in Ny-Ålesund for their help and support.

A number of people have helped to prepare the report. We wish to express our sincere thanks to Anne Lene Brungot, Torbjörn Gäfvert and Geir Rudolfsen at the Norwegian Radiation Protection Authority, Tore Nordstad and Guttorm Christensen at Akvaplan-niva, and Amund Måge and Kåre Julshamn at the National Institute of Nutrition and Seafood Research.

We also wish to thank the Arctic Monitoring and Assessment Programme (AMAP) for access to data, the Climate and Pollution Directorate for financial support for the monitoring programme at the Zeppelin Station and for funding the screening programme for new pollutants, and the Ministry of the Environment for funding NPI's monitoring of pollutants in the Arctic.

The Environmental and Mapping Department at NPI is also thanked for help and input in connection with the report.

Tromsø, March 2012

Geir Wing Gabrielsen

Content

The coal stockpile and containers at the Svea Nord Mine. Coal dust which blows away or is transported by water is a local source of pollution in Svalbard. Photo: Anders Skoglund, Norwegian Polar Institute

Summary

This report updates the status for environmental pollutants that are being monitored in the MOSJ system, which are organic pollutants, heavy metals and radioactive substances. It reviews the status, trends and effects of these pollutants, and gives advice on continued monitoring. Geographically, the report concerns only Svalbard, Jan Mayen and surrounding waters.

Sources

The principal sources of environmental pollutants in the Arctic are considered to be the more densely populated and industrialised parts of the world. Winds and ocean currents transport the substances to the Arctic, where they mainly accumulate in the marine food chains. The terrestrial food chains in the Arctic have low levels. Local sources of pollutants in Svalbard and Jan Mayen are small and geographically limited.

The settlements in Svalbard are sources of environmental pollutants in several different ways. Sewage deriving from buildings raises the content of organic material and heavy metals in marine sediments. Enhanced values of some organic pollutants (e.g. PAHs, PCBs, siloxanes and fluorinated compounds) have been measured offshore from the settlements in Svalbard, suggesting a link with waste water. Rubbish dumps are a source of environmental pollutants, and seepage from these may be a source of pollution.

Mining activities have been, and still are, a local source of certain environmental pollutants like PAHs, heavy metals and PCBs. Discharge of production water from mines have supplied, and still supply, some metals and PAHs to the marine environment. Furthermore, particles transported by wind and water from coal dumps, natural erosion of coal-bearing bedrock and leaching of naturally formed hydrocarbons help to raise PAH levels in Svalbard.

Organic pollutants

Time trends of organic pollutants in the MOSJ area vary appreciably, depending upon the substances and where measurements are performed. The atmospheric measurements show a rising trend for HCB, varying trends for PCBs and declining trends for HCH, chlordanes and DDT. No trends have been observed for PBDE, PFAS or TBA, which have been monitored in air since 2006. Compared with other parts of the Arctic, high PCB levels have been measured in air and lake sediments from Svalbard.

PCB levels in animals from the Norwegian Arctic show a declining trend, but PCBs are still the predominant environmental pollutants in the Arctic. As PCBs degrade very slowly, they will remain in the environment for many decades. Chlorinated herbicides show more varying trends, but mainly seem to be declining. Some groups of brominated compounds, like PBDE and PBB, have been observed to be declining, whereas others, such as α-HBCD, are increasing. The time trends for fluorine compounds in the Arctic are not clear and vary from one substance to another.

Management measures, such as bans and outphasing, lead to reductions in discharge and supply. We see that substances like PCBs and chlorinated spray chemicals decrease because of bans on their manufacture and use, whereas concentrations of substances which have not been banned internationally, such as HBCD and some fluorine compounds, are rising. The “new” pollutants discovered in the Arctic give grounds for concern and show that more substances than the well-known POPs have a potential for long-range transport. The concentrations of polluting substances that have been banned and phased out are expected to decline in the future, but the production and use of new compounds is continually increasing and these may impact the environment in the Arctic.

Heavy metals

The heavy metals cadmium, mercury and lead are regarded as problematical in arctic regions. Mercury emissions have been reduced in North America and Europe since the 1990s, but have risen sharply in Asia. The reduction in the use of leaded petrol has been very effective in achieving a reduction in lead pollution. Cadmium and mercury concentrations at the Zeppelin Station at Ny-Ålesund in Svalbard have not changed since measurements started in 1994, whereas lead has dropped by 30 %. There are lower levels of heavy metals in lake sediments from Svalbard than from mainland Norway. Mercury and cadmium levels in animals from Svalbard are on the whole lower than from other arctic regions.

Radionuclides

The most important sources of human-generated radioactivity have been global fallout from the atmospheric testing of nuclear weapons, discharges and emissions from reprocessing plants in Europe and the Chernobyl accident. In general, discharges from all nuclear plants to northern European waters have been reduced since the early 1990s, and radioactivity levels are continually dropping. It is expected that levels of human-generated radioactivity will continue to drop in the future.

Effects of environmental pollutants

Studies of the effects of organic pollutants have been performed in cell cultures, laboratory animals and the field. They have shown different kinds of negative impacts such as hormone disturbance, reduced power of reproduction, damage to the nervous and immune systems, and poorer survival. Heavy metals may give changes in the nervous system, disturb hormones, reduce the power of reproduction and give liver and kidney damage. Damage to the nervous system is especially disturbing for young, developing animals.

Negative effects deriving from organic contaminants have been reported in the top predators in the Arctic, the polar bear, arctic fox, glaucous gull, ivory gull and great skua. The heavy metals do not seem to pose a major threat, but some individuals, including people, which eat marine fish, mercury can still be a problem because it is both stable and highly toxic. The low concentrations of human-generated radionuclides measured in the marine and terrestrial environments in Svalbard are far below the threshold levels for effects.

Environmental pollutants in food

Compared with the coast of mainland Norway, seafood from the waters near Svalbard and Jan Mayen has relatively low levels of environmental pollutants. For instance, extremely low levels of human-generated radioactive substances are found in seafood and game from the Barents Sea and Svalbard. The highest levels of organic contaminants are found in blubber from marine mammals and in glaucous gull eggs. These are virtually not used as food by Norwegians and are therefore not regarded as a problem. Fish and shrimps from the Barents Sea also have low levels of heavy metals and organic pollutants, except for cod livers, which still have enhanced amounts of organic contaminants, and large Greenland halibut where mercury levels may exceed the maximum limits. No nutrition recommendations have been given for specific areas. However, for some foodstuffs, a general recommendation applies to the most vulnerable groups. That which is most relevant here concerns cod liver, which women of child-bearing age and children are advised not to eat. Pregnant and nursing women are also recommended to avoid Greenland halibut weighing more than 3 kg.

Climate change

The Arctic is one of the regions where the impacts of climate change will be greatest. A rise in temperature may affect the ability of the environmental pollutants to be transported northwards at the same time as those which are now locked in permafrost, ice and water may be liberated and washed out into lakes and the sea, or evaporate. Climate change may, moreover, alter the distribution of the species and the structure of the food chains in the Arctic, which in turn may affect the concentrations of pollutants in top predators.

Cruise ships in the Arctic contribute to the discharge of particles and CO_2 emissions. Here from a call at Ny-Ålesund.
Photo: Geir Wing Gabrielsen, Norwegian Polar Institute.

Environmental targets

The Norwegian environmental targets are described within a national framework and are difficult to assess in relation to an arctic standard. The Norwegian target that Svalbard must be the best-managed wilderness in the world means that separate, regional environmental targets should be drawn up for the arctic regions.

Environmental pollutants that are found in Svalbard, Jan Mayen and adjacent waters are mainly long-range transported. International legislation and regulations are therefore the most important instruments to reduce the supply to arctic regions. In addition, it is important to maintain a keen watch on local emissions and discharges in the Arctic.

Advice on further monitoring and research

This report points out both strengths and weaknesses in the MOSJ monitoring system. The main conclusion is that monitoring must continue, but the programme should be somewhat adjusted (Table 5). There are great differences in the extent to which targets have been achieved in the MOSJ indicators, and these are mostly due to funding. Measurements of air and radioactivity are part of well-defined monitoring programmes, whereas those from sediments, fish, mammals and birds are mainly by-products of research. Many of these series therefore suffer from inadequate regularity and accuracy. Because MOSJ lacks base funding to monitor environmental pollutants, data collection will be determined by the research activity on pollutants. This means that in the years to come the MOSJ environmental pollutant programme will not succeed in supplying data in line with the intentions. The solution is for MOSJ to receive base funding for environmental pollutants which will ensure the core of the monitoring. Money should also be set aside to screen new pollutants to ensure their mapping in the Arctic, either as part of MOSJ or by linking the screening programme for which the Climate and Pollution Directorate is responsible more strongly to the Arctic. It is most important that research is performed on the MOSJ data series. Very capable research groups are currently handling the data series and performing substantial research on modelling, trends and effects of environmental pollutants. This is one of the strong aspects of the current MOSJ programme and it is vital that this research is maintained.

1 Introduction

The polar regions are affected by human activity. Pollution from industrialised and densely populated regions is carried to the High North by winds and ocean currents. This takes place at the same time as we are experiencing increasing activity in the Arctic. The flow of tourists to Svalbard has grown in the last ten years and more and more people want to visit new locations in eastern Svalbard. The population in the archipelago has grown and research and education activities are increasing. The ice cover in summer in the Arctic is decreasing in extent and new areas are becoming interesting for transport, fishing and oil and gas activity. In view of the changes now taking place in the Arctic, it is important to continue the monitoring and research on environmental pollutants in this region in order to reveal changes and human impacts on the vulnerable arctic environment.

Environmental monitoring in Svalbard and Jan Mayen (MOSJ) is a monitoring system for Svalbard, Jan Mayen and the surrounding waters. It is managed by the Norwegian Polar Institute (NPI) and collects and compiles information on climate, flora, fauna, cultural heritage remains and impacts on the environment emanating from traffic, fishing, trapping, introduced species, hunting, encroachments on the environment and pollution. The information is presented on a web site (http://mosj.npolar.no) which provides interpretations of the environmental situation in the region concerned, and is directed at management authorities. In addition, MOSJ must prepare regular reports on the state of the environment in the region.

This report summarises knowledge about persistent organic pollutants, heavy metals and radionuclides in the Norwegian part of the Arctic and their possible impact on the health of people and animals. The national environmental targets relating to environmental pollutants are also evaluated. The report, furthermore, gives advice on the need for actions and recommendations for the monitoring of environmental pollutants in the MOSJ project in the years to come.

We were asked to prepare a report that evaluates the status of environmental pollutants in the Norwegian Arctic. This includes evaluating the extent to which relevant national environmental targets are being met and pointing out the need for any actions that might be required to improve the target attainment. The evaluations must concentrate on the environmental pollutants that belong in the three groups of substances covered by MOSJ: persistent organic pollutants, heavy metals and radioactive substances. Geographically, the report only concerns Svalbard, Jan Mayen and the waters surrounding them. The air, water, soil, snow and ice, and flora and fauna at different trophic levels are covered by the report. The report must be based on the indicators used by MOSJ. It must also be able to form a basis for evaluating revisions of the MOSJ indicators and parameters.

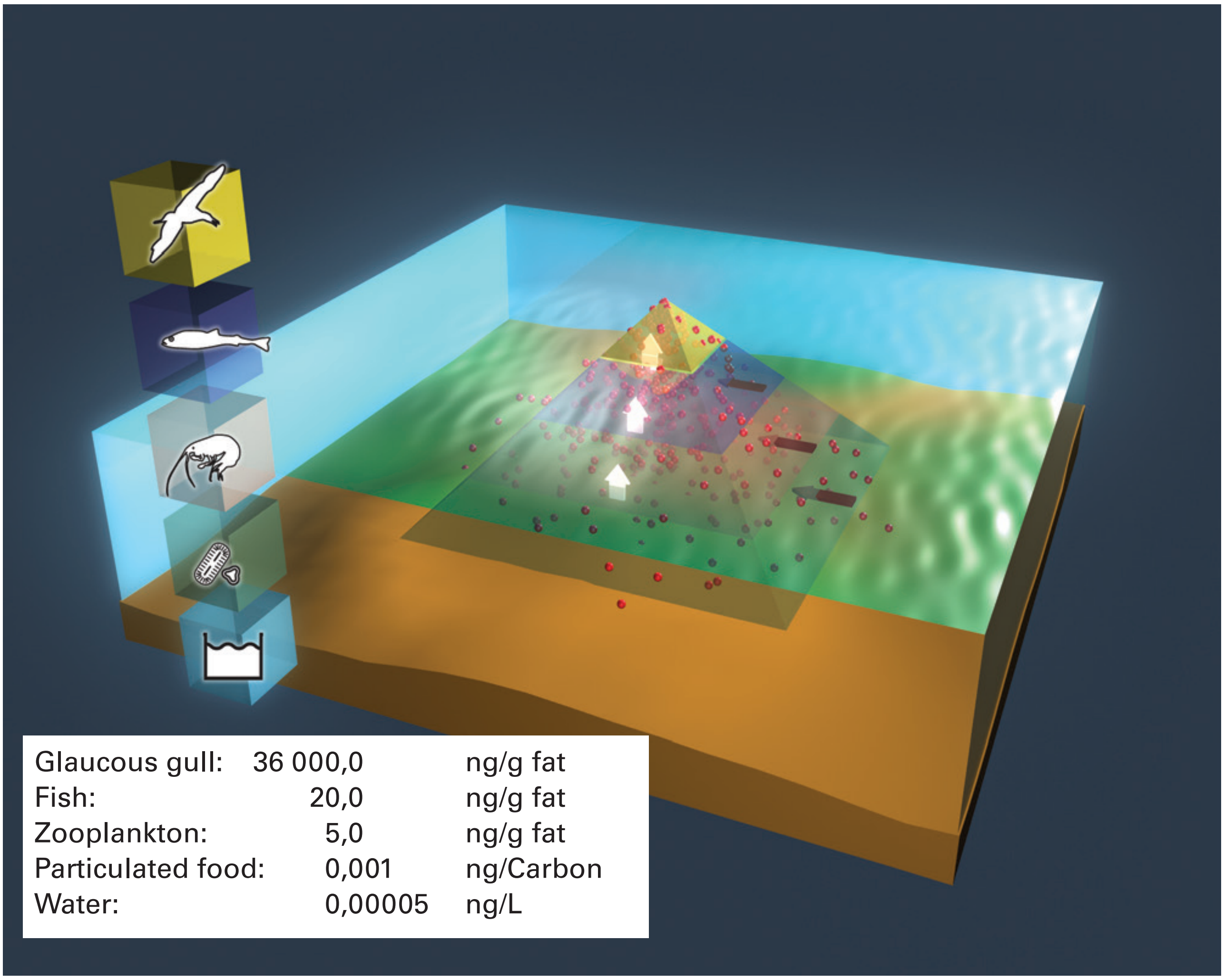


Figure 1. Black arrows illustrate bioaccumulation (accumulation in a living organism) and white arrows illustrate the biomagnification process (enhancing concentration through the food chain). The concentrations are actual examples from the food chain in the Arctic.
Illustration: Audun Igesund, Norwegian Polar Institute

2 Levels, status and time trends

2.1 Persistent organic pollutants (POPs)

Persistent organic pollutants (POPs) are defined as compounds with physical and chemical properties that make them slowly degradable in the environment. Most POPs have low water solubility and high solubility in fat, and their highest concentrations are found in animals high in the food chain. Because the substances degrade slowly, they will accumulate (bioaccumulate) in the body of an individual throughout its life. When the animal is eaten, the substances accumulate in the predator, which will thus attain a higher content of the pollutant, a process called biomagnification (Figure 1). The newer groups of pollutants that have been found in the environment in the past decade may have other physico-chemical properties. For instance, the fluorine-bearing PFAS group (perfluorinated and polyfluorinated alkyl substances) bind to proteins in the body. A feature all the POPs found in arctic regions have in common is that they have properties which make them capable of being transported in the atmosphere or in water over long distances (Berg et al., 2004; Hung et al., 2010; Ma et al., 2011). POPs is a collective term for many halogenated compounds with effects that are harmful to the environment and health. 16 substances or groups of substances have been identified as highly prioritised, problematic substances and are regulated globally through the UN Stockholm Convention on POPs (Appendix 1) and regionally through the Aarhus Protocol on Long-range Transboundary Air Pollution – the LRTAP Convention; www.unece.org/env/lrtap) (AMAP, 2004).

The atmosphere monitoring station at Zeppelinfjellet, Ny-Ålesund. Measurements from here have provided some of the longest time series for POPs in the world. Photo: Sebastian Gerland, Norwegian Polar Institute

2.2 Available data

Regional and global monitoring programmes have been established for POPs. The Climate and Pollution Directorate has assigned the Norwegian Institute for Air Research the responsibility for a long-term monitoring programme for POPs in the atmosphere at the Zeppelin Station near Ny-Ålesund (Svalbard). This monitoring began in 1993 and is still in progress. The results are reported to several international monitoring programmes, including AMAP (Arctic Monitoring and Assessment Programme) and EMEP (UNECE – European Monitoring and Evaluation Programme, part of LRTAP). The substances covered in this programme are shown in Table 1. This data series is now one of the longest, uninterrupted monitoring series for POPs in the atmosphere in the world. Similar, long-term monitoring of pollutants in the atmosphere is being performed at Alert, Ellesmere Island in Canada.

Scientific publications which use data from the Zeppelin Station (Su et al., 2006; Becker et al., 2009; Ma et al., 2011) are also included in this report to evaluate distribution, dispersion and local pollution. The annual national report on monitoring of long-range transported contaminated air and precipitation (Aas et al., 2011) has also been used as a source for trends and distributions of POPs around Svalbard.

PCB is a group of pollutants that is prioritised by both the Stockholm Convention and AMAP. As one of a circumpolar network of atmospheric monitoring stations, the Zeppelin Station plays an important international role in AMAPs long-term monitoring of POPs.

Table 1. Persistent organic pollutants (POPs) analysed in air samples from the Zeppelin Station (Ny-Ålesund, Svalbard)

Since 1993: Polychlorinated biphenyls (PCBs)	**Since 1993: Chlorinated pesticides (herbicides)**	**Since 1993: Industrial by-products**
PCB congenes nos. 18, 28, 31, 33, 37, 47, 52, 66, 74, 99, 101, 105, 114, 118, 122, 123, 128, 138, 141, 149, 153, 156, 157, 167, 170, 180, 183, 187, 189, 194, 206, 209.	Hexachloroyclohexanes: α- og γ- HCH, chlordanes: trans-/cis-chlordane, trans-/cis-nonachlor Dichlorodiphenyltrichloroethane (DDT): *o,p'- , p,p'-* DDT, -DDD, -DDE	Hexachlorobenzene (HCB).
After 2006: Perfluorinated alkyl substances (PFAS)	**After 2006: Brominated flame retardants (BFR)**	**After 2006: Biogenic substances**
Perfluoroctanoic acid (PFOA) Perfluoroctane sulphonate (PFOS) Perfluoroctane sulphonamide (PFOSA) Perfluorobutane sulphonate (PFBS) Perfluorodecane sulphonate (PFDcS) Perfluorobutanic acid (PFBA) Perfluorohexane acid (PFHA) Perfluoroheptanoic acid (PFHpA) Perfluorononanoic acid (PFNA) Perfluorodecanoic acid (PFDcA) Perfluoroundecanoic acid (PFUnA)	Hexabromocyclododecane (HBCD): α-, β-, γ-HBCD Polybrominated diphenyl ethers (PBDE) congenes nos. 27, 47, 49+71, 66, 77, 85, 99, 100, 119, 138, 153, 154, 183, 196, 206, 209	Tribromoanisole (TBA)

Glossary

Congenes	Different chemical forms within a group. For example, there are 209 congeners or chemical forms of PCB. Sum xx PCB means the aggregated value of a given number of PCB congenes.
Biota	All forms of living life. Present-day systematics divides the life forms into five or six kingdoms: bacteria, archaebacteria (prokaryotes), protists, plants, fungi, animals (eukaryotes).
Halogens	The term for group 17 in the periodic system, consisting of five elements: fluorine, chlorine, bromine, iodine and astatine.
Endemic	Used in biology about species with a restricted geographical distribution and isolated groups (populations) within a species.
Isotope	Alternative form of an element. An isotope differs from other atoms in the same element in the number of neutrons in its core. Some isotopes are unstable (radioactive) and disintegrate by emitting radiation.

