STILL A CHALLENGE

PCB ON SVALBARD

REPORT 2011

FOREWORD

Ice cores and sediments from Svalbard show a clear decrease in the supply of PCBs (polychlorinated biphenyls) after 1970. The international ban on PCB oil has had an effect. Nonetheless, an increase in PCBs in air was measured in the period 2004-2008 at the Zeppelin station, Ny-Ålesund, compared with the figures from 2004. We have by no means seen the last of a chemical product that industry started using around 80 years ago and which has been banned for 30-40 years.

Polychlorinated biphenyls are a group of hazardous substances. The "PCBs on Svalbard: Status of Knowledge and Management 2011" report summarises the systematic survey and updated knowledge we have on the environmental pollutant PCB on Svalbard.

The report was produced by the Governor of Svalbard in collaboration with a number of research communities and the Climate and Pollution Agency (Klif). It builds on the work carried out in the "Svalbard Free of Local PCB Sources" project, which was funded by the Ministry of the Environment. The project involved field work with surveys and removal, subprojects and seminars, and this final report. The research communities have identified areas where, from a research point of view, there are still gaps in our knowledge. The work has involved surveying, identifying and removing as many of the local sources as possible, finding/identifying the gaps in our knowledge, and measure-oriented management routines by the Governor aimed at further local follow-up. The report and work are documented on: Sysselmannen.no (http://sysselmannen.no/hoved.aspx?m=51645). The report is available in Norwegian, Russian and English language versions.

PCBs are a group of technical compounds that have proven to be serious hazardous pollutants. In a few years time we will commemorate the unwelcome 100th anniversary of these compounds. Literature studies and our own surveys show that PCBs can now be detected everywhere on Svalbard, in its ice, snow, water, soil, vegetation, wildlife and air. These compounds are dispersing effectively and uncontrollably into the Arctic environment.

Our experience with PCBs should give us pause for thought with respect to the introduction and scope of new chemicals with unknown and little understood long-term effects on health and the environment in Arctic regions. It is important to reduce emission of new types of environmental pollutants to air and water, and from products and consumer goods on the world's markets today, to limit their dispersal and consequences. New chemicals may have similar effects and consequences to those of PCBs. It is both cheaper and simpler to prevent than to remove and clean up afterwards.

Long range transported pollutants from other parts of the world are by far the largest source of the PCBs introduced to Svalbard. There are also local sources, especially in the Russian settlements of Barentsburg and Pyramiden, but a lot of these have now been removed. Climate change is amplifying the challenges presented by environmental pollutants on Svalbard. PCB contamination will therefore remain a major challenge for Svalbard in the future.

A lot of work has been done on reducing the use of PCBs over many decades, both nationally in Norway and internationally. PCBs have been strictly regulated in Norway and the EU for many years, and are also covered by the global Stockholm Convention. Action is needed to reduce long range transported PCB pollution to Svalbard and the Arctic. Measures for phasing out, removing and properly destroying PCB-containing materials and equipment should be followed up, both nationally and internationally. Knowledge about the major and all the minor local sources around the world should be used proactively in a goal-oriented international partnership.

Halvard R. Pedersen
Project Manager
The Governor of Svalbard

"The Governor has done what we can to prevent PCBs from local sources entering Svalbard's environment. The baton is now being passed on so that others can continue to work on their local sources. A preventive, effective international partnership is needed to reduce the amount of PCBs carried by air and oceanic currents to Svalbard."

Odd Olsen Ingerø
The Governor of Svalbard

ABOUT THE REPORT AND PROJECT WORK

PCBs on Svalbard: Status of Knowledge and Management, April 2011
The PCB Project on Svalbard started in 2008 after funding was granted by the Ministry of the Environment.

THE PRIMARY GOALS OF THE PROJECT ARE:

1. Survey local sources that can disperse PCBs
2. Remove all PCB-containing equipment that is in use or stored
3. Document the status of contamination
4. Share experience and contribute to international cooperation to prevent PCB contamination

PARTICIPATING INSTITUTIONS:

Akvaplan-niva
Directorate for Nature Management (DN)
Climate and Pollution Agency (Klif)
Geological Survey of Norway (NGU)
Norwegian Institute for Air Research (NILU)
Norwegian Polar Institute (NP)
Norwegian Institute for Water Research (NIVA)
Norwegian Water Resources and Energy Directorate (NVE)
Norwegian School of Veterinary Science (NVH)
The Governor of Svalbard
Trust Arktikugol (TA)
University of Bergen (UiB)
University Centre in Svalbard (UNIS)
Norwegian University of Life Sciences (UMB)

CONTRIBUTORS:

Project manager
Halvard R. Pedersen, pollution adviser, The Governor of Svalbard

Authors
Roland Kallenborn, *professor of chemistry/chemical technology, Norwegian University of Life Sciences*

Rolf Tore Ottesen, *Geological Survey of Norway, head of the geochemistry and environment research group, adjunct professor, Department of Chemistry, Norwegian University of Science and Technology*

Geir W. Gabrielsen, *senior researcher, zoophysiology, Norwegian Polar Institute, Tromsø, adjunct professor of marine biology at the University Centre in Svalbard, Longyearbyen*

Corinna Schrum, *professor of oceanography, Geophysical Institute, University of Bergen*