Akvaplan-niva, the National Institute for Nutrition and Seafood Research and the Norwegian Polar Institute supply MOSJ with data from sediments and biological systems so that they can be included in time series for organic pollutants. Four sediment stations (Adventfjorden, Colesbukta, Billefjorden and Grønfjorden), two species of fish (capelin (*Mallotus villosus*) and polar cod (*Boreogadus saida*)), two species of seabirds (glaucous gull (*Larus hyperboreus*) and Brünnich's guillemot (*Uria lomvia*)) and three species of mammals (polar bear (*Ursus maritimus*), ringed seal (*Phoca hispida*) and arctic fox (*Vulpes lagopus*)) are currently included in MOSJ to monitor organic pollutants (MOSJ, 2011). In addition, the Norwegian Radiation Protection Authority supplies data on radioactivity in fish (cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*)) and seawater.

2.3 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) were used as industrial chemicals from the 1940s until the early 1980s, when their use was banned in Europe. The global production of PCBs has been estimated at approximately 1.3 million tons from 1930-1992 (AMAP, 2004). PCBs consist of 209 separate components with 1-9 chlorine atoms in the molecule. PCBs are very slowly degradable and are carried to arctic regions with ocean currents and winds. PCBs have been used in many products, such as electrical equipment, hydraulic systems, paint and insulation.

2.3.1 Local PCB sources

The Governor of Svalbard and the Climate and Pollution Directorate have carried out a PCB project in Svalbard.

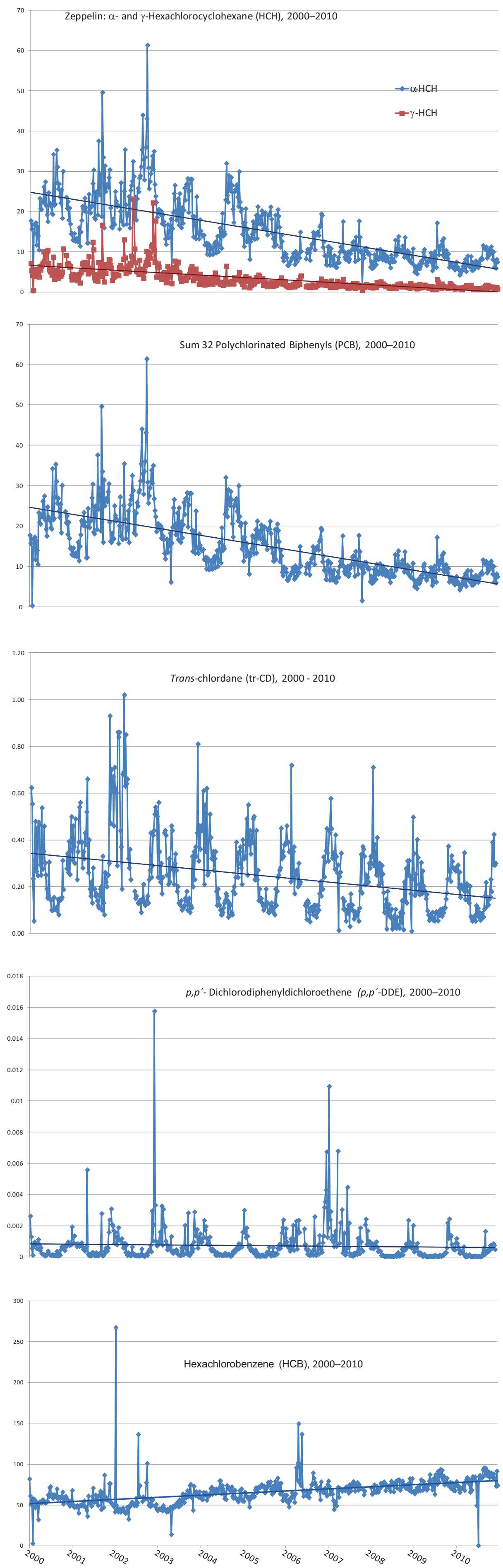


Figure 2. Time trends for PCBs and chlorinated herbicides from measurements of the air at the Zeppelin Station (pg/m³).

Sampling for PCB in mortar and tile adhesive in Grumantbyen.
Photo: Qno Lundkvist, Climate and Pollution Directorate

Equipment containing PCBs and local sources of PCBs from industrial and mining activities, rubbish dumps, paint, building articles and electrical articles were mapped (Jartun et al., 2007; Lundkvist et al., 2008; Jartun et al., 2009). Equipment and materials containing PCBs were also collected and removed from Svalbard. Local sources of PCBs that remain are primarily associated with buildings and contaminated earth, especially in the Russian settlements (Jartun et al., 2007; Jartun et al., 2009). Old PCB-bearing products are still in use, like electrical equipment, buildings and paint. PCB pollution will therefore remain a problem for Svalbard, especially in the event of major changes in climate (Ma et al., 2011; SWIPA, in prep.).

Some hot spots have been identified where significant PCB contamination has been found emanating from previous human activity, including in soil samples from Kinnvika in Nordaustlandet where research went on in the 1950s (Harris, 2008). However, a more recent investigation in Kinnvika only found low levels of PCBs in soil samples (Evenset and Christensen, 2011), including those from the same stations as were investigated by Harris (2008). Increased evaporation and remobilisation of PCBs from local sources has a potential to expose people and animals in Svalbard directly.

Local discharges of PCB from the settlements in Svalbard have been measured in sediments in 1998, 2005 and 2009. Off Longyearbyen, the PCB levels dropped from 1998 to 2009, whereas sediments off Barentsburg had their highest levels in 2005. The Russian settlement of Pyramiden in Billefjorden was abandoned in 1998. Decay and leakage from old equipment have been mapped by staff from the office of the Governor of Svalbard and the Climate and Pollution Directorate. The elevated PCB levels found in 2005 off Pyramiden were explained by increased seepage from contaminated soil because a flood in 2005 was stronger than normal (Evenset et al., 2009a).

2.3.2 PCBs in air

PCBs are always found in air samples at the Zeppelin Station and they have a minimum concentration of around 5-15 pg/m^3 for sum 32 PCBs (Figure 2). The main contributors to the PCB burden in Svalbard air are long-range transport and evaporation from secondary sources like ice, land and sea surfaces. The PCB concentrations in air at the Zeppelin Station are the highest of all the PCB measurements at arctic air monitoring stations and are at the same level as at Stórhöfði in Iceland. The Stórhöfði Station is further south and, hence, closer to potential source areas (Hung et al., 2010). A rising trend for sum PCB was observed from 2005 to 2008 due to an increase in the proportion of PCBs containing six and seven chlorine atoms (Hung et al., 2010). The concentrations dropped again from 2009 to 2010 (Figure 2). It is assumed that the rise in 2005-2008 was due to increased transport of air contaminated with PCBs from forest fires in eastern Siberia and Alaska.

2.3.3 PCBs in lake sediments PCBs in lake sediments

A nationwide investigation of environmental pollutants in lakes took place from 2005 to 2008. The following lakes were investigated in Svalbard: Ellasjøen and Øyangen on Bjørnøya (Bear Island), a lake on the northern part of Frankenhalvøya on Barentsøya and Kongressvatnet, Linnévatnet, Arresjøen, Åsövatnet and Richardvatnet on Spitsbergen. The main focus for the investigation was to map POPs and metals in sediments, but fish were also analysed in a few lakes. The content of POPs in sediments from lakes in Svalbard was found to be relatively high, significantly higher than is found in other parts of the Arctic and in northern Norway (Christensen et al., 2008). There are two possible explanations for the higher content of environmental pollutants in the north. Environmental pollutants transported northwards in the atmosphere fall down, evaporate and are then transported further (the “grasshopper effect”). They are “captured” in the north, because there is much less evaporation. The second explanation is that the pollutants come from seabirds which wash in the lakes. Their droppings contain pollutants and lakes investigated in Svalbard may be more affected by seabirds than those on the mainland. This has been found to cause the high levels of environmental pollutants in Ellasjøen on Bjørnøya (Evenset et al., 2007a). The average concentration of sum 7 PCBs in sediments from the lakes in Svalbard (n = 5) was 10.1 ng/g dry weight (dw), whereas the average for the mainland (n = 49) was about 1.9 ng/g dry weight. The highest PCB concentrations were measured in sediments from Ellasjøen and Kongressvatnet with 24 and 16 ng/g dw, respectively, but Åsövatnet also had a relatively high level of sum 7 PCBs (6 ng/g dw). Sediment cores have shown that the historical deposition of PCBs rose smoothly from the 1930s to the 1970s and then declined in the 1980s and 1990s (Evenset et al., 2007b). However, the reduction is not greater than sediments from the 1990s have a higher concentration of PCBs than those from 1950 (Evenset et al., 2007b).

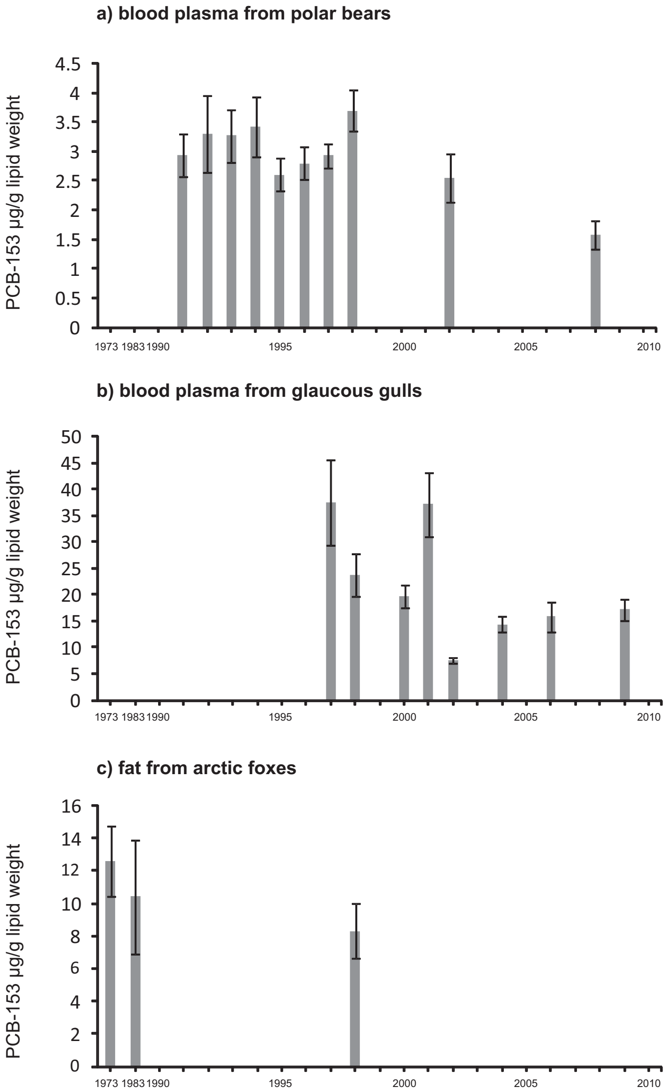


Figure 3. Time trends of PCB-153 (ng/g lipid weight) for a) blood plasma from polar bears, b) blood plasma from glaucous gulls, and c) fat from arctic foxes. Data from MOSJ.

2.3.4 PCBs in biota

PCBs are fat-soluble and tend to accumulate in the fat-rich marine food chains in the Arctic (AMAP, 2004; Gabrielsen, 2007; Letcher et al., 2010; Verreault et al., 2010b). The difference in the level of pollutants in zooplankton and predators at the top of the food chain may therefore be enormous. New data from 2010 show that zooplankton, capelin and polar cod, for example, have 2-30 ng PCB per gram fat, whereas glaucous gulls have 1000 times more in their blood plasma (Hallanger et al., 2011; Haugerud, 2011; MOSJ, 2011).

Investigations of organic pollutants in char (*Salvelinus alpinus*) have shown that the levels are generally higher in Svalbard lakes than lakes in northern Norway (Christensen et al., 2008; Christensen and Evenset, 2011). PCBs are still the predominant pollutant in char from all the lakes investigated. Char from Ellasjøen on Bjørnøya have the highest levels of pollutants, but elevated levels are also found in several other Svalbard lakes (e.g. Åsövatnet, Richardvatnet, Arresjøen and a lake southwest of Hakluythovden on Amsterdamøya), as well as in Nordlaguna on Jan Mayen) (Skjegstad and Gabrielsen, 1998; Christensen et al., 2008; Christensen and Evenset, 2011). The levels of PCBs and dioxin-like PCBs in char from Ellasjøen exceed the maximum values for human consumption set by the US Environmental Protection Agency and the EU.

The PCB levels in eggs from herring gulls (*Larus argentatus*), kittiwakes (*Rissa tridactyla*), puffins (*Fratercula arctica*), black guillemots (*Uria aalge*) and Brünnich's guillemots from the coasts of northern Norway and Svalbard were measured in 1972, 1983, 1993, 2003 and 2007. In accordance with the time trend for PCBs in the blood of glaucous gulls from Bjørnøya (Bustnes et al., 2010; Verreault et al., 2010a), all five species showed a decline of 60-80 % for PCBs (Barrett et al., 1996; Helgason et al., 2008; Helgason et al., 2012). Blood samples from 1997 to 2006 showed a significant decline for PCBs (Figure 3). The average change for PCBs in time series (n = 40) cited in the 2010 report from AMAP was estimated to be 1.9 % per year (Riget et al., 2011). They are from Alaska, Canada, the Faeroes, Greenland, Iceland, Norway and Sweden.

2.4 Chlorinated pesticides (HCB, HCH, DDT, chlordanes, dieldrin, toxaphene)

Chlorinated organic pesticides are a group comprising many hundreds of compounds formerly used by farmers to combat pests or weeds. As practically all these substances have been found to be harmful to the environment, stringent restrictions on their use and storage have been introduced. A number of pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlorine, hexachlorobenzene, mirex and toxaphene) were banned in the UN Stockholm Convention, which entered into force in 2004. The Convention added several more pesticides in 2009 (chlordecone, alfa- and beta-HCH, lindane and pentachlorobenzene) (www.pops.int).

The technical mixture of HCH was a common insecticide from the 1940s, and was used as a replacement for DDT in the 1960s and 1970s. The use of lindane, another HCH mixture, was permitted in Norway until 1992. In the year 2000, the use of technical HCH and lindane was forbidden in China and France, the principal nations using these mixtures at the end of the 1990s (Aas et al., 2011).

Chlordanes are a group of substances formerly used to combat insects, for the most part in subtropical regions of the USA, Central America and Asia; they have been very little used in Europe. It is therefore assumed that atmospheric long-range transport of chlordanes largely takes place from America and Asia. DDT was banned as an insecticide in the early 1970s. Its main breakdown product, p,p`-DDE, was the chief reason why many birds of prey in North America, Western Europe and Scandinavia suffered a thinning of their eggshells. Due to the need to effectively combat a rise in malaria in southerly regions, DDT was again permitted in tropical countries, but subject to considerable restrictions on its use and discharge (UNEP/AMAP Expert Group, 2011). There are therefore still fresh sources of DDT, especially in connection with large-scale combatment of the malaria mosquito in Asia and Africa. DDT and its breakdown products are transported by ocean currents and wind to arctic regions where they accumulate and are enriched (biomagnified) in the food chain.

Hexachlorobenzene (HCB) is a compound formerly used as a fungicide, but it now mostly occurs as an industrial by-product from the chemical industry. Its presence in the environment is therefore mainly due to industrial emissions.

No local sources of chlororganic herbicides have been recorded in Svalbard and Jan Mayen. These compounds are long-transported from sources further south.

2.4.1 Chlorinated pesticides in the atmosphere

Two variants of HCH (α- and γ-HCH) predominate in air samples from the Zeppelin Station. The average concentration of sum HCH in the atmosphere was 8.7 pg/m³ in 2010. This varied through the year from 5.3 to 13.0 pg/m³ (Figure 2). So far, sum HCH shows no obvious seasonal variation, but the figure is somewhat higher in the autumn. The annual mean concentration of HCH from 1996 to 2010 is shown in Table 2 and the value for 2010 was the lowest observed at the Zeppelin Station (Aas et al., 2011). The concentrations of α-HCH in air samples from the Zeppelin Station are usually three to ten times higher than γ-HCH (Figure 2). The level in air samples has declined throughout the period (Figure 2 and Table 2), most probably due to less use and emission of technical HCH, followed by a global ban on lindane since 2000. China, for instance, used 10 000 tons of α-HCH in 1980, but phased out HCH in 1983 (Li et al., 1996). In general, information on the present and former use of pesticides is difficult to find and is unreliable.

A recently published article has shown that the declining trend for HCH (α- and γ-HCH) in air is significantly weakened due to increasing evaporation of HCH from earlier deposits in soil, ice, water and ocean surfaces (Ma et al., 2011). A gradual rise is therefore expected in the pollution from such secondary sources of HCH and other volatile POPs to the air in the Arctic due to a warmer climate (Figure 15). Investigations from Canada of HCH in arctic surface water show that the sea is supersaturated with HCH in summer. The combination of lower concentration in the air as a consequence of reduced global use, and warming of the surface water in summer can give a net transport of α-HCH from the sea to the atmosphere in summer (McConnell et al., 1993; Jantunen and Bidleman, 1996; Willett et al., 1998; Ma et al., 2011).

Chlordanes are only found in very low concentrations in air samples from Svalbard. Cis- and trans-chlordane and cis- and trans-nonachlor are analysed and quantified at the Zeppelin Station. These four compounds represent the main components (90 %) in a technical chlordane mixture consisting of 210 possible chlordanes. The concentration of chlordanes (sum trans- and cis-chlordane and trans- and cis-nonachlor) varied from 0.58 to 2.11 pg/m³ in 2010. A clear declining trend for all the chlordane compounds in the atmosphere is observed for the entire period (Figure 2). The present chlordane level is lower than that recorded in the Canadian Arctic (Alert) (Hung et al., 2010), thus confirming the theory that the main supply of chlordanes comes from North America or Asia. Trans-chlordane is less stable than cis-chlordane and can be broken down by micro-organisms in the soil (Hung et al., 2005). The Zeppelin dataset therefore has a strong seasonal signal for trans-chlordane, in that it shows higher concentrations in winter than in summer (Figure 2).

DDE, the breakdown product of DDT, predominates in the DDT components in air samples from Zeppelin. A continuous declining trend is reported for all the DDT components. The concentration of p,p`-DDT in air samples from the Zeppelin Station are close to the lowest level the instrument can measure (Aas et al., 2011). The mean concentration of sum DDT in 2010 was 0.63 pg/m³, which was the lowest value measured for this group of substances throughout the period from 1994 (Aas et al., 2011). The annual mean values are summarised in Table 2. The concentration for 2010 of sum DDT (dominated by the 75-80 % of p,p`-DDE) varied between 0.05 and 2.27 pg/m³ (Figure 2).

The HCB concentrations in air samples from the Zeppelin Station show a clear rising trend (Figure 2). From 2000 to 2010, the average concentration rose from 56 to 79 pg/m³ (Table 2). Calculations and modelling indicate that air masses from western Russia, Belarus, Finland, Sweden and Norway can contribute to the HCB pollution over Svalbard (Aas et al., 2011). The ice-free winters along the west coast of Spitsbergen may have led to increased evaporation of HCB during the winter, which in turn contributed to the rising trend in the air samples (Hung et al., 2010; Ma et al., 2011).

2.4.2 Chlorinated pesticides in lake sediments

Chlorinated pesticides were measured in sediments from the same lakes as for PCBs. The HCB and DDT levels were significantly higher in sediments from Svalbard lakes than from lakes on the mainland in northern Norway (Christensen et al., 2008).

2.4.3 Chlorinated pesticides in biota

In common with PCB, organochlorine pesticides have a high potential for bioaccumulation and biomagnification, and are resistant to degrading. The pesticides, β-HCH, toxaphenes, HCB, oxychlordane, the breakdown product from technical chlordane, and p,p`-DDE, the breakdown product from DDT, predominate in mammals and birds. The continual decline of HCH reported from air samples is also reflected in biota (Figure 4) (MOSJ, 2011). The oxychlordane concentration was stable or sank slightly from 1993 to 2009, and concentrations of p,p`-DDE and HCB varied from year to year, but on the whole showed a weak decline from 1992 to 2010 (Figure 4) (MOSJ, 2011).

2.5 Brominated flame retardants (BFRs)

Brominated flame retardants (BFRs) have been in use since the 1970s to make products less inflammable. They have been used in building materials, electronic articles, furniture, motor vehicles plastics and textiles. The most used compounds have been polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA). These BFRs are considered to have physical properties resembling the chlorinated organic pollutants (PCB and DDT).

2.5.1 Local sources of BFRs

The long life time of products treated with brominated flame retardants will result in emissions from waste for several decades to come. A recent study of BFRs at two research stations in the Antarctic observed high concentrations of BFRs in dust, untreated sewage and biota around the sewage outlet. These results indicate that leakages of BFRs from untreated effluent may be a local source of BFRs in the Arctic, too (de Wit et al., 2010)

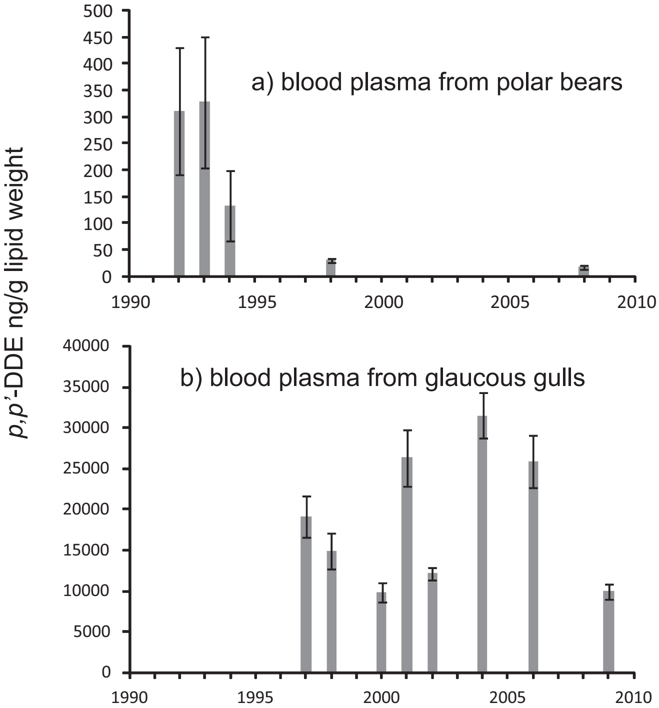


Figure 4. Time trends of chlorinated pesticides. a) HCH (ng/g lipid weight) in blood plasma from polar bears for 1992-2008. b) The breakdown product of DDT, p,p'-DDE (ng/g lipid weight), in blood plasma from glaucous gulls for 1997-2009.

2.5.2 BFRs in the atmosphere

PBDE was included in the Climate and Pollution Directorate and AMAP programme to undertake measurements of atmospheric pollution at the Zeppelin Station as early as 2006 (Aas et al., 2011). The highest value recorded in 2010 was 4 pg/m³, in the second week of August, but there was a similar occurrence (2.2 pg/m³) the following week. The contaminated air came partly from Greenland and northern Russia, but air masses from the Bering Strait and northern Canada contributed to the PBDE contamination in the second week of August (Aas et al., 2011). The concentrations of annual mean PBDE values have remained fairly constant throughout the monitoring period (Table 2).

HBCD was included in the measurements at the Zeppelin Station in 2006. The mean value for sum HBCD (α-, β- and γ-HBCD) in the atmosphere was 0.63 pg/m³ in 2010. γ-HBCD dominates in samples from the Arctic. α-HBCD was found in only five of 66 samples in 2010 and β-HBCD was only found in a single sample (Aas et al., 2011).

2.5.3 BFRs in lake sediments

Significantly higher levels of PBDE were found in lake sediments from Svalbard than in those from northern Norway (Christensen et al., 2008). Sediment cores show that the PBDE group arrived in Ellasjøen on Bjørnøya after the 1940s and their values rose strongly each decade until the 1990s, when measurements ceased (Evenset et al., 2007b).

2.5.4 BFR in biota

Most brominated flame retardants bioaccumulate in arctic food chains (Evenset et al., 2005; Sørmo et al., 2006; Verreault et al., 2007b; de Wit et al., 2010). Several compounds

Table 2: Annual mean concentration of chlorinated pesticides sum α- and γ-HCH, sum DDT, HCB, tetraBDE and TBA (pg/m^3) in air samples from the Zeppelin Station near Ny-Ålesund, Svalbard (Aas et al., 2011).

Year	sum α- og γ-HCH	sum DDT	HCB	tetraBDE	TBA
1993			93		
1994			116		
1995			98		
1996	73.1	2.67	92		
1997	66.0	1.87	99		
1998	47.4	2.23	82		
1999	42.8	2.00	88		
2000	26.5	1.22	56		
2001	27.1	1.45	55		
2002	34.1	1.47	56		
2003	23.2	1.46	54		
2004	19.9	1.03	65		
2005	17.8	1.01	67		
2006	12.7	1.87	71	0.38	7.56
2007	11.1	2.02	67	1.07	7.72
2008	10.5	0.80	73	0.49	4.62
2009	9.5	0.67	76	0.18	6.96
2010	8.7	0.63	79	0.30	7.65

which contain few bromatomes, especially BDE-47 and BDE-153, become more concentrated up the food chain, whereas those with a higher number of bromatomes are diluted up the food chain. The technical mixture of HBCD consists of three variants (α-, β- and γ-HBCD). In general, α-HBCD is taken up by animals, β-HBCD is metabolised (transformed) and γ-HBCD becomes diluted up the food chain (Law et al., 2008; de Wit et al., 2010).

Few time trend studies of BFRs have been performed. There are indications that the levels of the regulated compounds (penta- and octa-BDE) flatten out or are reduced in the environment, whereas compounds which were in use until 2011 are still rising (de Wit et al., 2010; Helgason et al., 2012). More data are required for BFRs before conclusions on time trends can be drawn (de Wit et al., 2010; Helgason et al., 2012). Several new BFRs are now being used as flame retardants and some of these have recently been discovered in the Arctic (de Wit et al., 2010; Sagerup et al., 2010).

The distributions of sum PBDE and HBCD in several species imply that the European Arctic is more polluted than the North American Arctic, which may suggest that the atmospheric transport routes for PBDE resemble those for the more established organic pollutants (PCB and DDT) (de Wit et al., 2010). Concentrations of PBDE in arctic biota are lower than in biota from southerly latitudes and are on the whole lower than for the chlororganic compounds (Carlsson et al., 2011).

2.5.5 Tribromanisole (TBA)

Some halogen-bearing substances may have both natural and man-made origins. Such compounds mainly arise through processes in marine micro-organisms. This particularly concerns brominated substances such as tribromoanisole (TBA) (Vetter et al., 2010). TBA is included as an indicator for natural supply in the programme to measure atmospheric pollution at the Zeppelin Station (Aas et al., 2011). The mean values of TBA in 2006 to 2010 are shown in Table 2. The concentrations of TBA resemble those for PCBs. In 2010, the highest level (28.2 pg/m^3) was recorded in the last week of July. Air came from the east coast of Canada northeastwards via Iceland to Svalbard during the sampling period. TBA levels vary through the year, the highest being in late summer. This implies a natural marine signal for TBA, since the growth of algae and processes in marine micro-organisms are at their maximum in summer.

2.5.6 New brominated flame retardants

Several "new" brominated flame retardants have been found in arctic biota (Sagerup et al., 2010). These substances are regarded as new because it has not previously been possible to analyse them in biological samples (Harju et al., 2009). Moreover, some are replacements for mixtures of PBDE whose use is now illegal. TBB (2-ethylhexyl- 2,3,4,5-tetrabromobenzoate) and BEHTBP (bis(2-ethylhexyl) tetrabromophthalate) were found in capelin, common eiders (*Somateria mollissima*), Brünnich's guillemots, kittiwakes and ringed seals, and TBB was also found in arctic foxes and polar bears. The concentrations of these new brominated flame retardants are much lower than many other groups of pollutants (Sagerup et al., 2010).

2.6 Perfluorinated and polyfluorinated alkylated substances (PFAS)

Perfluorinated and polyfluorinated alkylated substances (PFAS) belong to the type of contamination currently given highest priority in investigations of environmental pollutants in the Arctic. These substances are stable and are only slowly degraded in the environment. They have been included in the Climate and Pollution Directorate and AMAP monitoring programme since 2006. The group contains substances with a variety of properties. Many are soluble in neither water nor fat, and frequently become bound to proteins in animals. Some are volatile, while others are very little volatile. They have a wide area of use, including the manufacture of teflon, impregnation of clothing, fire-extinguishing foams and ski and floor wax. PFAS have been manufactured since 1940. In May 2000, 3M, the world's leading manufacturer of PFOS (perfluorooctane sulphonate), announced that it was voluntarily phasing out PFOS- and PFOS-related products because the substances had been found in the wild. Other types of PFAS are still being manufactured and used to a considerable extent all over the world (Butt et al., 2010). The Stockholm Convention has banned PFOS, but this regulation has many exceptions. Atmospheric transport and transport by ocean currents are

Extraction of pollutants in the laboratory.
Photo: Kjetil Sagerup, Norwegian Polar Institute

thought to be likely ways by which PFAS reach the Arctic, but their transport pattern is not well known (Butt et al., 2010).

2.6.1 Local sources of PFAS

No significant local sources for PFAS in the Arctic have been uncovered, but information on this is limited (Butt et al., 2010). Hence, PFAS in the Arctic are regarded as long-range pollution.

2.6.2 PFAS in the atmosphere

There is a clear annual variation in the PFAS concentrations in the atmosphere at the Zeppelin Station. The highest concentrations are recorded in the summer months (Aas et al., 2011). The mean concentration for sum PFAS in 2008 varied between 0.25 and 0.81 pg/m^3. No obvious trend for this kind of air pollution has been recognised at Zeppelin for the last five years (Aas et al., 2011). The sample with the highest concentration (1.07 pg/m^3 sum PFAS) was taken in the third week of June 2010, and comparison with the weather records showed that most of the air was transported from the Alaska-Bering Strait region and some from northern Russia (Aas et al., 2011).

2.6.3 PFAS in biota

PFAS have been found in all the organisms in the marine food chains that have been investigated, indicating that they are bioaccumulated and to some extent also biomagnified. In contrast to most chlorinated and brominated organic compounds which accumulate in fat, PFAS are associated with proteins. Consequently, they should not biomagnify to the same extent as the chlorinated and brominated organic pollutants (Butt et al., 2010).

The only time series available for PFAS in animals from the MOSJ area is from Brünnich's guillemots. This shows a complex picture. One group of PFAS (perfluorinated sulphonates, like PFOS and PFOSA) had reduced levels from 1993 to 2007, whereas another (perfluorinated carboxylic acids, like PFUnA and PFDcA) showed rising concentrations from 1993 to 2007 (Miljeteig and Gabrielsen, 2010). The same time trends were also observed for herring gull eggs from northern Norway, where PFOS, for example, showed a significant increase from 1983 to 1993 followed by flattening out until 2003 (Verreault et al., 2007a). Recent studies from northern Europe and the Arctic have shown an excess of PFAS compared with sum POPs (Herzke et al., 2009; Sonne, 2010), which has not previously been observed in the Arctic (Haukås et al., 2007; Verreault et al., 2007a). The high proportion of PFAS in arctic seabirds may reflect increasing exposure to this group of pollutants.

2.7 Endosulfan

Endosulfan is a chlororganic pesticide that has been widely used in many parts of the world for more than 50 years and is an effective substance to combat mites and many other insects. It is partially volatile and comparatively resistent to degrading. Endosulfan is one of the most frequently recorded pesticides in surface water and, after α- and γ-HCH, it is the pesticide that is most frequently found to have the highest concentrations in the atmosphere (Weber et al., 2010). Long-term monitoring through the 1990s and since 2000 showed that concentrations of endosulfan in the atmosphere, sediments, snow and ice, and marine biota were stable, probably due to its worldwide use (Weber et al., 2010). In 2011, the parties to the Stockholm Convention agreed to ban the use of endosulfan (Stockholm Convention, 2011).

2.8 Phosphororganic flame retardants (PFRs)

Phosphororganic substances (PFRs) are chiefly used in industry as flame retardants and plastic softeners. They are also used as lubricants, and as additives in hydraulic oils, floor polish and adhesives. PFRs are not regarded as harmful substances and approximately 4000 tons of 14 different PFRs were used in Scandinavia per year from 2000 to 2008 (SPIN2000, 2011). There are no known local sources for PFRs in Svalbard and Jan Mayen. Nevertheless, two studies of PFRs found 11 of the 14 investigated compounds in animals from the Svalbard area (Evenset et al., 2009b; Sagerup et al., 2011). These compounds must therefore have properties which enable them to be long-range transported.

The Brünnich's guillemot is the only species from the MOSJ area that has been investigated for PFAS over time. Photo: Hallvard Strøm, Norwegian Polar Institute

2.9 Heavy metals

Heavy metals is the term used for substances with metallic properties and a density in excess of 5 g/cm³ (five times heavier than water). Because heavy metals are elements, they are not degradable in the environment. Living organisms have difficulty ridding themselves of them, which means that the substances accumulate in the organism.

Heavy metals occur naturally in all ecosystems, but the concentrations vary with their availability in the local bedrock. These natural levels may increase or be reduced in response to human activity. Heavy metals are transported and redistributed in the Arctic via atmospheric and biological transport mechanisms and transport mechanisms in fresh water, the sea, ice and sediments (AMAP, 2005).

The heavy metals cadmium, mercury and lead are regulated through the heavy metal protocol of 1998 (LRTAP Convention; http://www.unece.org/env/lrtap/hm_h1.html). This protocol has been ratified by 31 nations and aims to get the discharges and emissions down to below the 1990 level by cutting those from industry, combustion and waste. The nations are also obliged to phase out leaded petrol and reduce the use of lead in batteries and electrical equipment.

2.9.1 Cadmium

Cadmium levels in the arctic environment have risen since the Industrial Revolution. Even though levels in a few species and marine organisms are sufficiently high to give cause for concern, effects have still not been found in free-living organisms in the Arctic (AMAP, 2005).

Sources

Zinc and lead production is the most important source of human-induced cadmium emissions to the atmosphere. Cadmium has been used as a pigment since the 19th century, and in the 20th century it was used to prevent corrosion of iron and steel, as a solder and as a stabiliser in plastics. Cadmium is still used in rechargeable nickel-cadmium batteries. Other important sources are stationary combustion of coal and oil, waste treatment and cement production. Small amounts are also released from iron and steel manufacturing.

Asia emits the greatest quantity of cadmium, followed by North America, South America, Europe, Africa and Australia. Emissions are declining in Europe and North America. Less than 2 % of the airborne cadmium emitted into the global atmosphere is deposited in the Arctic. The amount of cadmium transported by rivers draining to the Arctic Ocean resembles that transported in the atmosphere (AMAP, 2005).

2.9.2 Mercury

Mercury has been much used for thousands of years as a pigment, in cosmetics and medicine, to extract gold and in amalgam in tooth fillings. It is now chiefly used to manufacture industrial chemicals and in electrical products like fluorescent tubes.

Sources

Mercury is emitted into the atmosphere from a number of natural sources (volcanoes, forest fires and evaporation from the sea) and human-generated sources (waste and burning coal) (Nriagu and Pacyna, 1988). Human-generated mercury emissions have changed dramatically in the last 70 years (Pacyna et al., 1995; Pacyna et al., 2006). Mercury emissions have been reduced in North America and Europe since the 1990s, whereas those in Asia have greatly increased. China now leads the world in mercury emissions (Pacyna et al., 2006). In the atmosphere, mercury mainly occurs in gaseous form as elemental mercury. Under normal conditions, mercury remains relatively stable and can be carried over long distances in the atmosphere (Slemr et al., 2003).

Mercury has an unusually complex cycle in the Arctic. This includes deposition from the air to ice and snow, bonding to the water cycle, appearance in the organic carbon cycle, liberation when permafrost thaws, biomagnification or bioaccumulation in food chains and conversion to methylmercury due to changes in wetland or the organic carbon cycle (Macdonald et al., 2005). The Arctic is thought to be a global fallout site for mercury due to a set of extraordinary meteorological conditions which arise when the sun returns in spring. Elemental mercury in a gaseous state is rapidly oxidised and deposited from the atmosphere. This phenomenon, called atmospheric mercury depletion events (AMDEs), is a circumpolar phenomenon. During AMDEs, mercury in the air is converted into an oxidised form. It disappears rapidly from the atmosphere and results in substantial fallout of mercury onto snow and ice surfaces (Lindberg et al., 2002; Steffen et al., 2008). However, it is very uncertain what happens to the mercury after it has been deposited there. Recent research has discussed the possibility that deposited mercury returns to a gaseous state in a matter of days (AMAP, 2011).

2.9.3 Lead

Lead has been much used for more than 6000 years in pipes, cutlery, coins and paint pigment. Nowadays, it is mainly used in car batteries and to give protection against

The coal-fired power station in Longyearbyen is a source of emissions of, for example, cadmium, mercury and lead to the atmosphere. Photo: Jon Aars, Norwegian Polar Institute

X-rays and radioactive radiation. The reduction in the use of leaded petrol throughout the world has been an effective means of reducing lead pollution (AMAP, 2005).