Anita Evenset, *Manager, Arctic R&D, Akvaplan-niva*

Anders Ruus, *Dr. Scient, senior researcher, marine biology/ ecotoxicology, Norwegian Institute for Water Research*

Halfdan Benjaminsen, *Hydrogeological Department, Norwegian Water Resources and Energy Directorate*

Kjetil Sagerup, *researcher, Norwegian Polar Institute, Tromsø*

Guttorm Christensen, *senior adviser, Akvaplan-niva*

Ola Eggen, *researcher, Geological Survey of Norway*

Pernilla Carlsson, *research fellow in environmental chemistry, University Centre in Svalbard*

Emma Johansson-Karlsson, *engineer, University Centre in Svalbard*

Anuschka Polder, *Dr. Philos, researcher, environmental chemistry/ ecotoxicology, Norwegian School of Veterinary Science*

Halvard R. Pedersen*, pollution adviser, The Governor of Svalbard*

Qno Lundkvist, *chief engineer, Climate and Pollution Agency*

The report's editor was Qno Lundkvist, *Klif.*

"The *modern world's* use of environmental pollutants is impacting Svalbard's environment."

PCBs are hazardous substances that resist degradation in the Arctic environment. They account for the majority of the known pollutant load on Svalbard's wildlife. Their impact is so great that it produces negative outcomes for some individuals and populations of species such as the polar bear, Arctic fox, Great Skua, Ivory Gull and Glaucous Gull. An unscientific comparison may serve to clarify the magnitude of this impact: are animals becoming hazardous waste? If construction waste contained the high levels of PCBs found in, for example, Arctic foxes and polar bears on Svalbard, it could not, according to the regulations, be reused without undergoing a formal risk assessment.

The modern world is impacting Svalbard's environment through contamination by environmental pollutants. This impact can be well illustrated by PCB contamination. PCBs can be used as a model for other old and new environmental pollutants. The effects on the environment are similar to some extent. Where PCBs are found one will often also find many of the other environmental pollutants with similar properties.

Long range transported pollutants from other parts of the world are by far the largest source of the PCBs introduced to Svalbard. This is also true for many other well-known pollutants.

Significant local sources of PCBs were discovered and registered during the project. PCB-containing equipment in all existing and abandoned settlements on Svalbard has now been surveyed, sampled, removed and treated.

Knowledge about local sources and their relationship to long range transported pollutants is vital if the management is going to initiate appropriate local measures, and the authorities are going to prioritise work internationally.

Action is needed to reduce PCB contamination on Svalbard from long range transported pollutants. This must include measures for phasing out, removing and properly destroying PCB-containing materials nationally and internationally. Knowledge about the all large and small local sources of PCBs around the world must be used actively in an international, result-oriented partnership to ensure a much needed reduction in PCB emissions from man-made sources occurs as soon as possible.

Norway's national action plan for reducing emissions of PCBs could play a vital role in achieving a binding international partnership working to ensure the prompt, preventive phasing out and destruction of those PCBs that can still be found in places such as buildings, structures and electrical equipment. The facts described in this report and its conclusions could also play an active role in any such future-oriented work.

THE REPORT HAS SEVEN CHAPTERS:

1 PCBS – A CHALLENGE FOR SVALBARD. The first chapter summarises the conclusions and recommendations from the project work. The summary is based on the surveys described in chapter 3.

2 PCBS ON SVALBARD – INTRODUCTION. The second chapter provides an introduction into, and a framework for, the problems associated with PCBs.

3 PCBS IN SVALBARD'S ENVIRONMENT. The third chapter summarises the status of our knowledge on PCB contamination based on openly available sources and surveys.

4 PCBS – SOURCES, PATHWAYS AND CLIMATE CHANGE. The fourth chapter describes how PCB contamination occurs. It also explains the potential development of PCB contamination due to climate change.

5 REFERENCES. The fifth chapter documents the information materials on which the report is based.

6 SUMMARY OF REPORTS FROM LOCALISED ENVIRONMENTAL POLLUTANT SURVEYS. The sixth chapter lists the surveys of PCBs and environmental pollutants conducted in geographically limited areas on land and in sediments in Svalbard.

7 APPENDIX. The seventh chapter contains appendices that supplement some of the information in earlier chapters.

Footnotes are collated at the end of each chapter.

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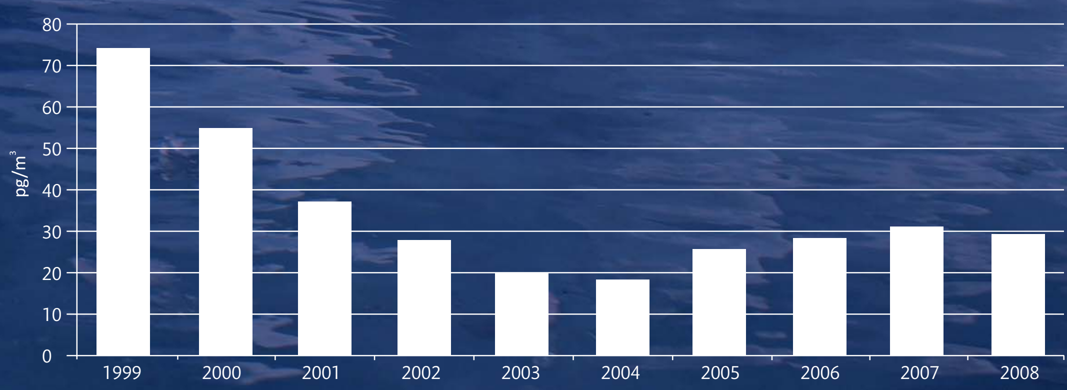
After a 30 year ban on PCBs: the quantities in air have increased



Levels of PCBs in the atmosphere have increased: The atmosphere is perhaps the medium in which we can measure changes in the presence of these chemicals the fastest. Following a period of decreasing levels, increased levels of PCBs were registered in the atmosphere at the Zeppelin station in 2004-2008.

1. PCBS - A CHALLENGE FOR SVALBARD

"Wherever we look we find the hazardous substance PCB. The unspoilt is no longer unspoiled. The reality is even scarier. PCBs are just one of many environmental pollutants and this toxic mixture can be more dangerous than PCBs on their own."

Professor Rolf Tore Ottesen, Geological Survey of Norway

1.1 BACKGROUND

Polychlorinated biphenyls (PCBs) are a group of hazardous substances that have very serious effects on human health and nature. For example, PCBs are known to disrupt hormones. PCBs are an important group of environmental pollutants in both a global and an Arctic context because of their stability and dispersal. Today, earlier emissions of PCBs can be found in people, animals, sediments, air, water and soil around the world. PCBs have been found in all the media that have been surveyed on Svalbard. This shows that these substances disperse effectively and without particular restrictions to, and in, the Arctic environment.

PCBs have a negative effect on development at the early stages of life; foetuses and children are especially exposed and vulnerable. Long-term exposure, even to small quantities, can impact things such as the immune system, reproductive ability, and hormonal balance. These compounds also effect nervous systems and can disrupt other human and animal development.

Most of the surveyed PCB-containing equipment and materials on Svalbard have now been removed. The remaining local sources of PCBs are primarily linked to buildings and contaminated soil, especially in the Russian settlements. The main challenge comes from long range transported pollutants, which today account for the largest source of new PCBs. Climatic conditions and Svalbard's geographical location mean that air and oceanic currents and ice transport across the Arctic Ocean carry PCBs from industrialised areas in Europe, the USA, Russia and Asia to the archipelago. These compounds are still used in old equipment in large parts of the world and can be found in many types of products, primarily in association with electrical equipment, buildings, installations and paint. PCB contamination will therefore remain a major challenge for Svalbard in the future, especially in the event of major climate changes. After a steady decrease in PCBs up to 2004, an increase in the levels of PCBs in the atmosphere was measured at the Zeppelin station in Ny-Ålesund.

PCBs that are emitted or remobilised in Europe and on other continents can be transported by air currents to Svalbard in just a few days or weeks. Roughly 60% of the long range transported PCBs in a gaseous phase or attached to particles arrive on Svalbard via air currents, 30% arrive via oceanic currents and 10% via ice transport over the Arctic Ocean (Kallenborn, personal communication).

The Governor has neither the ability nor the authority to reduce the supply of, or inspect, long range transported pollutants.

FACTS PCBs have a negative effect on development at the early stages of life; foetuses and children are especially exposed and vulnerable. PCBs have adverse effects even in very small concentrations.

MAIN FINDINGS

1. The PCB levels in Svalbard's environment are having documented adverse effects on several animal species
2. Levels of PCBs in the atmosphere are increasing again
3. Levels of dioxin-like PCBs and dioxins have been found in freshwater fish and seafood that border on or exceed the limits for human consumption
4. PCBs have been found in all examined media and food chains
5. PCBs account for the largest proportion of the total pollutant load in many organisms on Svalbard

See chapters 3 and 5 for the academic basis for the report

International cooperation is required to properly phase out PCB products, properly treat PCB contamination on site, and implement climate change measures. It is important that Norway continues to contribute heavily to this work, especially in relation to the UN conventions (the Stockholm and LRTAP[1] conventions). It is also important that international agreements and conventions with consequences for Svalbard and the Arctic environment are enforced in line with their intentions and obligations. The resources, means and authorisations on which Norway's contributions to such international work are based are primarily the responsibility of the Ministry of the Environment and the Climate and Pollution Agency.

The Zeppelin station near Ny-Ålesund continuously measures pollutants, including PCBs, in the air. It plays a crucial international role in the efforts to monitor persistent organic pollutants over the long term.
Photo: Tor Ivan Karlsen, Norwegian Polar Institute