Sources

Vehicles have been the primary source of lead emissions to the atmosphere. Production of metals, stationary combustion of coal and oil, and cement production follow as secondary sources. The greatest contributors to lead emissions are Asia, followed by Europe, North America, Africa, South America and Australia. Airborne lead reaching Svalbard and Jan Mayen originates chiefly in Europe and Russia. It has been estimated that 2-5 % of the lead emissions from these areas are deposited in the Arctic. The amount of lead transported to the Arctic by rivers draining to the Arctic Ocean resembles that brought in the atmosphere (AMAP, 2005).

2.9.4 Heavy metals in the atmosphere

Most heavy metals are emitted as aerosols, tiny particles of greatly varying size. When they enter the atmosphere, heavy metals can be transported over several thousands of kilometres, depending on the particle size, and be deposited on land and sea. The concentration of heavy metals in the suspended dust has been measured at the Zeppelin Station near Ny-Ålesund since 1994. It is higher in winter than in summer because of the location of the station in the large-scale weather system. The high-pressure system over Siberia pushes the Polar Front southwards in winter and spring so that important areas of pollution fall inside the arctic air masses at this time of year (Aas et al., 2011).

From 1994 to 2010, the average annual mean concentration of cadmium in the air was 0.026 ng/m³ (Figure 5). The levels are comparable with those measured in Resolute in the Canadian Arctic (Li et al., 2003). No significant changes in the cadmium concentration have been observed at Zeppelin since 1994 (Figure 5). This is in agreement with Berg et al. (2004), who found that government regulations of cadmium had still not had any effect on the cadmium levels measured at Zeppelin, or that measurements at the station started first after the measures were introduced. Similar measurements from the Canadian Arctic show a significant reduction of cadmium in the air from 1973 to 2000 due to reductions in human-generated emissions (Li et al., 2003).

From 1994 to 2010, the average concentration of lead in the air was 0.60 ng/m³ and the annual mean varied from 0.3 to 1 ng/m³. Since 1994, the concentration has dropped by 30 % (Aas et al., 2011) (Figure 6). Lead concentrations at Alert in Canada dropped from 1980 to the mid 1990s, but have since flattened out (Gong and Barrie, 2005). The introduction of unleaded petrol in Europe and North America explains the considerable reduction in lead emissions. In Norway, the sale of low-octane leaded petrol was banned in 1987, and high-octane petrol was banned in 1997. Lead emissions from road vehicles in Norway peaked in 1978 at over 500 tons per year (www.miljodirektoratet.no).

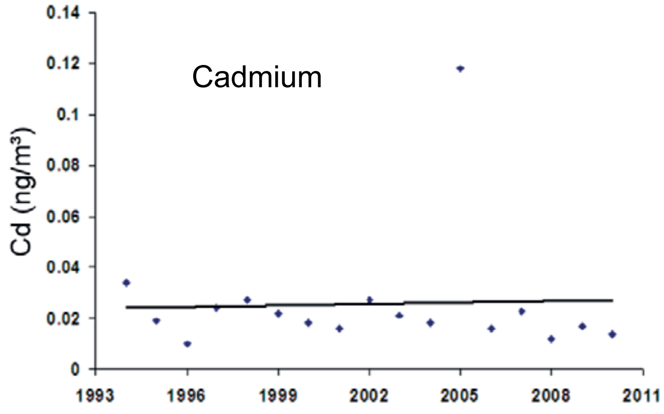


Figure 5. Annual concentration of cadmium on particles in air from the Zeppelin Station near Ny-Ålesund, Svalbard (1994-2010)..

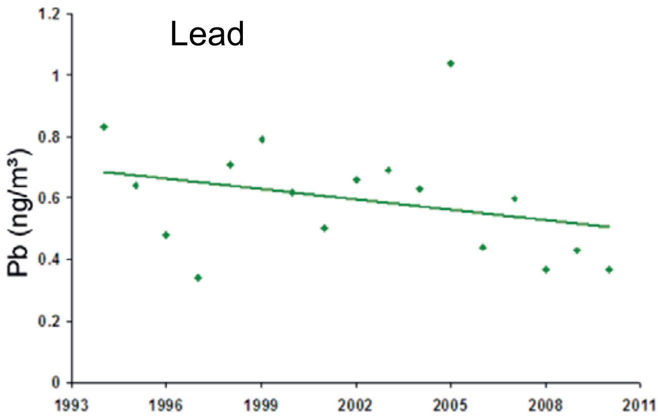


Figure 6. Annual concentration of lead in air from the Zeppelin Station near Ny-Ålesund, Svalbard (1994-2010).

From 1994 to 2010, the average concentration of elemental mercury measured at Zeppelin was 1.58 ng/m³, and the annual mean varied from 1.18 to 1.79 ng/m³ (Figure 7). The background concentration of elemental mercury in the Northern Hemisphere is estimated at 1.5 to 1.7 ng/m³ (Slemr et al., 2003). Sinking concentrations have been observed at some monitoring stations in Europe and North America, such as Rörvik in Sweden (Wangberg et al., 2007), Mace Head in Ireland (Ebinghaus et al., 2011) and near centres of population in Toronto and Montreal in Canada (Temme et al., 2007). The Arctic seems to react differently to changes in the emissions. Analyses of the two longest time series in the Arctic show a weak, but significant reduction in the annual mean value at Alert in Canada, but no change in Ny-Ålesund (Figure 7) (Cole and Steffen, 2010; Berg et al., in prep.). The background for these trends is uncertain, but a reduction in sea ice and a change in where mercury is emitted geographically may explain some of these trends (Cole et al., 2011).

2.9.5 Heavy metals on land and in lakes

Vegetation is the basis for terrestrial food chains. Some plants, like mosses and lichens, lack root systems and absorb pollution and nutrients from the air. They are therefore

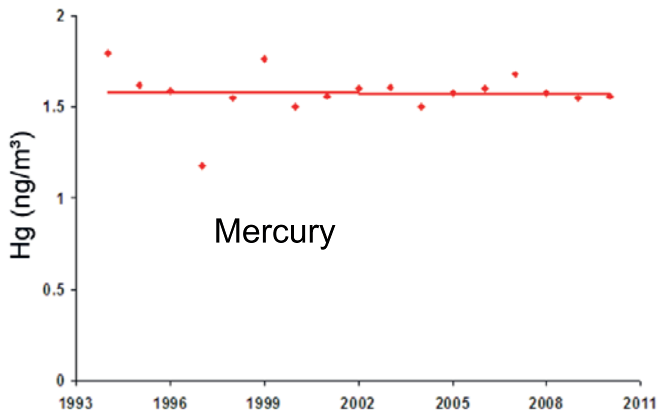


Figure 7. Annual concentration of elemental mercury in air from the Zeppelin Station near Ny-Ålesund, Svalbard (1994-2010).

very suitable for monitoring pollution fallout from the air (Steinnes, 1995). Sampling and analysis of moss and lichen is an established means of studying deposition from the air on large geographical scales. Monitoring the fallout of heavy metals has taken place in Norway every fifth year since 1975.

Cadmium concentrations in moss fell until 2000, but have remained constant since then. The level and geographical distribution of mercury in moss was relatively constant from 1985 to 2010 (Steinnes et al., 2011). However, investigations have shown increasing concentrations of mercury along the Barents Sea coast, but the reason for this is so far unknown. The concentration of lead in moss has dropped substantially, and in 2005 it was less than 10 % of that found in 1977 (Berg and Steinnes, 1997; Steinnes et al., 2003; Steinnes et al., 2011).

Lake sediments from mainland Norway and Svalbard show that the level of mercury is higher than prior to the Industrial Revolution (Boyle et al., 2004; Rose et al., 2004; Sun et al., 2006; Rognerud et al., 2008). Lake sediments from mainland Norway have shown a slight increase in mercury concentration recently, but no such increase has been observed for lakes in Svalbard. The highest levels of mercury in lake sediments from Svalbard were recorded in lakes affected by seabirds (Rognerud et al., 2008). In an area of 60-80 km around the power stations in Longyearbyen, Pyramiden and Barentsburg, there is a small, but measurable signal from local pollution in lake sediments (Boyle et al., 2004). However, the concentration of heavy metals in lake sediments is lower in the Arctic than in mainland Norway (Rognerud et al., 2000).

The soil in Svalbard is affected by human activity. Significantly elevated lead values were found in soil sampled around the former Russian mining town of Pyramiden (Gulinska et al., 2003). Lead contamination derives from former mining and the levels were five to ten times higher than European threshold values. Long-range transport was not found to contribute to the contamination.

2.9.6 Heavy metals in plants and animals

It is estimated that 92 % of the mercury concentration in arctic wildlife has a human-generated origin (Dietz et al., 2009). Based on observations of tissue samples from arctic mammals and birds, the mercury level has increased more than ten times since the mid 1800s (Outridge et al., 2005; Dietz et al., 2006a; Dietz et al., 2006b; Dietz et al., 2009; Outridge et al., 2009). Monomethylmercury is the most toxic form of mercury and the one which accumulates in the food chain, whereas inorganic mercury and elemental mercury have little ability to bioaccumulate (Mason et al., 1996). Monomethylmercury is formed from inorganic mercury in water (Lehnherr et al., 2011). The amount of monomethylmercury in the water is thus an important factor determining the concentration of mercury at higher trophic levels (Louis et al., 2011).

Levels of mercury and cadmium in wildlife in Svalbard are generally lower than in other arctic regions (Savinov et al., 2003; Riget et al., 2005; Helgason et al., 2008; Jæger et al., 2009; Riget et al., 2011). Even dying glaucous gulls which contained extremely high values of POPs had low mercury levels (Sagerup et al., 2009). It has been shown that mercury levels are lower and cadmium levels slightly higher in ringed seals from Svalbard than from the Baltic Sea, but no differences were found for lead (Fant et al., 2001; Nyman et al., 2002). Even though cadmium is found in arctic wildlife, the present level of knowledge hardly suggests that cadmium is accumulated in the food chains (Dehn et al., 2006; Routti et al.,2012). The lead concentration in wildlife is, in general, very low (Fant et al., 2001; Nyman et al., 2003). Time trend studies of mercury in seabird eggs (Helgason et al., 2008) and polar bear hides (Riget et al., 2011) show no rising trend in Svalbard. Some studies show increasing mercury concentrations in Greenland and the Canadian Arctic (Riget et al., 2007).

2.10 Radioactive substances

Radioactive substances are unstable isotopes of elements which emit particles or gamma rays to attain a stable state.

Light-coloured reindeer lichen (*Cladonia arbuscula*) on Kongsøya, Svalbard. Lichens lack a root system and absorb toxins directly from the air. Photo: Øystein Overrein, Norwegian Polar Institute

Environmental pollutants in glaucous gulls are monitored by collecting eggs. Photo: Geir Wing Gabrielsen, Norwegian Polar Institute

The composition may be changed if two protons and two neutrons are emitted from the core simultaneously (alfa particles). A proton can, moreover, be transformed into a neutron, or a neutron into a proton, while an electron (beta particle) is emitted. When the core is transformed, excess energy may also be emitted (gamma radiation). The various radionuclides emit different types of radiation.

The intensity of the radiation will gradually decline as more and more atoms shift from an unstable to a stable state. This breakdown takes place in an absolutely pre-determined time pattern which is characteristic for the various radioactive substances. The half-life varies greatly, from fractions of microseconds to billions of years. Likewise, we speak of a biological half-life, which is the time it takes before half of a radioactive substance has left an organ or a living organism. The biological half-life varies with age, gender and individual differences, and differs in different species of animals and plants.

In Norway, radioactive waste has been regulated by the Pollution Control Act since 1 January 2011. This Act defines when a substance is considered radioactive waste. All emissions of radioactive material require a permit from the Norwegian Radiation Protection Authority. One of the largest sources of radioactive emissions to Norwegian waters is produced water from the petroleum industry, and other smaller sources are hospitals, research laboratories and nuclear waste treatment plants.

Sources

The most important sources of human-generated radioactivity that have affected the levels in the Norwegian marine environment are fallout from atmospheric nuclear weapon tests in the 1950s and 1960s, discharges of liquid waste from reprocessing plants at Sellafield (Great Britain) and Cap de la Hague (France) and the Chernobyl accident in 1986. Even though the Chernobyl accident occurred 25 years ago, the Baltic Sea is still a secondary source for Cs-137 to Norwegian waters because contaminated water flows out from the Baltic. The Sellafield discharges have decreased in recent years, but sediments in the Irish Sea that are contaminated by discharge peaks in the 1970s and 1980s still function as sources for Cs-137 and plutonium isotopes (Cook et al., 1997; Leonard et al., 1999). On the whole, discharges from all the nuclear plants to northern European waters have been reduced since the early 1990s (OSPAR, 2010) and levels of radioactivity from the atmospheric nuclear weapon tests and the Chernobyl accident are declining all the time.

It is expected that levels of human-generated radioactivity will continue to sink in the years to come. Another source of radionuclide emissions is naturally occurring radioactive substances from non-nuclear industry, such as produced water from the petroleum industry. Produced water contains low concentrations of radium isotopes (Ra-226 and Ra-228). Even though the concentration of these radionuclides is low, the amount of produced water is so great that the discharges are substantial. Discharges of radioactive substances from produced water from the Norwegian petroleum industry have been relatively stable in recent years (NRPA, 2011). The sunken nuclear submarine Konsomolets, which lies at a depth of 1700 m 180 km southwest of Bjørnøya, may become a local source of radioactive contamination to the Svalbard area. Elevated levels of Cs-137 in sediments close to the submarine may indicate leakage from the reactor chamber (Kolstad, 1995). Norway, including Svalbard, experienced radioactive fallout from atmospheric nuclear weapon tests in the 1950s and 1960s. However, whereas southern parts of Norway received substantial fallout from the Chernobyl accident in 1986, the Svalbard region was relatively unaffected.

2.10.1 Occurrence in the environment

In the marine environment, radionuclides may be bound to particles and sediments (e.g. Pu isotopes and Am-241), or may exist in a dissolved form and thus be transported away from the emission point by ocean currents (e.g. Sr-90, Tc-99 and Cs-137). Radionuclides bound to sediments can return to a dissolved state and be transported elsewhere by the currents. Following discharges to the sea, radionuclides may accumulate in organisms like plankton, macro-algae, invertebrates, fish and marine mammals. Biomagnification through marine food chains has only been observed for some radionuclides, such as Cs-137 (Dahlgaard, 1994; Andersen et al., 2006). On land, radionuclides may bind to soil particles and be strongly bound to surface soil (e.g. Cs-137 and Pu isotopes), or be more mobile (e.g. Sr-90) and leak into the groundwater. Radionuclides can be absorbed by plants, either through direct deposition on the plant or by uptake through the root system. Plants transfer radioactivity effectively through terrestrial food chains, like, for example, the transfer of Cs-137 in the lichen – reindeer – human food chain.

2.10.2 Monitoring
Norway currently has two monitoring programmes for radioactivity in the marine environment, and these are coordinated by the Norwegian Radiation Protection Authority. One is funded by the Ministry of the Environment and focuses on monitoring radioactivity in coastal areas and the open sea, and the other is funded by the Ministry of Fisheries and focuses on monitoring radioactivity in commercially important species of fish. Each year, samples of seaweed and seawater are taken at 13 coastal stations. Seawater, sediments and marine biota from the open sea are sampled in cooperation with the Norwegian Institute for Marine Research. Radioactivity is also included in the supply programme funded by the Climate and Pollution Directorate. However, few samples in this programme are analysed with respect to radioactivity. In Svalbard, terrestrial monitoring of radionuclides is carried out by the Norwegian Radiation Protection Authority in cooperation with the Norwegian Polar Institute and the Governor of Svalbard. In addition, samples of various plants, berries, fungi, soil, fresh water, fish and mammals are collected.

2.10.3 Geographical trends
Global fallout from atmospheric nuclear weapon testing in the 1950s and 1960s (Cs-137, Sr-90 and plutonium isotopes) was at a maximum between latitudes 40^0 and 50^0 N (UNSCEAR, 2000). Fallout in the 70^0 to 80^0 N sector was about a tenth of that in the 40^0 and 50^0 N sector (UNSCEAR, 2000). The distribution of this fallout was influenced by ocean currents, dilution and sedimentation. The Gulf Stream and the Norwegian Coastal Current transported much of the fallout through Norwegian waters into the Arctic Ocean. Discharges from European nuclear waste reprocessing plants were transported from the Irish Sea (Sellafield) or the English Channel (Cap de la Hague) to the North Sea and thereafter by the Norwegian Coastal Current into the Barents Sea. A general trend for these radionuclides is that the levels in seawater sink with increasing distance from the emission point. Data available from the terrestrial environment in Svalbard show low levels of radionuclides, especially compared with mainland Norway. Time series from Svalbard are not available, but the present low level is expected to be further reduced over time due to physical degrading.

2.10.4 Time trends
The level of human-generated radionuclides in the sea off northern Norway is low at present. The time trends show that the concentrations are either fairly constant or declining. This may be explained by reduced emissions, physical degrading, dilution and sedimentation. The present levels of Cs-137, Sr-90 and Tc-99 in seawater are among the lowest observed since the 1990s or shortly after 2000.

Based on the present situation and without new sources of radioactive contamination, levels of human-generated radionuclides in Norwegian waters are expected to continue to sink. However, it should be remarked that potential new sources exist in the MOSJ area. These may be a leakage from the reactor in the sunken nuclear submarine Komsomolets, southwest of Bjørnøya, an accident in a nuclear plant in Europe or Russia, or an accident in a nuclear-powered vessel. Moreover, climate change may result in more transport of nuclear material in the northern regions and increased petroleum activity will result in more discharges of produced water which can contain natural radioactive substances.

3 Effects of environmental pollutants

Prolonged exposure to environmental pollutants may have effects that are injurious to the health of human beings and animals. Pollutants can disturb molecules, cells, tissues or the individual as a whole. If the negative effect is small, the individual may cancel it out, but harm will arise with prolonged, significant exposure. Exposure to environmental pollutants may affect the ability of animals to reproduce and survive, which may lead to effects on the population. In arctic animals, the effects of environmental pollutants have mainly been studied on molecules, cells and tissues in predators like kittiwakes, glaucous gulls and polar bears. Their significance at the population level has only been studied for glaucous gulls on Bjørnøya. The results show that

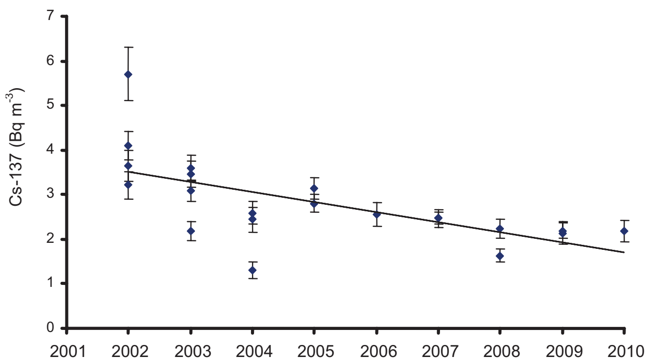


Figure 8. Cs-137 in surface water from Hillesøy in the county of Troms in 2002-2010.