1.2 STATUS OF KNOWLEDGE ON PCBS ON SVALBARD AND IN NEIGHBOURING AREAS – MAIN FINDINGS

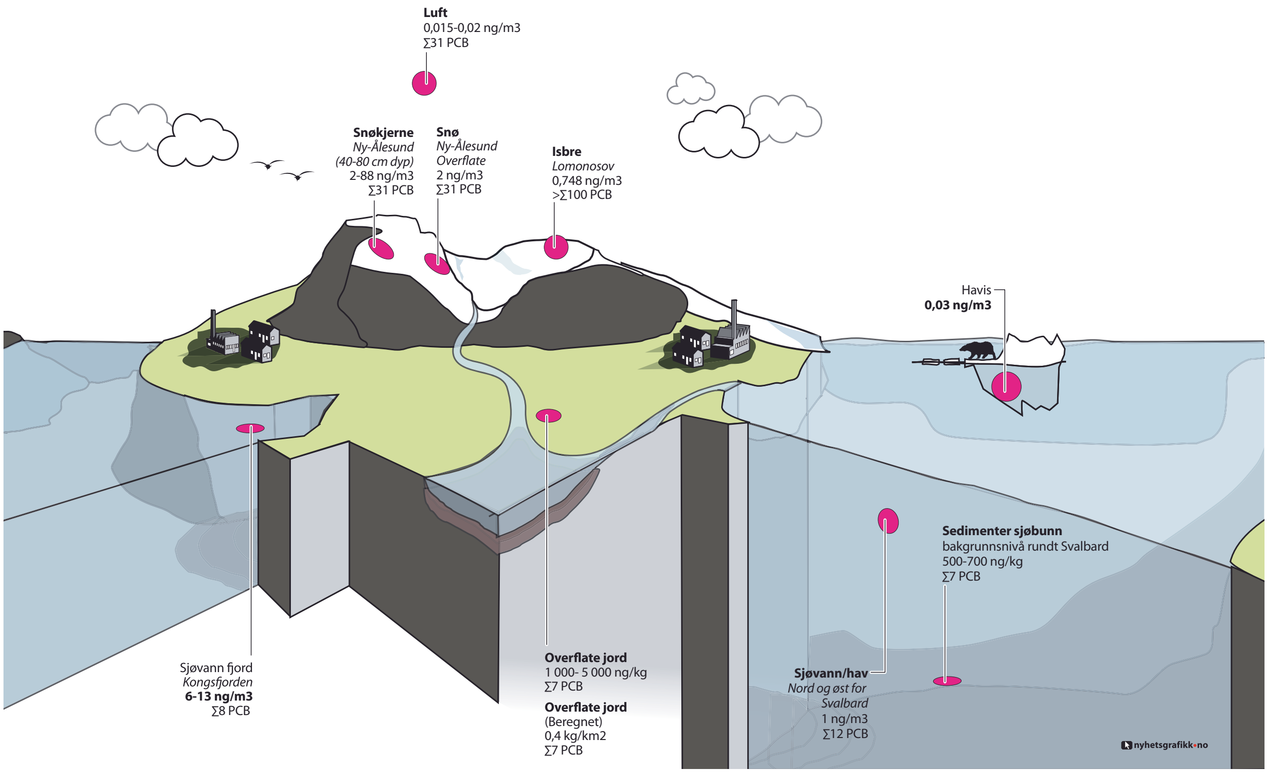
PCBs were found in all surveyed media and food chains: The fact that PCBs now constitute an unwanted and increasingly integrated part of the ecosystems on Svalbard is well documented. The compounds can be found in air, water, soil, sediments, and organisms, and can be measured everywhere on and around Svalbard.

The levels of PCBs in Svalbard's environment are already having adverse effects on a number of animal species: PCBs, together with other environmental pollutants, have negative effects on Arctic foxes, polar bears, orcas, Northern Fulmars, Glaucous Gulls, Great Skuas and Ivory Gulls. The PCB concentrations now in top predators can cause physiological, immunological and reproductive stress, which in turn can have a negative impact at an individual and population level.

Little is known about how PCBs affect organisms at lower trophic levels.

Levels of PCBs in the atmosphere are increasing again: The atmosphere is perhaps the medium in which we can measure changes in the presence of these chemicals the fastest. Following a period of decreasing levels, increased levels of PCBs were registered in the atmosphere at the Zeppelin station in 2004-2008. PCB contaminated air also affects water and sediments, directly and indirectly.

Levels of dioxin-like PCBs and dioxins that border on or exceed limits for human consumption have been found in freshwater fish and seafood: Arctic char from Ellasjøen on Bjørnøya have levels of PCBs and dioxin-like PCBs that exceed the limits for human consumption set by the US Environmental Protection Agency and the EU. Fish taken from Richardvatn, Arresjøen and Annavatn also have elevated levels of environmental pollutants. NIFES has established that Greenland halibut caught near sampling stations



Here we can see the normal background levels of PCBs in Svalbard's environment due to long range transported pollutants. (The figures are stated in nanograms per kg. 1 ng/kg equals 0.000000001 g/kg).

PCB levels in polar bears are already having adverse effects on, for example, hormone and immune systems. PCB contamination also affects reproduction and survival. Photo: Halvard R. Pedersen

off Svalbard have concentrations in which the sum of the dioxin-like PCBs and dioxins exceed the EU's upper limits. The Institute of Marine Research found that some seafood from the Barents Sea exceeds the accepted limits for dioxin-like PCBs and dioxins, and that the safety of seafood could come under pressure if the pollutant load increases above its present level.

PCBs account for the largest proportion of the total pollutant load in many organisms on Svalbard: Despite finding new types of environmental pollutants and decomposition products, PCBs still dominate. PCBs account for more than half of the total pollutant load for a number of species, e.g. species of bivalves, fish and seals, and Glaucous Gulls and polar bears.

The PCB contamination has geographic gradients: PCBs are steadily dispersing northwards over the globe due to evaporation, condensing in colder layers of air, and deposition through means such as precipitation.

In some media higher levels of pollutants can be detected the further east you go on Svalbard. A crude trend like this has been found in seals, several species of whale, Arctic foxes, polar bears, and air. This may indicate major air and sea-based long range transport of PCB compounds into the Barents Sea and Svalbard region.

Model calculations show that an increased supply of PCBs with melt water from sea ice, layer formation in the ocean due to warming, and increased melt water in the summer will result in higher concentrations of PCBs in surface water in the northern part of the Barents Sea.

Any decrease in measured PCB levels does not necessarily mean the environmental pollutants have decomposed: most of the PCBs arrive in the Svalbard region via air and oceanic currents and end up in the water, snow, ice or soil on or near the archipelago. PCBs resist degradation in the Arctic climate.

Many surveys have been conducted that show that, once they have arrived in Svalbard's environment, the compounds are effectively transported and dispersed from areas with background pollutants or polluted ground into the marine environment. A long-lasting temporary movement between different media takes place because the compounds are remobilised, e.g. from air to snow, onwards to soil and water, and finally to sediments. A measured fall in concentrations in one medium does not necessarily mean that they have decomposed and been rendered harmless. PCBs may have temporarily moved to another medium where the compounds are available to be taken up by organisms. When chemicals are in circulation like this they accumulate in food chains and affect animals and people.

Leaking electrical equipment has been removed. From the removal work in Pyramiden. Photo: Halvard R. Pedersen

PCB levels in a number of media vary depending on the time of year/season. The level of pollutants in the atmosphere and water varies with the season, which indicates that PCBs are released when snow and ice melts. Flood water also washes out PCBs from soil and polluted ground. These fluctuations can also be detected in plankton. PCB levels in animals fluctuate strongly due to factors such as the availability of food, type of food and overall stress level.

Local PCB pollutants in the settlements disperse into the marine environment. and ecosystems: The composition of PCB pollutants in Grønfjorden (where Barentsburg is located) and Billefjorden (where Pyramiden is located) differs to that in Adventfjorden, Isfjorden and Kongsfjorden. This indicates that local pollutants are dispersed into marine sediments, benthic fauna and sedentary marine animals. PCBs that have been taken up from local contamination can be detected in bottom-dwelling organisms and sedentary fish, e.g. scorpion fish and redfish, and Glaucous Gulls.

Local primary sources[2] for PCBs have been surveyed and measures implemented: To avoid future emissions the Governor has surveyed, removed and treated PCB-containing equipment in all existing and abandoned settlements on Svalbard. Buildings and facilities have been inspected for equipment that was in operation or stored and could potentially contain PCBs. If the presence of PCBs was suspected samples were taken and analysed. What has not been removed is primarily bound in paint in buildings or lies in soil near the buildings. PCBs were demonstrated in ten of the surveyed buildings in Longyearbyen, although the levels were low compared with Barentsburg. 60% of the buildings in Barentsburg and Pyramiden contain building materials that contain PCBs. More than 90% of the painted surfaces here contain PCBs.

Most of the PCBs that can be found on Svalbard now are secondary sources[3] which it is difficult to implement effective measures against: The pollutants are temporarily bound in soil, snow, ice, water, sediment, air, vegetation and animals. Since these compounds resist degradation, benthic fauna in the sea (sediment living animals/invertebrates) will eventually be exposed to these environmental pollutants. Invertebrates are low down in the food chain and most have only a limited ability to convert/degrade PCB compounds. Invertebrates can remobilise the bioaccessible portion of the pollutants that end up on the seabed. Since they are prey for other organisms they will transfer PCBs from the seabed to the animals that eat them. The environmental pollutants will thus re-enter the food chains.

1.2.1 HOW MUCH PCB IS PRESENT?

The status of PCB levels and effects in various media are provided below. The PCB levels are also provided in the table in chapter 1.2.2. In this table the PCB levels are provided in common units so the levels of pollutants can be compared more easily.

1.2.1.1 Air *(read more in chap. 3.1)*

The background level of PCBs in air is higher on Svalbard than at six other Arctic monitoring stations[4]: The background level in the atmosphere at the Zeppelin station in Ny-Ålesund was 15-20 pg/m^3 ∑31PCB[5] in the period 2000-2006. Following a decrease in PCBs up to 2004, an increase in the levels of a number of PCB congeners has been measured in the atmosphere at the Zeppelin station. 40-50 pg/m^3 ∑31PCB was measured on Bjørnøya in the period 2000-2003. The levels on Bjørnøya reflect a significant contribution from neighbouring regions.

Observations show that PCB congeners with a low molecular weight can remain in a gaseous phase in the climatic conditions that prevail on Svalbard.

Air pollution in the settlements varies more than background measurements: Between 0.8-5.6 pg/m^3 ∑21PCB was measured in Longyearbyen (November 2009). 5-34 pg/m^3 ∑21PCB was measured in September-October 2009 in Barentsburg. There is reason to assume that PCB sources in Barentsburg are contributing to the local air pollution in the settlement.