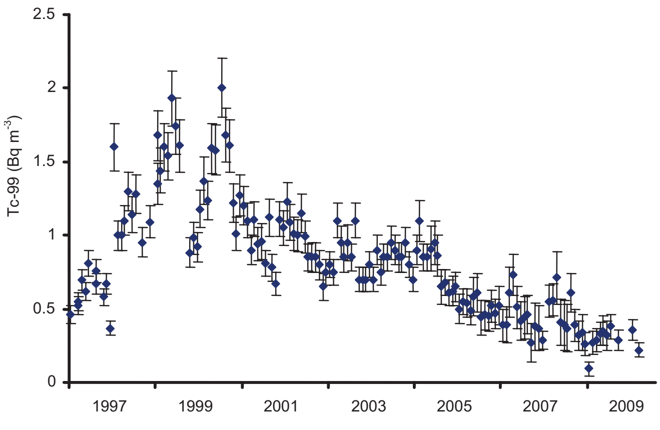


Figure 9. Tc-99 in surface water from Hillesøy in the county of Troms in 1997-2010.

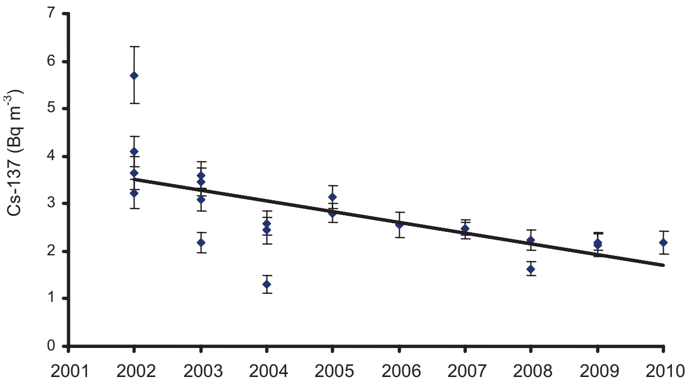


Figure 10. Sr-90 in surface water from Hillesøy in the county of Troms in 2002-2010.

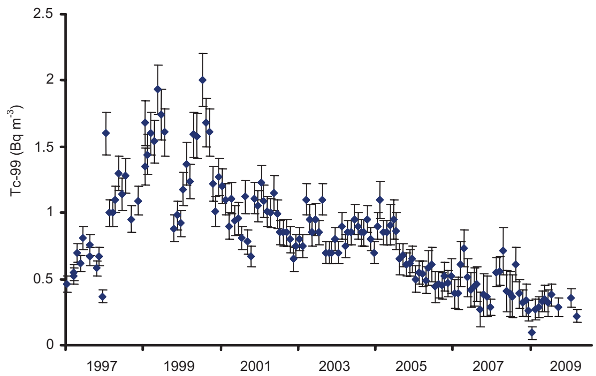


Figure 11. Tc-99 in surface water from Bjørnøya and Jan Mayen in 2001-2010.

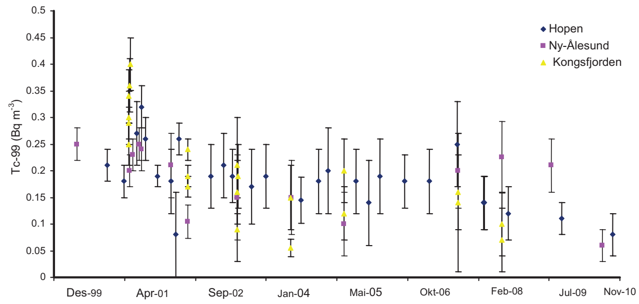


Figure 12. Tc-99 in surface water from Hopen, Ny-Ålesund and Kongsfjorden in 1999-2010.

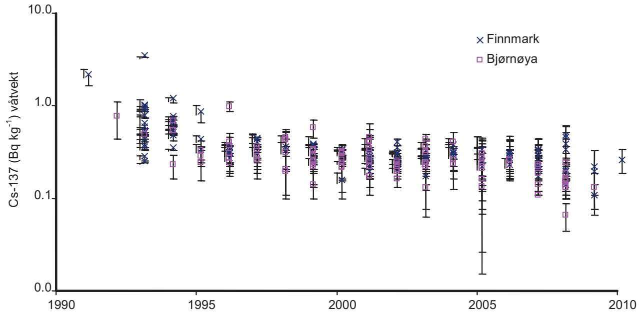


Figure 13. Cs-137 in cod (*Gadus morhua*) from the coast of Finnmark and the waters around Bjørnøya in 1991-2010.

pollutants have negative effects on the ability to reproduce and on adult survival. A recent modelling study on glaucous gulls on Bjørnøya clearly shows that the level of pollutants has negative consequences for population development (Section 3.4.5).

It is difficult to study effects of pollutants in free-living organisms because they are always exposed to an unknown cocktail of pollutants (POPs, heavy metals and radionuclides). In such a mixture of pollutants, the concentrations of the various pollutants frequently co-vary, making it difficult to establish the causal connection of the specific pollutants against measurable changes. In addition to the composition of the pollutant cocktail, biological factors like age, gender and fitness will play a role. For instance, an animal which fasts will mobilise energy from fatty tissue so that the pollutants stored in the fat will be liberated into the blood. They will then circulate and may reach vital organs like the liver and brain (Helgason, 2011).

Harmful effects from pollutants are often evaluated by comparing the pollutant concentration with a measured effect, called a biomarker (Figure 14). Biomarkers are defined as measurable changes or reactions caused by unnatural (synthetic) substances. The difficulty in using biomarkers is that they are natural processes in the body which have a natural variation. It is therefore important to know a great deal about both the marker and the physiological status of the animal before conclusions on effects can be drawn.

The risk evaluation of negative health effects in animals has often been based on threshold values, that is, comparison of pollutant levels in free-living animals with pollutant levels from experimental trials (de Wit et al., 2004; Sonne, 2010). Unfortunately, this method has its limitations. Ideally, there should be threshold values for each species, but for practical and economic reasons this is impossible. Until recently, it was, moreover, only the parent compounds of the pollutants that had any threshold value. The biotransformation products (the metabolites), which are often more toxic, have not been taken into account. This means that transferring threshold values for effects of pollutants from laboratory trial animals to free-living animals is difficult.

3.1 Evaluation of effects from organic pollutants

Studies of effects of pollutants in cell cultures, on animals in laboratory trials and the field have demonstrated various kinds of negative effects. These may be disturbances in hormones, reduced ability to reproduce, damage to the nervous and immune systems and stress-related effects on cells in the body. All of them may be explained by exposure of the animal to pollutants.

In the liver, enzymes can convert pollutants into two main types of metabolites, hydroxyl (OH) and methylsulfonyl ($MeSO_2$) metabolites (Letcher et al., 2000), which may be more toxic than the original pollutants (Letcher et al., 2000). The capacity of the individual to biotransform pollutants increases with increased exposure and the capacity for

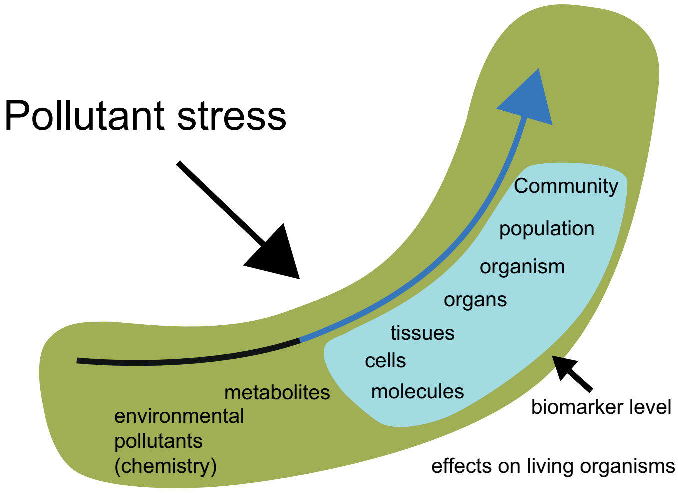


Figure 14. Possible effects of environmental pollutants on a living organism. A biomarker relates exposure or concentrations of pollutants to a measurable response on various biological processes in an organism. Figure: Norwegian Polar Institute.

biotransformation is species specific. In arctic animals, this capacity varies from highest to lowest in this order: polar bear > ringed seal > fulmar (*Fulmarus glacialis*) > kittiwake = glaucous gull (Verreault et al., 2005; Gebbink et al., 2008a; Gebbink et al., 2008b; Routti et al., 2008; Routti et al., 2009a; Routti et al., 2009b; Helgason et al., 2010a).

The negative effects from PCBs can be divided according to the structure of the PCB molecule. PCB molecules with a structure where the two phenyl rings which form the backbone of the molecule are twisted out of plane (non-dioxin like) have been linked to effects on the nervous and immune systems. PCB molecules where the two phenyl rings lie in a plane give dioxin-like effects. The dioxin-like effects may lead to changes in the enzyme system, destruction of tissue, cell death and abnormal foetus development (Giesy et al., 2006; Lyche et al., 2006).

Hormone disturbances have been linked to various kinds of environmental pollutants such as PCBs, chlorinated pesticides and flame retardants like PBDEs. A hormonal change may have great consequences for the individual since hormones control important body functions like metabolism, growth, ability to reproduce and ability to react to external impacts.

Metabolites of chlorinated and brominated pollutants may disturb hormones more effectively than the original pollutants because the structure of the metabolites is often more like the natural hormones. These pollutants, often called endocrine disruptors, act by changing the transport of hormones, or activating or inhibiting hormones (van den Berg, 1990; Hamers et al., 2008; Mercado-Feliciano and Bigsby, 2008).

Potential health effects from fluorine compounds have not been studied as intensely as those from chlorinated and brominated pollutants. Recent studies indicate that exposure to fluorine compounds may lead to negative changes in fat metabolism, liver function, immunology and cell-related stress (Wei et al., 2009).

3.2 Evaluating effects from heavy metals

The heavy metal mercury can give changes in the nervous system, which is particularly unfortunate for young animals, and may damage the liver and kidneys (Grandjean et al., 2004; Dietz et al., 2011). It may also disturb hormones and have a negative effect on the function of the adrenal gland and the ability to reproduce (Tan et al., 2009).

3.3 Evaluating effects from radionuclides

The criterion for protecting the environment from radiation used to be expressed as follows: if people were protected, the environment around would be protected (IAEA, 1999). This view has shifted with the statement by the International Commission on Radiological Protection (ICRP) that a lucid framework is needed for other species than man to evaluate the relationship between exposure and dose, dose and effects, and ultimately the consequence of the effects. The most relevant factors to determine the risk for species in the ecosystem are mortality rates, resistance to disease and ability to reproduce.

In Svalbard and Jan Mayen, no data are available on biological effects of radiation, neither on the molecular nor the population levels. The threshold value for radiation effects on plants and animals has been reported to be between 0.5 and 1 mGy per day for radiation exposure (Sazykina et al., 2003). Considering the low concentrations of human-generated radionuclides measured in the marine and terrestrial environments in Svalbard, these doses lie far below the threshold values for effects.

3.4 Effects of environmental pollutants on arctic animals

3.4.1 Polar bear

Polar bears around Svalbard and in the Barents Sea have higher levels of pollutants than those in the rest of the Arctic (Letcher et al., 2010). This population has been studied for possible effects of pollutants for the last 15 years. These studies have used samples from living polar bears, which reduces the number of potential biomarkers. The majority of the studies have focused on the hormone and immune systems. Studies have found both positive and negative relationships between sum PCB and hormones, depending upon the gender and the type of hormone (free/total thyroxine and triiodothyronine) (Braathen et al., 2004). Recent tests of polar bear plasma from Svalbard suggest that the seats for binding of hormones to a given carrier protein (transthyretine for thyroid hormones) are totally saturated by metabolites from pollutants (Gutleb et al., 2010). This was confirmed by Bytingsvik et al. (2011), who found that pollutants in polar bear cubs are bound to these seats. In addition, pollutant levels dropped significantly between 1998 and 2008 in both adult females and cubs-of-the-year (Bytingsvik et al., 2012). Moreover, the binding affinity of the pollutant cocktail to the thyroid hormone carrier protein in the cubs dropped between 1998 and 2008, showing that the amount of pollutant with this property was also reduced in the same period (Bytingsvik et al., 2011). Disturbances in the levels of sex hormones have also been linked with pollutants in polar bears from the Barents Sea. Oskam et al. (2003) showed that polar bears which had the highest pollutant levels had the lowest testosterone levels. The amount of progesterone has, moreover, also been shown to increase with the pollutant concentration, whereas there is no relationship to estradiol (Haave et al., 2003). A recent study supports earlier studies showing that sex hormones may be affected by pollutants in polar bears (Ciesielski et al., 2011). Vaccination studies performed on polar bears from the Barents Sea and Hudson Bay show that immune defence may be weakened by pollutants (Lie et al., 2004; Lie et al., 2005), which means that the animals are more prone to diseases.

3.4.2 Seals

Effects of pollutants have been carefully studied in ringed seals in recent years, because this species has been recommended as a model species for effects of pollutants in arctic mammals (de Wit et al., 2004; Letcher et al., 2010). A study has been carried out on approximately 50 adult ringed seals from Svalbard as a "clean" reference population for the strongly contaminated Baltic Sea population. Svalbard ringed seals are thought to belong to a healthy population (Tryland et al., 2006), whereas effects like reduced reproductive ability and disturbances of hormones and vitamins A and E have been linked to high levels of pollutants in Baltic Sea ringed seals (Helle et al., 1976; Nyman et al., 2003; Routti et al., 2010). In addition, a changed signal (genetic expression) is seen for fat metabolism in Baltic Sea ringed seals in relation to seals from Svalbard (Castelli et al., 2014).

3.4.3 Whales

There are few studies of effects of pollutants in whales from the Svalbard region. A recently published study showed negative relationships between levels of brominated flame retardants and hormones (Villanger et al., 2011).

3.4.4 Arctic foxes

There are no studies of effects on wild arctic foxes from the Svalbard region. Experimental studies, on the other hand, have shown that exposure to pollutants can lead to changes in both growth and sex hormones, but these effects are not equally prominent in all age groups (Hallanger, 2006; Rogstad, 2007).

3.4.5 Glaucous gulls

Monitoring of the glaucous gull in Svalbard has shown that this species accumulates a wide range of pollutants, such as organic and inorganic metal compounds and halogenated and non-halogenated organic compounds. The levels measured in glaucous gulls from Bjørnøya exceed threshold values for negative health effects in birds. Studies from Bjørnøya have shown both biological and ecological effects of pollutants (summarised in Verreault et al., 2010a) measured on the molecular, cellular and population levels (Figure 14). More specifically, research revealed effects on the liver enzyme activity, vitamins, hormones, rest metabolism, temperature regulation, immune system, regulation of genes, egg structure, ability to reproduce, behaviour and survival. In sum, these negative effects constitute a great burden. The nesting season is a period when adults expend a great deal of energy to produce chicks. The burden of environmental pollutants therefore comes as an additional stress factor in this physically exhausting period. A model estimate that takes into account natural stress and the stress caused by the pollutants shows that contamination has negative consequences for the population development of glaucous gulls on Bjørnøya (Erikstad and Strøm, 2012). Pollutants in glaucous gulls may therefore have contributed to the negative development the glaucous gull population has experienced on Bjørnøya (Strøm, 2007; Erikstad and Strøm, 2012).

3.4.6 Ivory gulls

The ivory gull (*Pagophila eburnea*) is a rare species with fewer than 14 000 breeding pairs (Gilchrist and Mallory, 2005). Ivory gulls are regarded as opportunistic in their choice of food, but their food mainly consists of small fish and macrozooplankton. They are, however, also carrion eaters and therefore also eat the blubber of marine mammals. Only a few studies have measured pollutant levels in ivory gulls, and only one study has looked at the health effects. It reported 7-17 % thinner shells in eggs with the highest concentrations of pollutants (Miljeteig et al., 2009). In general, a 16-18 % thinning of the eggshell is considered likely to lead to lower breeding success and, hence, a population decline. As pollutant levels measured in ivory gulls exceed those measured in glaucous gulls, it is possible that detrimental health effects may also occur in ivory gulls.

Trapping of arctic foxes in Svalbard is a valuable contribution to the research on pollutants. All the carcasses are handed in and the researchers can obtain a full range of samples. Photo: Tore Nordstad, Norwegian Polar Institute

3.4.7 Fulmars

Fulmars accumulate high levels of dioxin-like components compared with other arctic seabirds with a similar diet (Helgason et al., 2010b). The potential for effects from dioxin and dioxin-like PCBs can be measured through the EROD activity. In the fulmar, a strongly positive link has been observed between EROD activity and dioxin-like PCBs, which means that the system was activated by the pollutants and is thus affecting the birds (Helgason et al., 2010b).

3.4.8 Other seabirds

It is likely that pollutants may affect the health of other arctic seabirds than those mentioned above. Attention has been directed at the great skua (*Stercorarius skua*), for instance, since high levels of pollutants have been measured in it. Seabirds that are high in the food chain are regarded as being most vulnerable to detrimental health effects from pollutants (Letcher et al., 2010).

3.4.9 Freshwater fish

Even though high levels of environmental pollutants have been found in several char stocks in Svalbard, little has been done to investigate which effects they might have on them (Evenset et al., 2004; Evenset et al., 2005). It has been shown that char from Ellasjøen on Bjørnøya, which contain extremely high levels of organic pollutants, have increased EROD activity in their liver compared with char from Øyangen, a lake with lower pollutant levels (Skotvold et al., 1999; Wiseman et al., 2011). Char from Ellasjøen also have higher levels of some stress-related biomarkers than char from Øyangen (Wiseman et al., 2011).

3.5 Environmental pollutants and food safety

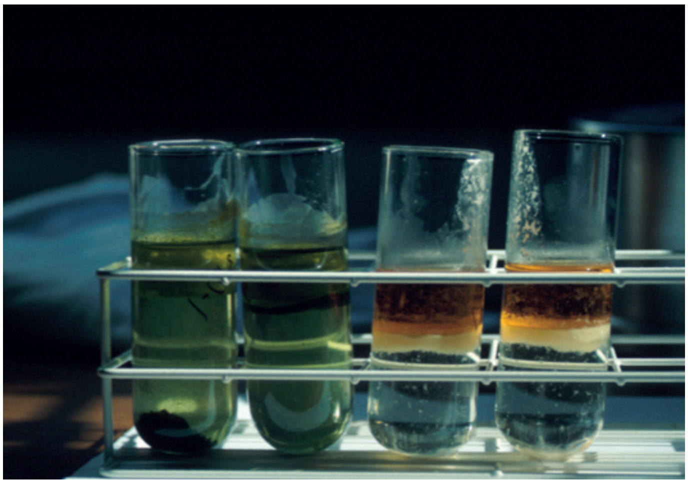
Environmental pollutants can influence human health if people are exposed through the food they eat. Whether they have any health effects depends upon the amount of pollutants in different kinds of food, how much is eaten of the various foodstuffs and how toxic the various substances are. Based on knowledge of the toxicity of different substances, limits are calculated for how much a person can consume over time without suffering ill-health, called tolerable intake (monthly, weekly or daily). The calculations are based on the most vulnerable groups, which is often foetuses and small children. Based on such intake limits and knowledge of the amounts of pollutants different groups are exposed to through food, the EU has set upper maximum limits for pollutants in food (EU, 2006). These have also been adopted by Norwegian authorities. When they are determined, allowance is usually also made for how much of the substances are found naturally in various organisms, that is, the natural background level. For instance, as regards fish, large predatory fish, like swordfish, halibut and many others, will quickly attain mercury concentrations that exceed the threshold value, even in little polluted areas. To permit these species to be marketed nonetheless, the EU has set a higher threshold value especially for these species. This is partly because of the awareness that, even though they may sometimes contain comparatively large quantities of pollutants, fish also contain many valuable nutrients. There is a general desire that people should eat more fish because their positive health effects to a large extent overshadow any negative effects from the pollutants (Alexander et al., 2006).

3.5.1 Radionuclides in food

The Norwegian Food Safety Authority has set an upper limit for the legal level of radiation from caesium (Cs-134 and Cs-137) in food. This is from 370 Bq/kg (Becquerel) in milk and food intended for children and up to 3000 Bq/kg in reindeer meat, game and freshwater fish. For other foodstuffs, like honey, fungi and berries, the limit is 600 Bq/kg. Owing to the short half-life of Cs-134 (two years in contrast to 30 years for Cs-137), and the relative contribution of radiation from other sources, it is considered that only Cs-137 is found in the Svalbard environment. In recent years, the levels of Cs-137 in Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and Svalbard ptarmigan (*Lagopus muta hyperborea*) have been found to be in general below 1 Bq/kg (Gwynn et al., 2005; unpublished data).

Studies of glaucous gulls on Bjørnøya have shown that pollutants have a negative impact on the population. Photo: Odd Harald Selboskar, Norwegian Polar Institute

For seafood, the Norwegian Food Safety Authority has set an upper limit for Cs-137 of 600 Bq/kg, which is identical to the EU threshold values for imported foodstuffs (Table 3). The Cs-137 levels measured in fish and shellfish from the Norwegian Sea and the Barents Sea are generally under 0.5 Bq/kg (NRPA, 2007; 2009; 2011). Similar Cs-137 levels have been observed in several species of seals in Svalbard waters, which are allowed to be hunted (Gwynn et al., 2005; unpublished data). Cs-137 in fungi is not being measured in Svalbard at present, but given the Cs-137 values for soil, those in fungi are expected to be under the defined threshold value (Gwynn et al., 2004). It is assumed that the radiation levels measured in Svalbard cannot lead to effects that are detrimental to health when local food is consumed or people stay in the archipelago



Samples of phytoplankton and zooplankton being analysed.
Photo: Katrine Borgå, Norwegian Polar Institute

3.5.2 Heavy metals and organic pollutants in food

For the population in Svalbard and Jan Mayen, fish will probably be the greatest hazard for intake of pollutants. Marine mammals comprise a larger share of the diet in other arctic regions, especially among indigenous peoples, and the majority of pollutants in their food will originate from marine mammals. The threshold values for seafood in the EU and Norway can be found in Table 3.

Exceptions to the threshold values are made for certain kinds of food, like brown meat from crabs, at the same time as the more vulnerable sections of the population are advised to avoid them or limit their consumption. In August 2011, the EU adopted new maximum values for PAHs to be effective from September 2012 (EU, 2011). It also adopted new maximum values from 1 January 2012 for dioxins and dioxin-like PCBs and the sum of six indicator PCBs (PCB6) (Table 3). The EU and Norway have not set threshold values for many undesirable substances, because knowledge is lacking about how toxic they are to people. One example is arsenic, which is found in relatively large amounts in seafood in general, but the arsenic in seafood is mainly found as arsenobetaine, a non-toxic form of arsenic. However, relatively few data are available on the actual content of the most toxic, inorganic forms of arsenic found in various kinds of food. The European Food Safety Authority (EFSA) has therefore called for more data on the content of inorganic arsenic in, among other things, seafood, and the National Institute of Nutrition and Seafood Research has investigated the content of inorganic arsenic in many species of fish (Julshamn et al., 2011). Preliminary results show very low concentrations of inorganic arsenic in fish. Another example is polybrominated diphenyl ethers, PBDEs, but knowledge about their toxicity for people is uncertain and too little is known about their intake (JECFA, 2006).

3.5.3 Monitoring pollutants in seafood from the Barents Sea

Since the publication of the Management Plan for the Barents Sea in 2006, the National Institute of Nutrition and Seafood Research has performed annual monitoring of pollutants in cod, shrimps, capelin and polar cod from the Barents Sea. The results are published in annual reports from the monitoring team for the Barents Sea (Fossheim, 2010) and at miljøstatus.no. Some random cod samples were also analysed before the management plan was published, and these data go back to 1995 (www.nifes.no/sjømatdata). In 2011, a major basic investigation improved the data available on pollutants in cod. Fillets and livers from as many as 800 cod from the Barents Sea were analysed, and the investigation provided a unique basis for future monitoring. The content of pollutants in Greenland halibut (*Reinhardtius hippoglossoides*) has also been mapped (Julshamn et al., 2006; Nilsen et al., 2010; Julshamn et al., 2011).

Cod

Since the publication of the Management Plan for the Barents Sea in 2006, the National Institute of Nutrition and Seafood Research has performed annual monitoring of pollutants in cod, shrimps, capelin and polar cod from the Barents Sea. The results are published in annual reports from the monitoring team for the Barents Sea (Fossheim, 2010) and at miljøstatus.no. Some random cod samples were also analysed before the management plan was published, and these data go back to 1995 (www.nifes.no/sjømatdata). In 2011, a major basic investigation improved the data available on pollutants in cod. Fillets and livers from as many as 800 cod from the Barents Sea were analysed, and the investigation provided a unique basis for future monitoring. The content of pollutants in Greenland halibut (*Reinhardtius hippoglossoides*) has also been mapped (Julshamn et al., 2006; Nilsen et al., 2010; Julshamn et al., 2011).

Shrimps

Cooked, shelled shrimps from the Barents Sea in general have a low content of pollutants. The concentration of arsenic is relatively high, but this is most probably the non-toxic, organic forms. Methylmercury may accumulate in the muscle because it becomes bound to the protein. The total mercury concentration in aggregated samples of shelled shrimps from the Barents Sea varied between 0.03 and 0.21 mg/kg wet weight, well below the threshold value of 0.5 mg/kg wet weight. The cadmium content in whole shrimps is quite high, but in shelled shrimps, the edible portion, the level is from 0.033 to 0.23 mg/kg wet weight, well below the threshold value of 0.5 mg/kg wet weight. The concentrations of organic pollutants were very low in both shelled and whole shrimps.

Capelin and polar cod

Capelin and polar cod are monitored due to the important roles they play in the Barents Sea ecosystem. When the stock is sufficiently high, capelin is used to produce fishmeal and fish oil, which, in turn, are used to make fish feed.

Table 3. Overview of Norwegian and EU upper threshold values for pollutants in various kinds of seafood (EU, 2006; 2011).

	Fish fillets	Fish liver	Shellfish	Crustaceans[a]
Caesium-137 (Bq/kg)	600	600	600	600
Mercury (mg/kg ww)	0.5 (1,0)[b]		0.5	0.5
Cadmium (mg/kg ww)	0.05 (0,1)[c]		1.0	0.5
Lead (mg/kg ww)	0.3		1.5	0.5
Sum dioxins and furans (ng 1998-TE/kg ww)	4.0		4	4
Sum dioxins, furans and dioxin-like PCBs (ng 1998-TE/kg ww)	8.0 (12)[d]	25	8	8
PAHs: Benzo(a)pyrene (µg/kg ww)	2.0 (5)[e]		10	5
Sum dioxins and furans (ng 2005-TE/kg ww) from 1 January 2012	3.5		3.5	3.5
Sum dioxins, phuranes and dioxin-like PCBs (ng 2005-TE/kg ww) from 1 January 2012	6.5 (10)[d]	20	6.5	6.5
PCB6 (µg/kg ww) from 1 January 2012	75.0 (300)[d]	200	75	75
PAHs: Benzo(a)pyrene (µg/kg ww). Valid from 1 September 2012	5.0[e]		5	5[e]
Sum 4 PAHs: Sum of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene. Valid from 1 September 2012	30.0[e]		30	30[e]

[a] Only claw meat (no threshold values exist for brown meat)
[b] Large predator fish, incl. halibut, wolffish, anglerfish, golden redfish, tuna and swordfish
[c] Some species, incl. mackerel, eel, sardine and tuna
[d] Eel
[e] Smoked products

Polar cod is a little used resource in Norway, but it is used as food in Russia. Aggregated samples of whole capelin and polar cod contain low concentrations of most pollutants. In some samples, whole polar cod have given cadmium concentrations over the threshold value of 0.05 mg/kg wet weight, but since whole fish were analysed it is not entirely relevant to compare with the threshold value, which just concerns edible parts. The analysis is relevant if whole fish are eaten. Cadmium concentrations in capelin have been low.

Concentrations of organic pollutants in capelin and polar cod are, for the most part, extremely low relative to food safety. The levels of hexachlorobenzene (HCB) and dieldrin in capelin have sometimes been somewhat higher than the threshold values that apply for marketing fish feed, but these values are only valid if dried capelin are used as the raw material for the feed without being processed to fishmeal and fish oil first. No threshold values have been set for these substances in food. In the case of polar cod, the level of lower brominated PBDEs (sum of PBDE 28, 47, 99, 100, 153, 154 and 183) seems to have decreased since 2006.

Greenland halibut

Mercury concentrations in fillets of Greenland halibut caught along the continental shelf margin between Bjørnøya and Svalbard have exceeded the threshold value of 0.5 mg/kg wet weight. A major survey of pollutants in Greenland halibut from all the Norwegian waters where they are fished showed that the mercury level from the Bjørnøya-Svalbard area was higher than in Greenland halibut caught further south (unpublished data from the National Institute of Nutrition and Seafood Research). This can probably be explained by the Greenland halibut caught furthest north being larger, older and leaner than those caught further south, along the Norwegian coast. The mercury concentration in Greenland halibut fillets increases with increasing age and size, and decreases with a rising fat content.

Greenland halibut fillets also have relatively high concentrations of organic pollutants, but they are lower furthest north. Between 8 and 22 % of the fish caught at different locations in the Bjørnøya-Svalbard area, nevertheless, had concentrations of sum dioxins and dioxin-like PCBs above the threshold value of 8 ng TE/kg wet weight. However, the average concentrations were not above the threshold values for either mercury or dioxins and dioxin-like PCBs. Greenland halibut caught in the Barents Sea off East Finnmark had only low levels of mercury and organic pollutants. The

Cod with liver and roe (mølje).
Photo: Eva Brænd, Norwegian Seafood Council

Norwegian Food Safety Authority advises pregnant and nursing women not to eat Greenland halibut weighing more than 3 kg.

Compared with the coast of mainland Norway, seafood from areas near Svalbard and Jan Mayen has comparatively low levels of pollutants. For instance, there are very low levels of human-generated radioactive substances in both seafood and game in the Barents Sea and Svalbard. The highest levels of organic pollutants are found in blubber from marine mammals and in the eggs of glaucous gulls. These are virtually unused as food in Norway and are therefore not regarded as a problem. There are also low levels of heavy metals and organic pollutants in fish and shrimps from the Barents Sea. Exceptions are liver from cod, which still has elevated values of organic pollutants, and mercury levels in large Greenland halibut, which may exceed the threshold value. No dietary advice is given regarding specific areas, but for some foodstuffs some general advice is given for the most vulnerable groups. Cod liver is most relevant here, and women of fertile age and children are advised not to eat it. Pregnant and nursing women are, moreover, recommended to avoid Greenland halibut that weigh more than 3 kg.

4 Pollutants and climate change

The Arctic is one of the regions which will feel the greatest effects of climate change (IPCC, 2007). Some of the changes have already taken place, including melting of ice sheets, less perennial ice, increased supply of fresh water from rivers, thawing of permafrost, melting of glaciers, higher surface temperatures and higher inflow of Atlantic water masses. The changes in climate may alter both the distribution of species and the structure of the food chains in the Arctic (Stirling et al., 1999; Regehr et al., 2007; UNEP/AMAP_Expert_group, 2011; Wassmann et al., 2011), and also the exposure of the arctic environment to pollutants. Rising temperature in the atmosphere and the ocean surface will affect the ability of pollutants to be carried northwards, and leakage and evaporation from deposits in permafrost, ice and water (Macdonald et al., 2003; Macdonald et al., 2005; Noyes et al., 2009; Guay et al., 2010; UNEP/AMAP Expert group, 2011). Modelling and sensitivity analyses have identified sea ice, temperature, precipitation and changed primary production as having the greatest influence on the potential of the pollutants for transport and accumulation in the arctic environment (AMAP, 2003; Hassol, 2004; Lamon et al., 2009; Borga et al., 2010).

4.1 Organic pollutants and climate change

Ma et al. (2011) combined monitoring data from the Zeppelin Station with modelling of emissions to estimate future concentrations of pollutants in Svalbard air (Figure 15) based on a probable temperature rise in the Arctic (IPCC, 2007). A continuous increase in the level of volatile pollutants in the air is predicted if the average ambient temperature rises by 0.7 °C by the year 2100. Volatile PCBs like PCB-28 and PCB-52 will increase until about 2030 and then decrease continually. PCB-153 is not volatile and is transported in particle-bound form in the atmosphere. It will increase continually until 2100. The main source for these pollutants is assumed to be direct evaporation and remobilisation from the surfaces of the ocean and the land (Ma et al., 2011).

Changes in the food web and the distribution of sea ice will be reflected in pollutant levels in the top predators. Less sea ice and its earlier break up have been related to changes in the diet and higher pollutant levels in polar bears and seals in Hudson Bay (Gaden et al., 2009; McKinney et al., 2009; McKinney et al., 2010). The COPOL project, part of the International Polar Year in 2007-2008, found that the increase in the influx of warm water into Kongsfjorden in 2007 and 2008, and thus less ice, meant that there were fewer cold-water species of zooplankton and fish. This led to a shift in the diet of kittiwakes and little auks, which indirectly led to changes in their exposure to pollutants. In addition, these birds had to fly further to find food.

Less sea-ice cover has resulted in a reduction in the fitness, ability to reproduce, survival and distribution of polar bears (Stirling et al., 1999; Regehr et al., 2007). When ice is absent, polar bears have limited access to food and must resort to their fat reserves to survive (Atkinson et al., 1996; Polischuk et al., 2001). Mobilisation of fat reserves will liberate pollutants stored in the fat. The pollutants may be carried in the blood to vital organs like the liver and brain (Helgason, 2011). This may bring negative effects in the animal, through enzyme activation, hormone influence and an impaired immune system, which, in turn, may result in less ability to reproduce and poorer survival.

4.2 Mercury and climate change

Temperature and ice are decisive for the mercury dynamics observed in the Arctic. Climate change will therefore alter the pattern of atmospheric depletion of mercury. The Arctic will probably be an effective trap for cadmium and lead, because significantly more precipitation is expected (Macdonald et al., 2005). Atmospheric Mercury Depletion Events, or AMDEs, are strongly linked to ice-related processes. Less ice cover in the central Arctic Ocean will therefore directly affect AMDE-related processes. Moreover, changes will arise in the source areas for mercury as regards just where the emissions occur. Europe and America have reduced their mercury emissions, whereas those in Asia are increasing. All these factors are expected to have significant effects on transport mechanisms for mercury to the Arctic.

Despite its complexity, the mercury dynamics in the physical environment in the Arctic is better understood than that in biological systems. A study from the Canadian Arctic, however, shows that enhanced mercury levels in burbot (*Lota lota*) are already related to higher temperatures and reduced ice cover (Carrie et al., 2010). Furthermore, the

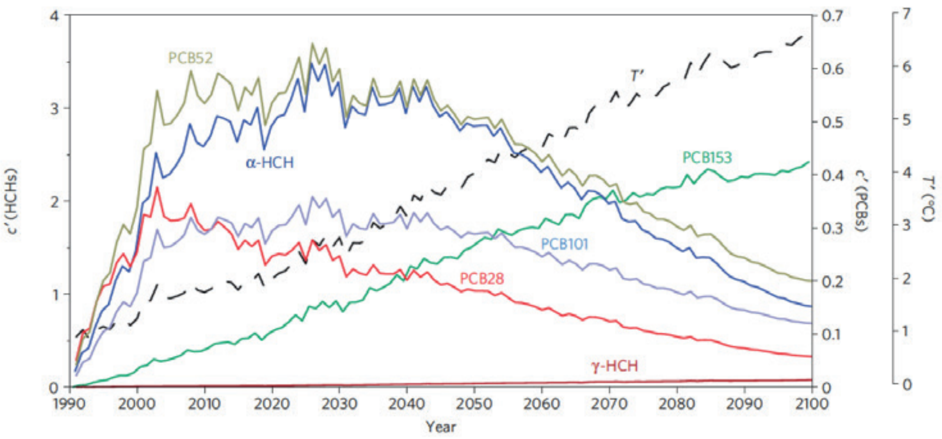


Figure 15. Temperature-dependent trend estimates for selected PCB congenes and HCH (Ma et al., 2011).

length of the ice-free season is related to mercury levels in ringed seals in the Canadian Arctic (Gaden et al., 2009). The potentially most important effect of climate change may be the formation of monomethylmercury in aquatic ecosystems in the Arctic (Outridge et al., 2008). The effect of climate change on the mercury cycle remains a little studied topic.

4.3 Radionuclides and climate change

All changes in the structure and composition of food chains as a consequence of climate change can influence the transfer of radionuclides between species in the food chains. Changes in precipitation and thawing of permafrost may result in increased mobility and uptake of radionuclides in terrestrial environments (AMAP, 2003; Dowdall, 2005). Increased precipitation and runoff from melting glaciers may also bring changes in the amount of radionuclides washed out into the sea.

Owing to uncertainty about the changes in the marine system, it is only possible to speculate a little concerning climate change and radionuclides. If the ice cover is reduced, especially in summer, sea ice will become less important as a means of transporting radionuclides. In addition, it may result in more vertical mixing in arctic waters which, in turn, may lead to radionuclides which enter through the North Sea staying longer, thus causing less export in the surface water through the Fram Strait (Karcher et al., 2010). An expected reduction in the ice cover may lead to new sources of radioactive contamination arising as a consequence of oil and gas extraction and associated discharges of produced water, and because more ships may transport radioactive materials in the region.

Samples of zooplankton (krill and Parathemisto sp.) to analyse new pollutants in the Arctic.
Photo: Geir Wing Gabrielsen, Norwegian Polar Institute

5 Evaluation and assessment in relation to national environmental targets

Parliamentary Bill no. 1 for 2011-2012 (Miljøverndepartementet, 2011) describes Norwegian environmental targets for pollutants in general terms within the area of international cooperation and specifically when reviewing the results of a toxic-free environment. Pollutants in Svalbard, Jan Mayen and surrounding waters are mainly long-range transported; there are only a few small, local sources. International legislation and regulations are the most important instruments to reduce the supply of pollutants to the Arctic. In addition, it is important to maintain stringent control of local discharges. In Svalbard, the Governor of Svalbard fills this function and is responsible for cleaning up old pollution around the settlements and in areas where former activity has polluted the natural environment. The County Governor of Nordland has this responsibility in the case of Jan Mayen.