PCBs are formed and emitted by incineration sources: Verification measurements of the new formation of PCBs in the incineration process in the power station in Longyearbyen indicate emissions of around 2-3 g ∑7PCB/year. A rough estimate indicates that this corresponds to annual emissions of around 10 g when all PCB congeners are included.

1.2.1.2 Soil *(read more in chap. 3.2.1 and 3.2.2)*

Total concentrations of PCBs in soil on Svalbard are markedly higher than on mainland Norway: The background level in soil on Svalbard is around 1–5 µg/kg ∑7PCB. Surveys of grass covered soil on the mainland show a median value of 0.40 µg/kg ∑31PCB. This indicates markedly higher total concentrations of PCBs on Svalbard than on the mainland. A rough estimate indicates general surface contamination on Svalbard of 0.4 kg/km^2 ∑7PCB. Similarities between the types of PCB (congener distribution) in the sea areas around Svalbard and the surface soil on Svalbard indicate that the PCBs on land and in the seawater may come from the same dominant source.

The soil in the Russian settlements of Barentsburg and Pyramiden is highly contaminated: A rough calculation of PCBs in the surface soil in these settlements indicates 430 kg/km^2 ∑7PCB for Pyramiden, 300 kg/km^2 for Barentsburg and 3.3 kg/km^2 for Longyearbyen. These roughly correspond to around one thousand times and ten times the background levels. The levels of PCBs in the surface soil in Barentsburg are clearly higher than what has previously been measured in surface soil from Norwegian and European cities.

Known landfill sites, in use or closed, have been surveyed, fenced off and registered: The heavy metals from these sites have a greater environmental impact than PCBs.

1.2.1.3 Seabed, river and lake sediments *(read more in chap. 3.2.3 and 3.3.3)*

The levels of PCBs in sediments in surveyed lakes are significantly higher than those found in other regions of the Arctic and Northern Norway: PCBs were found at the bottom of all surveyed lakes. The average concentration of ∑7PCB in sediments from lakes on Svalbard was 10.1 ng/g dry weight (dw), while the average for the mainland was around 1.9 ng/g dw. The content of environmental pollutants is significantly higher than those found in other regions of the Arctic and Northern Norway:

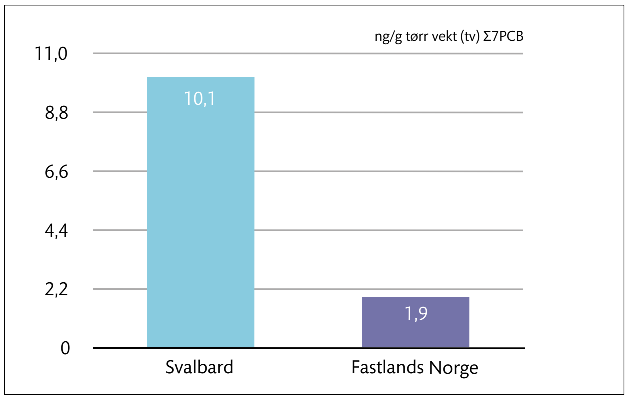
Ellasjøen on Bjørnøya and Kongressvatn on Spitsbergen had the highest levels with 24.25 and 15.79 µg/kg ∑7PCB tw respectively. It has been established that Ellasjøen is affected by PCBs supplied by guano (excrement from birds).

Russian measurements show that sediments from Stemmevatn and Grøndalselva contain approx. 1-4 µg/kg and 1-2 µg/kg ∑7PCB respectively.

Elevated PCB levels in the seabed (marine sediments) were measured off the Russian settlements: Typical concentrations in marine sediments in the Barents Sea around Svalbard were 0.5 - 0.7 µg/kg ∑7PCB. Sediment measurements indicate increasing concentrations from south to north and from west to east. This pattern can be explained by the currents, increasing summer concentrations in the bottom water in the north due to increasing PCB supply from melting sea ice, and increasing sedimentation in the summer due to biological activity.

The levels in marine sediments in Isfjorden are higher near the settlements. This is due to dispersal from local sources on land out to sea. PCBs remain the dominant environmental pollutant in the samples and dioxin-like[6] PCBs account for a substantial proportion of the ∑PCB in the samples (up to 43%). The concentrations in sediments in Grønfjorden off Barentsburg varied from 0.53 – 8.76 µg/kg dw ∑59PCB (Russian data). Norwegian surveys varied from 0.33 – 3.29 µg/kg ∑7PCB dw. Concentrations in sediments off Pyramiden varied from 1.8 – 20.2 µg/kg dw (Norwegian data).

A rough calculation of the transport of eroded materials (from surface soil, including polluted ground in the settlements, and river transport) on the archipelago results in an annual total transport/flux to the sea and marine ecosystems of 2.8 kg ∑7PCB.



The levels of PCBs in sediments in surveyed lakes are significantly higher than those found in other regions of the Arctic and Northern Norway.

1.2.1.4 Ice and snow *(read more in chap. 3.2.4 and 3.3.2)*

PCB levels in ice and snow are higher on Svalbard than on Greenland: ice from cores taken in 2000 from Lomonosovfonna show a clear decrease in the supply of PCBs via air currents after 1970. The ice had a PCB concentration (> 100 congeners) of 748 pg/l (2000). Analyses of spring snow from 2001 in Ny-Ålesund showed 742 pg/ l ∑80PCB. Surface snow at the Zeppelin station had PCB levels of 2 pg/l ∑31PCB (depth of 0-40 cm) and 2 - 88 pg/l in snow cores taken from a depth of 40-80 cm. Significantly lower concentrations were measured on Greenland (Summit) in surface snow and snow profiles (Greenland: max. 1100 pg/l, Ny-Ålesund: max. 2000 pg/l ∑31 PCB).