The environmental targets are described within a national framework (Parliamentary Bill no. 1 for 2011-2012) (Miljøverndepartementet, 2011). Compared with the mainland, there is little industry and a low population density in Svalbard and Jan Mayen. In addition, the Government has expressly stated that Svalbard must be the best-managed wilderness in the world. This means that separate, regional environmental targets should be drawn up for pollutants in the arctic regions.

When the national environmental targets for the MOSJ area are evaluated (Table 4), it is seen that three of six targets can report good results as a consequence of various hazard-reducing measures. These are "7. Delimit the impact and risk of impact on the environment in the northern and polar areas as a consequence of human activity", "9.2. The risk that discharges and use of chemicals are the cause of harm to human health and the environment must be minimised", and "9.5. Emissions, risk of emissions and spreading of radioactive substances which can cause harm to human health and the environment must be kept at the lowest possible level. All radioactive waste must be handled properly in an approved manner".

However, it is very uncertain how the effects of radioactivity on health should be measured. White Paper no. 11 (2009-2010) (Utenriksdepartementet, 2010), which takes up the cooperation with Russia on nuclear activity and the environment in the northern regions, reviewed the results achieved and the way ahead. Norwegian efforts in the years to come will include focusing on problems in Andrejeva Bay, training and information work in the atomic energy sector, cooperation with authorities, supervision, environmental monitoring and contingency. In addition, the wrecks of Komsomolets in the Norwegian Sea and K-159 in Murmanskfjord will be monitored. The fire in the nuclear submarine at Severomorsk, north of Murmansk, in December 2011 reminded us yet again that potential sources can become realities.

The results achieved for three of the environmental targets are not satisfactory. These are "9.1. Discharge and use of chemicals which pose a serious threat to health and the environment must be continually reduced with the aim to halt the discharges by 2020", "9.3. Spreading of pollutants from contaminated earth must be halted or significantly reduced. Spreading of other chemicals that are a hazard to health and the environment must be reduced, based on a specific risk assessment", and "9.4. Sediment on the seabed that is contaminated with chemicals which are a hazard to health and the environment must not run the risk of becoming a serious pollution problem". The main reason why the target achievement is considered unsatisfactory is chiefly linked to lack of knowledge in the MOSJ area. Furthermore, it is thought that the predicted change in climate to warmer and wetter conditions may affect runoff and evaporation from secondary sources.

Two researchers, Heli Routti and Kjetil Sagerup, are taking samples from a Brünnich's guillemot to analyse pollutants. Photo: Tor Ivan Karlsen, Norwegian Polar Institute

Table 4: Evaluating the national environmental targets for pollutants. The table only evaluates targets which concern Svalbard and Jan Mayen

What is evaluated?	Is the target attained?	Justification	If the target is not attained, is there an improvement ↑, a deterioration ↓, or a status quo ↔	How great is the uncertainty in the measurement evaluation?		Comments	Indicator
				Degree	Justification		
"7. Delimit the impact and the risk of impact on the environment in the North and the polar region as a consequence of human activity."	Yes	International regulations have led to the levels of the regulated pollutants decreasing.		Low		Climate change may affect the pollutant levels in the Arctic (Chapter 3).	"The level of selected contamination components in the arctic environment."
"9.1 Discharge and use of chemicals which pose a serious threat to health and the environment must be continually reduced with the aim of halting the discharges by 2020."	No	A great deal has been achieved with the old, regulated substances. Concentrations in the environment are sinking (declining trend).Much remains to be learnt about the dispersal and effects of new substances that are relevant for the environment.	For "old" regulated substances ↑ The "newer" and "new" substances ↑/↓/↔.	Low for old pollutants, high for new ones. Discharges for the primary sources are under control.	Uncertainty is attached to secondary sources like deposits on the ground, in water and snow and ice, and seepage from rubbish dumps.	We need to take regional and global transport systems of water, air and sea ice into account. Need for knowledge: we need to know more about unstable substances in medicines and cosmetics (PPCP). Through MOSJ, there is a need for separate screening programmes accommodated to arctic regions.	No indicator mentioned in the description of national environmental targets.
"9.2 Risk that the discharge and use of chemicals cause harm to health and the environment must be minimised."	Yes	The targets have been attained through international regulations. No industry in the area can discharge chemicals on a large scale. The exceptions are the power stations at the settlements in Svalbard. Coal production in Svalbard is a significant source of pollution which may contribute.		High	Great uncertainty is attached to the risk associated with long-range pollution. Increasing activity in northern regions may enhance the risk of impact.	Potential source areas outside the MOSJ area are included in the evaluation. Indicators for this aim are lacking. Major gaps in the regulation regarding which substances are regulated, how effectively it is implemented and which countries are committed by the regulations.	"Risk indicator for potential exposure to chemicals that are harmful to health and the environment." The authors of this report do not know how this indicator is to be measured.
"9.3 Spreading of pollutants from contaminated ground must be halted or significantly reduced. Spreading of other chemicals that are harmful to health or the environment must be reduced on the basis of a specific risk assessment."	No	Seepage from Pyramiden has been identified. Measures have been implemented to prevent seepage from contaminated ground (a rubbish dump) on Jan Mayen. The PCB project run by the Governor of Svalbard and the Pollution Directorate is a good example of mapping and cleaning up waste containing PCBs, but removal of contaminated earth is not included in the project.	↑ / ↔	Low	Some uncertainty is attached to old dumps and a few areas where the ground has not been investigated.	Climate change, especially affect-ing the reduction of permafrost, may influence the stability of contaminated ground. Changes in the precipitation pattern may also affect runoff. Cultural heritage legislation prevents the clean up of potentially contaminated areas. Clean up of contaminated ground on Jan Mayen and in Barentsburg, Pyramiden, Longyearbyen, Ny-Ålesund and Colesbukta should be considered.	"The number of known localities with seriously contaminated ground."
"9.4 Sediment on the seabed contaminated with chemicals that are harmful to health or the environment must not lead to risk of a serious pollution problem."	No	Sediments off Pyramiden (status class 3). In accordance with practice on the mainland, no action will be taken. Two hot spots have also been identified, Nordlaguna on Jan Mayen and Ellasjøen on Bjørnøya.	↔	High	Time trends for pollutants in sediments should be investigated in the hot spots. The hot spots must be monitored, especially in relation to climate change and changes in the permafrost.	No dredging within the MOSJ area. Some areas receive seepage from contaminated ground in Barentsburg, Pyramiden and perhaps on Jan Mayen. Knowledge is lacking on limits for measures in the Arctic.	"The amount of selected substances that are harmful to health and the environment and are dealt with by dredging and covering over so that they no longer constitute a source for a serious pollution problem." Sediments off three settlements are included as indicators in MOSJ.
"9.5 Emissions, the risk of emissions and the spreading of radioactive substances which may harm human health and the environment must be kept at the lowest possible level. All radioactive waste must be dealt with properly in an approved manner."	Yes, but the aim is a continuous process.	Strong reduction in emissions from European reprocessing plants. The break up of 120 decommissioned nuclear submarines in northwestern Russia was completed in 2010. In 2009, the last strontium batteries in lighthouses off north-western Russia were removed. In 2006, Svalbard and Jan Mayen were included in the Norwegian nuclear contingency plan.	↑ / ↔	High	Good time series from coastal stations. Some uncertainty concerning the supply of far-transported radioactive substances carried along the Norwegian coast and up to the High North, and discharges and supply to Norwegian territory by rivers in northwestern Russia.	There is a risk of new sources arising if human activity in the High North increases. Monitoring is one of several risk-reducing measures which are especially important in arctic regions. It is important to continue the monitoring and examine trends and development over time. There is reason to assume that the simultaneous presence of several different contaminants may give synergic effects and thus help to give a greater impact than each one alone. It may be necessary to deal with waste on land in connection with petroleum activity, and this may result in discharges. Nuclear plants and dumps of used fuel and radioactive waste still give cause for concern, and possible climate change may affect the stability of plants and dumps, with a consequent risk of accidents and emissions.	"Total annual emissions of selected radioactive substances from national sources." "Levels of selected radioactive substances in the environment." "Proportion of various types of radioactive waste dealt with in an approved manner." "Estimated risk of emissions from selected foreign sources that can affect Norway." The Management Plan for the Norwegian Sea proposed that discharges from petroleum installations in the Norwegian Sea should be a separate indicator.

6 The need for measures

With the help of several hazard-reducing measures, the Norwegian plan for handling nuclear waste and bilateral cooperation between Norwegian and Russian authorities have decreased the risk of dispersal and emission of radioactive material in our northern regions.

- In 2010, the breaking up of 120 decommissioned nuclear submarines in northwestern Russia was completed. Norway has funded the breaking up of five of them.
- In 2009, the last strontium battery was removed from lighthouses in northwestern Russia.
- In the last decades, several hazard-reducing measures have been implemented at nuclear power stations on the Kola Peninsula, resulting in a reduction in the number of events at these stations.

Svalbard and Jan Mayen have been included in the Norwegian nuclear contingency plan and this work is continuing. It will be important to follow the development in the northern regions, particularly with a view to the possible use of new technology like floating nuclear power stations. When they go into operation, their effect will be comparable with a reactor-powered vessel and they will be used to produce power in arctic regions. Where such a power station will be located is still undecided.

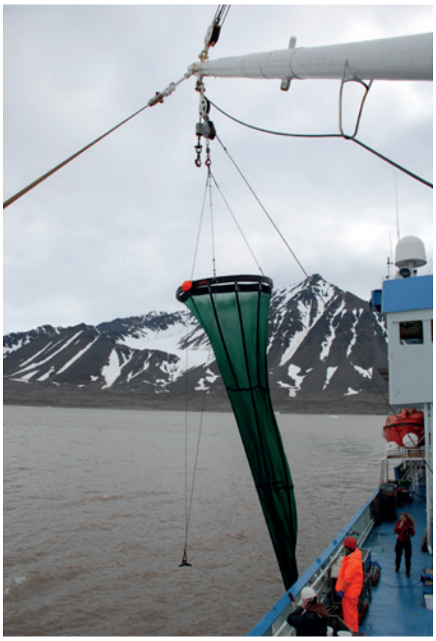
In addition, reactor-powered vessels, mainly ice breakers and submarines, are sailing in Norwegian waters. Northern waters here presently contain two sunken submarines with nuclear reactors on board, Komsomolets in Norwegian waters and K-159 in Russian waters, and they need to be monitored in addition to the existing monitoring of the marine ecosystem.

6.1 Measures to prevent the spread of local pollution

In Svalbard, the highest pollutant levels have been found in paint and earth in Russian settlements (Pyramiden and Barentsburg). To some extent, the pollution has spread to the marine sediments in the fjords close to the settlements and there may be a need to start clean up operations in these areas. Measures to deal with contaminated earth and sediments are very expensive, especially in Svalbard. Decisions regarding such measures should be based on good data. A risk assessment for marine bottom sediments based on the limited data available concludes that work should primarily be undertaken on land to prevent the spread of pollutants to the marine environment (Evenset, 2010). According to Evenset (2010), the following measures should be undertaken (applies to all areas with contaminated earth, if not otherwise noted):

- Waste and material containing PCBs should be removed and dumped in an approved manner.
- Plans for dealing with waste must be drawn up and followed. They must include plans to dispose of and dump demolition waste.

Removal and destruction of high-voltage electrical equipment which leaks PCB in Pyramiden. Photo: Halvard R. Pedersen, Sysselmannen på Svalbard (Governor of Svalbard)



Collecting zooplankton in Kongsfjorden during a cruise with the research vessel *Lance*. Photo: Geir Wing Gabrielsen, Norwegian Polar Institute

- Earth containing extremely high levels of pollutants (hot spots) should be removed and dumped in a prescribed manner. Removal of contaminated earth in steep terrain should also be considered if there is a risk of it sliding into the sea.
- Areas containing moderate to high concentrations should be covered with clean earth. Wind transport is probably an active process which helps to disperse pollutants, particularly in Barentsburg where there are large, flat areas of bare ground. Surface soil is especially accessible to wind transport during fairly long periods of dry weather and when there is black frost, because under such conditions there will be no moisture in the surface soil to bind the particles.
- Ditches should be dug to drain water from the most polluted areas, or maintained where they already exist (they already exist in Barentsburg, but are not optimally constructed and some are in very poor shape). Ditches will lead seepage and surface water away from the most polluted areas and reduce the transport of pollutants

from contaminated ground to the sea. Due to a low content of organic carbon in arctic soils, a comparatively large proportion of the PCB pollution will probably be available for water transport (not very strongly bound to particles).

7 Advice on monitoring and research

MOSJ – Environmental monitoring in Svalbard and Jan Mayen – is a monitoring system which compiles data and interpretations from a variety of monitoring programmes from the northernmost parts of Norway, Svalbard and Jan Mayen. MOSJ was established at the Norwegian Polar Institute in 1999 (Sander, 2005). The monitoring programmes included in MOSJ are differently organised, have different sources of funding and different solutions of data. In the case of pollution, with which this report is concerned, the best data are for atmospheric pollution and radionuclides in seawater and fish. These data series have a solution of one year and comparable measurements have been carried out since the series started. As regards atmospheric pollution, the solution in the Norwegian Institute for Air Research monitoring programme is better than that presented in the MOSJ web pages.

According to the overview of MOSJ indicators (MOSJ, 2011), sediment samples should be analysed every fourth year and those from capelin and polar cod every year. Samples from polar bears, arctic foxes and glaucous gulls should be analysed every third year. In addition, samples from ivory gulls, Brünnich's guillemots and ringed seals should be analysed every third to fifth year, and those from walruses, bearded seals and beluga whales every tenth year (Table 5). The sampling intervals have been adjusted since MOSJ started in 1999.

Nicholas Warner from the Norwegian Institute for Air Research is processing a sediment sample which is to be analysed for new pollutants (including siloxanes). Photo: Geir Wing Gabrielsen, Norwegian Polar Institute

Pollutants in sediments, fish, mammals and birds vary more with respect to the planned intervals between analyses being performed and whether they have actually taken place at those times. As there is a discrepancy between the desired and the actual interval for many of the environmental indicators, it is considered that the targets for these indicators have, for the most part, not been attained. This is because data have not been supplied in accordance with the stated intervals.

The main reason why targets for analysing pollutants have not been attained is too little funding to cover the cost of the analyses. It is extremely expensive to perform analyses for pollutants (especially new ones). Analyses of samples from sediments, fish, birds and mammals depend upon funding from research or management assignments to be able to report pollutant data to MOSJ. So far, MOSJ has received very little money from management bodies (except for atmospheric measurements). The data supplied to MOSJ for sediments, fish, birds and mammals have mainly been by-products from research projects and assignments from the business sector. Because the MOSJ programme lacks basic funding for monitoring pollutants, data collection will be determined by the research activity on pollutants. This means that the pollutant programme in MOSJ in the years to come will not succeed in supplying data in accordance with the intentions. The solution will be for MOSJ to receive basic funding for pollutants which secures the core of the pollutant monitoring. Money should also be set aside to screen new pollutants to ensure their mapping in the Arctic.

Local pollution in the Arctic is confined to small, limited areas. The arctic regions can therefore function as valuable reference areas to be able to identify the ability of new pollutants for long-range transport. Provided there are no local sources in the Arctic for a chemical substance, the discovery of the substance will be a very strong indication that it is stable in the environment and can be transported a long way. If it is also possible to show that it accumulates in arctic food chains, three of the four criteria stated in the Stockholm Convention to be able to define a substance as a pollutant (persistence, long-range transport and accumulation) have been met. Research and monitoring in MOSJ have been important to uncover the stability, long-range transport and accumulation of new substances in the Arctic. This knowledge has been important to be able to regulate the manufacture and use of substances both nationally and internationally through conventions and cooperative programmes like the Stockholm Convention, REACH, AMAP, OSPAR and OECD. Inclusion of endosulfan in the Stockholm Convention in 2010 took place in part because of discoveries in snow and ice on Austfonna in Svalbard (Stockholm Convention, 2011).

In the years to come, it will be important to link the monitoring of pollutants to effects on people and animals.

Studies have been performed in the Arctic which show clear effects of pollutants on individuals or populations. Such data mean that MOSJ can also contribute data for the fourth criterion (effects) in the Stockholm Convention, which may result in hazardous substances being removed from the market.

7.1 Which substances should be monitored?

MOSJ should be able to give trends of old and new substances linked to the regulation of substances and changes in climate. Even though many of the old substances have been banned for decades, they should not be given less priority. The old substances like PCBs and chlorinated pesticides still constitute the greater proportion of the total burden of pollutants in arctic biota. They are also highly toxic and are a threat to the top predators. This has been documented in several scientific articles published in 2010 (Letcher et al. 2010; Verreault et al. 2010; Sonne 2010). Even though discharges and emissions from the primary sources are under control, great uncertainty is attached to those from pollutants from secondary sources (earth, water, sediment, snow, ice and seepage from landfills) which may be strongly influenced by changes in climate. Of new substances, it is important to follow up those which are included in Conventions, including PBDEs, HBCD, PFAS, endosulfan and chlorinated paraffins.

Follow-up investigations of the state of polluted areas (hot spot areas) in Svalbard and Jan Mayen are also recommended. Specifically, this concerns pollution of the ground and lake sediments at Ellasjøen on Bjørnøya, in Nordlaguna on Jan Mayen and in landfills in Pyramiden and Barentsburg.

Industrial activity in the MOSJ area must be monitored and strict environmental demands must be imposed on industrial concerns. The mining industry is the most important industrial activity at present. Increasing offshore activity and shipping is also expected everywhere in the Arctic if the changes in climate lead to larger ice-free areas. Climate change, more shipping and more industrial activity demonstrate a clear need to monitor pollutants in the Arctic.

There are now no good parameters recommended for monitoring the effects of pollutants on arctic animals. We therefore recommend that effect studies are performed as research-based studies and focus is placed on one species, one substance or one end point of an effect at a time. Such studies should be performed on species containing comparatively high levels of pollutants. They may be top predators like polar bears, arctic foxes, beluga whales, glaucous gulls, great skuas or ivory gulls. In controlled trials, it may be relevant to use plankton or fish as model creatures. In connection with effect studies, it is most important to investigate levels of pollutants and their metabolites and take into account physiological differences and gender.

Pollutants in polar bears should be measured yearly.
Photo: Nick Cobbing, Norwegian Polar Institute

7.2 Which series (indicators) should be included in MOSJ?

MOSJ currently has a set of indicators which it wishes to monitor for pollutants (Table 5). The indicators have been evaluated and adjusted several times since MOSJ started. Table 5 shows that pollutants and radionuclides must be measured in several abiotic media and in plankton, fish and several species of mammals and birds. The intervals between each sampling varies from one to ten years, even though it is quite clearly recommended that samples should be taken each year to perform analyses of monitoring series for organic pollutants and heavy metals (Henriksen et al., 2001; Bignert et al., 2004; Riget et al., 2011). We therefore recommend that the indicators be revised again, based on the recommendations given in this report.

In general, we recommend keeping the abiotic indicators as they are now. We also recommend that monitoring of pollutants in plankton and fish is kept as now. We recommend considerable changes for mammals and birds, and propose reducing the interval between each sampling from 3 years to 1 year, because that will increase the statistical power (Henriksen et al., 2001; Bignert et al., 2004; Riget et al., 2011), and to monitor fewer species, partly because time-trend studies show the same development pattern for the majority of species. Hence, it is not necessary to include many species to investigate time trends. When it proves, in practice, that the intentions for analysing pollutants in mammals and birds cannot be fulfilled for economic reasons, it is essential to make priorities. The changes proposed are summarised in Table 5.