Little research has been carried out on PCB levels in sea ice but the levels referred to around 30 pg/l.

1.2.1.5 Water *(read more in chap. 3.2.5 and 3.3.1)*

Little research has been carried out into PCB levels in freshwater: Water samples from Ellasjøen and Øyangen on Bjørnøya show 129 pg/l ∑11PCB for Ellasjøen and 23 pg/l for Øyangen respectively. Ellasjøen is supplied with PCBs via guano from seabirds. Russian measurements in Stemmevatn near Barentsburg in 2002-2009 show seasonal variations of PCBs in surface water. Concentrations of around 0.4 ng/l ∑7PCB have been measured in the last couple of years.

Total concentrations of PCBs in soil on Svalbard are markedly higher than on mainland Norway. Photo: Halvard R. Pedersen

Little research has been carried out into PCB levels in seawater: The take up of the compounds and the resulting PCB levels at the bottom of many Arctic food chains depend on exposure to unbound PCBs in seawater. 6-13 pg/l ∑8PCB was measured in Kongsfjorden and seasonal variations found. Measurements in the sea areas around Svalbard show between 94 – 1748 fg/l unbound ∑12PCB and particulate between 222 – 876 fg/l in the Arctic mixed layer. The highest values were measured on the east side of Spitsbergen. Observations conducted in the Barents Sea show that particulate bound PCBs represent a larger proportion than unbound PCBs.

Seawater collected near Bjørnøya shows 10 pg/l ∑18PCB.

Model calculations show that an increased supply of PCBs with melt water from sea ice and layer formation in the ocean because of warming and increased melt water in the summer will result in higher concentrations of PCBs at the surface in the northern part of the Barents Sea. Concentrations of PCBs in water near the seabed vary a lot between nearby areas.

1.2.1.6 People

No data for PCBs in people who work on Svalbard are available: We are unaware of any measurements of PCBs in people who have been exposed to the compounds on Svalbard.

1.2.1.7 Plants *(read more in chap. 3.4.2)*

Little research has been carried out into PCBs in vegetation: PCBs can be detected in mosses and vascular plants from Barentsburg (Russian measurements). The averages for ∑15PCB was 589.7 µg/kg in mosses and 97.5 µg/kg in vascular plants.

1.2.1.8 Mammals *(read more in chap. 3.4.3 and 3.4.4)*

Concentrations of PCBs in Svalbard reindeer are lower than those in reindeer on mainland Norway: The levels of PCBs in Svalbard reindeer are lower than the detection limit (background level). Svalbard reindeer from Nordenskiöldland had values that were below the detection limit of 0.03 ng/g wet weight (ww), and close to the detection limit for two of the decomposition products (metabolites) from PCBs.

PCB levels in seals vary greatly between species: The average PCB concentration in the blubber of ringed seals, harp seals and walruses varies between 0.5-9.5 mg/kg fat/lipid weight (lw). The highest level was measured in harp seals, followed by walruses and ringed seals.

Narwhals are the whale species with the highest PCB levels near Svalbard. PCB concentrations in the blubber of narwhals are on average 10 mg/kg ∑23PCB lw, while they are around 3 mg/kg ∑23PCB lw in white whales. Narwhals are a toothed whale that eat higher up the food chain than minke whales. These two whale species have even higher levels of pesticides than PCBs. Minke whales, which eat krill and amphipods, have PCB levels of 1-5 mg/kg ∑21PCB lw. Blubber samples from white whales from the Svalbard area show higher levels of PCBs than samples from Canada and Greenland. The level of environmental pollutants in several whale species increase as one moves from Canada and Greenland towards Svalbard.

PCB levels in polar bears exceed the limits for effects on hormone and immune systems. The concentrations of ∑72PCB in fat samples from female bears varied from 3–9 mg/kg (2007). The levels of environmental pollutants in polar bears have passed the thresholds for affecting the hormone and immune systems and one can expect the reproductive ability and/or survival of certain individuals to be affected. Studies from Canada show that polar bear young have lower survival rates when the polar bear mother has high concentrations of chlorinated organic compounds. Since polar bears on Svalbard have higher PCB levels than polar bears in Canada, one possible effect of environmental pollutants will be a lower survival rate for polar bear young from the most heavily impacted polar bear mothers. An overall assessment indicates that the polar bear must be monitored with regard to both the levels and the effects of environmental pollutants. Concentrations of PCBs and other chlorinated organic compounds appear to increase from the western to the eastern populations of polar bear in the circumpolar Arctic. Of the fat-soluble environmental pollutants it is primarily PCBs that contaminate polar bears.

PCB levels in Arctic foxes are probably having an effect on health: The demonstrated PCB levels in Arctic foxes (10-12 mg/kg ∑7PCB lw) are higher than the levels measured in polar bears. This provides reason to believe that the contamination is having an effect on the health of Arctic foxes.