We propose increasing the measurement frequency for polar bears, arctic foxes, glaucous gulls and Brünnich's guillemots (Table 5), all of which are arctic top predators that are exposed to high levels of pollutants. Their monitoring is important to be able to demonstrate changes in pollutant trends and the health of these species. Polar bears, Brünnich's guillemots and glaucous gulls represent the marine environment, while arctic foxes are attached to both the marine and the terrestrial environments. None of these species need to be killed to obtain samples.

To see possible climate-related changes in their diet and the effect of this in pollutant levels, it is recommended that the levels are measured at ten-year intervals for ringed seals, bearded seals, beluga whales and walruses.

1. Pollutants in polar bears
- Change to a yearly interval.
- The polar bear is a circumpolar, marine top predator. It is exposed to high levels of pollutants which can lead to poorer health. A number of negative health effects of pollutants have been found in polar bears from Svalbard, Greenland and Canada. As a top predator, the polar bear acquires high levels of pollutants through its food and can build up correspondingly high levels of substances which it does not metabolise. Polar bears have good capacity to metabolise a number of pollutants. Recent research on polar bears has shown that metabolites are an important part of the total burden of pollutants and may have important functions to cause effects. Metabolites from the pollutants will be included in each analysis, because standard methods to analyse these have now been established.
- Plasma samples of ten adult females.
- Sampling in connection with the annual research performed on polar bears.

2. Pollutants in arctic foxes
- Change to a yearly interval.
- The arctic fox is a top predator in both the terrestrial and marine environments. Like the polar bear, it is exposed to high levels of pollutants that can give negative health effects. The species is not as well studied as regards pollutants as other arctic species, as reflected in MOSJ by only three measuring points since 1973.
- Liver samples of ten young individuals annually.
- Sampling performed using material handed in by hunters and on which obductions are performed by the Norwegian Veterinary Institute and the Norwegian Polar Institute each year.

3. Pollutants in glaucous gulls
- Change to a yearly interval.
- The glaucous gull is a circumpolar, marine top predator. It is exposed to sometimes extremely high levels of pollutants and has been intensively studied with a view to effects. A number of negative effects of pollutants have been revealed. The glaucous gull stays in the Arctic throughout the year and will reflect long-transported pollutants.
- Eggs from ten individuals annually.
- Sampling in connection with the annual seabird studies undertaken by the Norwegian Polar Institute.

4. Pollutants in ivory gulls
- To be removed from the MOSJ indicator set.
- The ivory gull is a species of seabird that is extremely dependent upon ice and is therefore very exposed to climate change. It also has high levels of pollutants and is interesting from a monitoring viewpoint, but its biology means that it is very difficult and expensive to obtain samples. The species is therefore poorly suited for monitoring, and we recommend removing it from the list of indicators. The pollution aspect should be made a research topic.

5. Pollutants in ringed seals
- Change to a ten-year interval.
- The ringed seal is a circumpolar species that is dependent on ice. It is the main food of polar bears. Ringed seals have been monitored by MOSJ for some years, but it has been difficult to monitor the pollutants. A variety of research projects have supplied data, but because they had differing angles of approach these data have not been comparable. Ringed seals have been sampled in spring when they can be found lying on the fjord ice in Svalbard while moulting. Since they do not eat during this period, they consume food reserves (fat). How long the seals have lain on the ice is therefore crucial for the level of pollutants since the concentration of fat-soluble pollutants rises as the quantity of fat declines. The time a seal has lain on the ice may vary between individuals and from year to year. It is therefore not certain that seals shot on the same date in different years have lain an equally long time on the ice. Variations in pollutant concentrations between years may therefore be due to the time the seal has lain on the ice and not be a real variation in pollutants from year to year. Ringed seals are therefore not well suited for monitoring. Consequently, we suggest that this species is included as a research object and the data for MOSJ are changed to a ten-year time interval.

6. Pollutants in Brünnich's guillemots
- Change to a yearly interval.
- The Brünnich's guillemot is a circumpolar species which eats fish and molluscs. It is monitored for pollutants in the other arctic countries in connection with the AMAP work. Norway should follow up AMAP and include the Brünnich's guillemot in the monitoring series. The species does not migrate far south in winter, but moves westwards towards the Labrador Sea (between the southern tip of Greenland and Newfoundland) and will therefore reflect pollutants in the northern regions.
- Eggs from ten individuals annually.
- Sampling in connection with the annual seabird studies undertaken by the Norwegian Polar Institute.

7. Radioactivity to be replaced by three new lines in the table to describe the activity more precisely than results shown in the present indicator overview for MOSJ. At the same time, the three lines now describing the radioactivity measurements in MOSJ are to be removed from the table. The three new lines are:
- Radioactivity in cod.

– Radioactivity in water.
– Radioactivity in polar bears. Radioactivity in polar bears will be measured in individuals shot in Svalbard. They are shot in self-defence and are taken over by the Governor of Svalbard. Usually, between none and three polar bears are shot each year in Svalbard.

8. Pollutants in Svalbard ptarmigan
– To be removed from the MOSJ indicator set.
– Svalbard ptarmigan contain very small amounts of organic pollutants. This is a terrestrial species which is not affected by the present-day situation regarding pollutants in the Arctic. The concentration of heavy metals in Svalbard ptarmigan probably reflects background concentrations in the bedrock. It is therefore recommended that pollutants in ptarmigan become a research topic and are entirely removed as a MOSJ indicator.

9. Pollutants in char
– The char is a species of fish that may have considerable amounts of pollutants.
– Effects have been found on char in Ellasjøen on Bjørnøya. Since this species is at risk, the interval should be changed from every tenth to every fifth year.

10. Pollutants in lake sediments
– New indicator.
– Lake sediments can be used to measure the deposition of pollutants over a very long time period because it is possible to determine the age of the sediment layers. The uppermost layer of sediment can supply information on the deposition of pollutants in the last year and is therefore suitable as an indicator for pollutants that are being monitored and to screen new ones. Since AMAP and the Climate and Pollution Directorate intend to monitor lake sediments every tenth year, it is suggested that these data are included as part of MOSJ.

A Svalbard reindeer at Kongsfjorden. It is proposed to remove the species from the MOSJ indicator set. Photo: Anders Skoglund, Norwegian Polar Institute

11. Pollutants in Svalbard reindeer
– To be removed from the MOSJ indicator set.
– Svalbard reindeer have very small amounts of organic pollutants. This is a terrestrial species which is not affected by the present situation regarding pollutants in the Arctic. Low, in part unmeasurable, levels of "old" and "newer" organic pollutants and Caesium-137 have been recorded in Svalbard reindeer (Gwynn et al., 2005; Polder et al., 2009). It is therefore recommended that pollutants (organic and radionuclides) in Svalbard reindeer become a research topic and are completely removed as a MOSJ indicator.

12. Pollutants in geese
– To be removed from the MOSJ indicator set.
– There are three species of goose in Svalbard, all of which have different biology and wintering locations. There is, in general, little organic pollutant in these geese. Investigations show that the wintering site influences the composition of the pollutants (Steindal, 2009). These three terrestrial species are not as affected by pollution as marine species. It is therefore recommended that pollutants in geese are taken up as a research topic and are removed as a MOSJ indicator.

13. Pollutants in great skuas
– To be removed from the MOSJ indicator set.
– The great skua is a top predator, like the glaucous gull. High levels of pollutants have been found in the great skua, but the species is not particularly abundant in Svalbard. The largest colony is now found on Bjørnøya. The population has been growing since the beginning of the 20th century, and the great skua has gradually extended its breeding area northwards and eastwards into the Barents Sea (Strøm, 2006). That the species has high levels of pollutants makes it interesting for monitoring, but as it currently nests in a scattered fashion, collecting samples is comparatively expensive. Samples from glaucous gulls cover the need to monitor top predator seabirds. We therefore recommend that the great skua be removed from the indicator list and the pollutant aspect of the species is made a topic for research.

14. Proposed new indicator: pollutants in harbour seals
– It is proposed to place the harbour seal on the indicator list, with a sampling frequency of every tenth year.
– The harbour seal is very widely distributed, but even so, an endemic, isolated population is found on the west side of Svalbard, with a core area on Prins Karls Forland (Kovacs and Lydersen, 2006). It does not migrate out of this area, and is therefore the marine mammal in Svalbard with the most limited distribution. The harbour seal moults in autumn, making the summer ideal for sampling.
– Fat biopsy of ten individuals every tenth year.
– Sampling in connection with monitoring of marine mammals in Svalbard.

Table 5: Compressed version of parameters from MOSJ. The main overview for the impact factor, "pressure", and the indicator, "pollution". Proposed changes in the right-hand column.

Indicator	Parameter	Pri	Frequency	Proposed change
Atmospheric pollution in Ny-Ålesund	Sum 10 PCBs, sum DDT, HCB, HCH, chlordanes, PFAS, PBDE, HBCD	A	Yearly	
Atmospheric pollution in Ny-Ålesund	Hg, Cd, Pb, H2SO4, NO3+HNO3, CO2, methane, KFK, laughing gas, aerosols, black carbon	A	Yearly	
Pollutants in polar bears	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	A	Every 3 years	Yearly
Pollutants in arctic foxes	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	A	Every 3 years	Yearly
Pollutants in glaucous gulls	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	A	Every 3 years	Yearly
Pollutants in ivory gulls	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	A	3-5 years	To be removed
Pollutants in ringed seals	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	B	Every 5 years	Every 10 years
Pollutants in Brünnich's guillemots	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	B	Every 5 years	Yearly
Pollutants in polar cod	Organic pollutants, heavy metals	B	-	
Pollutants in capelin	Organic pollutants, heavy metals	B	-	
Pollutants in zooplankton	Organic pollutants, heavy metals	B	-	
Beach litter	Breibogen, Isflakbukta, Brucebukta: annual amounts	B	Yearly	
Radioactivity in the atmosphere	Air, water, seaweed	C	Yearly	Replaced by three new lines*
* Radioactivity in cod	Caesium-137	A	Yearly	
* Radioactivity in water	Caesium-137, Technetium-99	A	Yearly	
* Radioactivity in polar bears	Caesium-137	B	-	
PCBs in bottom sediments near settlements	Longyearbyen, Barentsburg, Pyramiden, Colesbukta, Jan Mayen, Barents Sea	C	Every 5 years	To be retained
Pollutants in walrus	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	C	Every 10 years	To be retained
Pollutants in bearded seals	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	C	Every 10 years	To be retained
Pollutants in beluga whales	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	C	Every 10 years	To be retained
Pollutants in Svalbard ptarmigan	Heavy metals	C	Every 10 years	To be removed
Pollutants in char	Organic pollutants, Hg	C	Every 10 years	Every 5 years
Pollutants in lake sediments	Organic pollutants, Hg	C	Every 10 years	NY
Pollutants in polar bears	Caesium, Strontium, Technetium	E		To be removed + see the suggestion above
Pollutants in cod	Organic pollutants, heavy metals	E		
Radioactivity in cod and polar cod	Caesium-137	E		To be removed + see the suggestion above
Pollutants in shrimps	Organic pollutants, heavy metals	E		
Pollutants in Svalbard reindeer	Heavy metals	E	Every 10 years	To be removed
Pollutants in geese	Organic pollutants, heavy metals	E		To be removed
Ozone-depleting substances		E		
Pollutants in great skuas	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	-	-	To be removed
Acidification	pH in seawater	-	Yearly	
Pollutants in harbour seals	PCB-153, DDT, chlordanes, HCB, HCH, dieldrin, toxaphene, PBDE, PFAS, Hg	C	Every 10 years	New

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Stockholm Convention Factsheet

Budget of Stockholm Convention for the biennium 2010-2011

General Trust Fund	$11,677,850
Special Trust Fund	$7,164,200
Total	$18,842,050

General trust funds are earmarked contributions while special trust funds are based on voluntary contributions

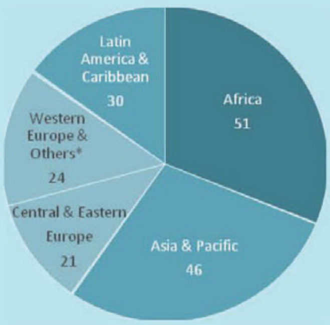
Top Five Donors to the General Trust Fund during 2010

Switzerland	$1,873,536
Japan	$879,598
Germany	$489,984
UK	$379,442
France	$359,961
TOTAL	$3,982,521

Top Five Donors to the Voluntary Trust Fund during 2010

Norway	$687,857
USA	$400,000
Sweden	$207,519
Netherlands	$204,200
Germany	$102,917
TOTAL	$1,602,493

Number of Parties per region



Total : 172 Parties as of 1 March 2011

What is the Stockholm Convention?

The Stockholm Convention on persistent organic pollutants (POPs) is a global treaty to protect human health and the environment from highly dangerous, long-lasting chemicals by restricting and ultimately eliminating their production, use, trade, release and storage.

Mission: To protect human health and the environment from POPs.

Key milestones:

- **February 1997** - UNEP/GC Decision 19/13C establishes POPs intergovernmental negotiating Committee (INC) to develop a global treaty on POPs
- **23 May 2001** - Conference of plenipotentiaries: 92 countries and EC sign the treaty
- **17 May 2004** - Entry into force of the Convention
- **May 2009** - COP4 : Amendments to the Convention to add 9 new POPs
- **26 August 2010** - Entry into force of the amendments on new POPs

What are the POPs covered under the Convention?

The first 12 compounds covered under the Convention are Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Hexachlorobenzene, Mirex, Polychlorinated Biphenyls, Polychlorinated dibenzo-p-dioxins, Polychlorinated dibenzofurans, and Toxaphene.

The 9 new POPs added to the Convention are Alpha hexachlorocyclohexane, Beta hexachlorocyclohexane, Chlordecone, Commercial octabromodiphenyl ether (hexabromodiphenyl ether and heptabromodiphenyl ether), Commercial pentabromodiphenyl ether (tetrabromodiphenyl ether and pentabromodiphenyl ether), Hexabromobiphenyl, Lindane, Pentachlorobenzene, Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOS-F).

Areas of focus of the Convention

1. Intentional POPs

- **Wastes and PCBs**

Supports Parties in establishing, implementing and strengthening their national capacities to address POPs/contaminated wastes including PCBs. The Convention provides guidance and facilitates the exchange of information on environmentally sound management of wastes, equipments and oils containing PCBs.

- **DDT**

Evaluates the continued need to use DDT for malaria vector control. The Convention collaborates with other stakeholders to promote the development and deployment of alternatives to DDT.

2. Unintentional POPs

Encourages the reduction of the total release of unintentional POPs derived from different anthropogenic activities such as incinerators and open burning through the gradual implementation of best available techniques (BAT) and best environmental practices (BEP) for existing and new sources.

3. Consideration of future POPs candidates

Establishes a scientific committee consisting of government-designated experts to review new chemicals proposed for addition under the Convention.

4. Technical Assistance and Financial Mechanism

Facilitates the provision of technical and financial assistance for eligible Parties to assist them in implementing the Convention. The Global Environmental Facility serves as the principal entity entrusted with the operation of the financial mechanism. Established under the Convention.

5. Effectiveness Evaluation and Global Monitoring

Collects national reports and regional monitoring data to facilitate the evaluation of its implementation as an effective tool to protect human health and the environment from POPs.

Stockholm Convention key dates

Intergovernmental negotiations

First session
Montreal, 29 June-3 July 1998

Second session
Nairobi, 25-29 January 1999

Third session
Geneva, 6-11 September 1999

Fourth session
Bonn, 20-25 March 2000

Fifth session
Johannesburg, 4-9 December 2000

Sixth session
Geneva, 17-21 June 2002

Seventh session
Geneva, 14-18 July 2003

Conference of plenipotentiaries

Stockholm, 21-22 May 2001

Conference of the Parties

First meeting
Punta del Este, Uruguay, 2–6 May 2005

Second meeting
Geneva, 1–5 May 2006

Third meeting
Dakar, 30 April–4 May 2007

Fourth meeting
Geneva, Switzerland, May 2009

Simultaneous extraordinary meetings of the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions
Bali, Indonesia, 22-24 February 2010

Fifth meeting
Geneva, Switzerland, April 2011

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30 March 2011

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UNITED NATIONS UNEP Stockholm Convention

Environmental and Health Effects of POPs

POPs have contributed to our general well-being like other chemicals. However, exposure to them can also cause serious health problems. Health and environmental concerns associated with POPs include:

- Persistence for long periods in the environment
- Travelling long distances and depositing far away from their sources of release
- Accumulating in the fatty tissues of living organisms
- Causing complications like cancer and birth defects
- Triggering adverse effect on the ecosystem and biodiversity
- Potentially disrupting immune and reproductive systems and even diminishing intelligence

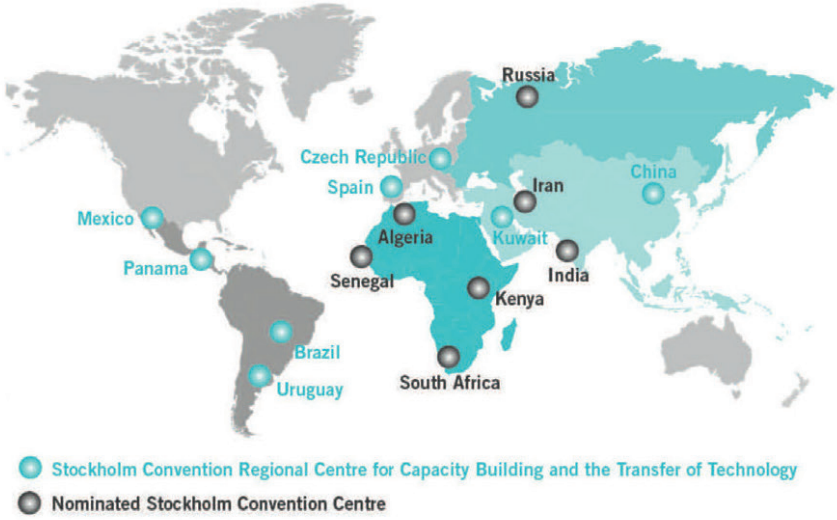
Regional Centres

There are 8 Stockholm Convention regional and sub-regional centres for capacity-building and the transfer of technology, located in:

- Sao Paulo, Brazil
- Beijing, China
- Brno, Czech Republic
- Kuwait City, Kuwait
- Mexico City, Mexico
- Panama City, Panama
- Barcelona, Spain
- Montevideo, Uruguay

There are 7 Nominated Stockholm Convention Centres located in:

- Algiers, Algeria
- Nagpur, India
- Teheran, Islamic Republic of Iran
- Nairobi, Kenya
- Moscow, Russian Federation
- Dakar, Senegal
- Pretoria, South Africa



Partners

The Stockholm Convention collaborates with many partners to meet its objectives, including:

- Basel Convention
- Rotterdam Convention
- Global Environment Facility
- United Nations Environment Programme
- Inter-Organization Programme for the Sound Management of Chemicals
- Non-Governmental Organizations
- United Nations Institute for Training and Research