1.2.1.9 Marine animal life (fish, zooplankton and bivalves)
(read more in chap. 3.4.5, 3.4.6 and 3.4.8)

Levels of PCBs in zooplankton from Svalbard are relatively similar to the levels measured in zooplankton from the White Sea and Barents Sea: The levels of PCBs in zooplankton and krill from Kongsfjorden are around 10-15 µg/kg ∑8PCB lw. There are no indications that the PCB contamination comes from local sources. There are seasonal variations in the amount of PCBs in zooplankton. Concentrations are highest in May (after the ice melts and during spring bloom) and decreases during the season up to August.

Capelin and polar cod are important plankton eaters and their diet includes Calanus finmarchicus. PCB levels in the fish are 3 to 45 times higher than in their prey. Plankton-eating fish are eaten by other fish, including Atlantic cod and haddock. The levels in their livers increase to 13 to 57 times above the level in Calanus finmarchicus.

PCB levels in polar cod are lower than those in Atlantic cod from the North Sea. The concentrations in samples of whole polar cod from the Barents Sea collected annually from 2006 to 2009 vary from 0.097 to 0.43 ng TEQ[7]/kg ww for total dioxin-like PCBs and dioxins.

Analysed Atlantic cod livers show that a large proportion exceed the EU's upper limit:
Liver samples from Atlantic cod *(Gadus morhua)* caught in the Barents Sea in 2009 show that total dioxin-like PCBs and dioxins exceeded the EU's upper limit of 25 ng TE/kg ww in almost a quarter of the samples. The average concentration was 20.5 ng TE/kg ww. Dioxin-like PCBs accounted for the largest proportion of the total.

A large proportion of Greenland halibut have PCBs that exceed the EU's limit: Analyses show levels of approx. 30 µg/kg ww ∑7PCB. The proportion of Greenland halibut that exceed the EU's upper limit of 8 ng TE/kg ww at the three stations off Spitsbergen was high (22%, 20% and 8% respectively).

PCB levels in sedentary, bottom-dwelling fish are higher than in fish that are not sedentary. Surveys conducted in 2009 off Barentsburg show that the highest concentrations of PCBs were measured in the relatively sedentary, bottom-dwelling scorpion fish species (average of 5.3 ∑59PCB ww for bull routs and 6.8 µg/kg for the Arctic staghorn sculpin). Redfish, which are also a bottom-dwelling fish, had PCB levels matching those in scorpion fish. The lowest levels were measured in Atlantic cod and haddock (average 0.77 and 0.37 µg/kg ∑59PCB ww). Dioxin-like PCBs accounted for 0 – 43%.

PCBs accounted for up to 80% of the total pollutant load in bivalves: Analyses of bivalves from Kongsfjorden and north of Svalbard show that PCBs account for up to 80% of the total so-called POP[8] load in the organisms. The study also shows that concentrations in bivalves vary among the species, and in the different fjord systems on the north-west coast of Svalbard. The bivalves from Kongsfjorden show considerably higher levels of PCBs compared with bivalves

Svalbard Ptarmigan are less contaminated by PCBs than seabirds. This is because the food the ptarmigan eat contains less PCBs than the food seabirds find in the sea. Photo: Halvard R. Pedersen

from the northern fjords. In general, the concentrations are lower in these invertebrates compared with organisms higher up the food chain (such as fish, marine mammals and seabirds). The average value was 63 ng/g ∑16PCB lw for those species that were analysed.

Little research has been carried out into PCBs in benthic fauna: PCBs in benthic fauna (benthic invertebrates) collected off Barentsburg varied from 3.03 (in the bristleworm Pectinaria) to 18.6 µg/kg ∑59PCB ww (in the bivalve Ciliatocardium ciliatum).

PCBs in freshwater fish from Svalbard are higher than in fish from Northern Norway: The highest levels of PCBs were measured in Arctic char from Ellasjøen (134 – 2072 ng/g ∑64PCB ww). The average level in Arctic char from Ellasjøen (1235 ng/g ∑64PCB ww) was > 20 x higher than those measured in Arctic char from the lake with the next highest levels, Arresjøen (52,6 ng/g ww). Arctic char from Richardvatn (32.9 ng/g ww) and Annavatn (28.9 ng/g ww) had higher PCB levels than fish from the other examined lakes. The analysis results show that PCBs are the dominant environmental pollutants in fish from all the lakes that were examined.

1.2.1.10 Birds *(read more in chap. 3.4.7)*

The levels of PCBs in ptarmigan were lower than in seabirds on Svalbard: The levels of PCBs in ptarmigan from Longyearbyen and Ny-Ålesund are low (background level).

PCB levels in Glaucous Gulls are causing harm: Measurements from Glaucous Gulls in recent years show levels of 15,000-20,000 ng/g lw of the congener PCB#153 in livers. PCBs dominate and account for more than 60% of the total pollutant load on Glaucous Gulls. Surveys indicate effects on the birds' behaviour and immune, enzyme and hormone systems. The reproductive ability of individuals with the highest levels of environmental pollutants is weaker and adult survival rates for these individuals is lower. Dead Glaucous Gulls from Svalbard and Bjørnøya have 10 to 100 times higher PCB levels in the liver and brain respectively compared with healthy birds.

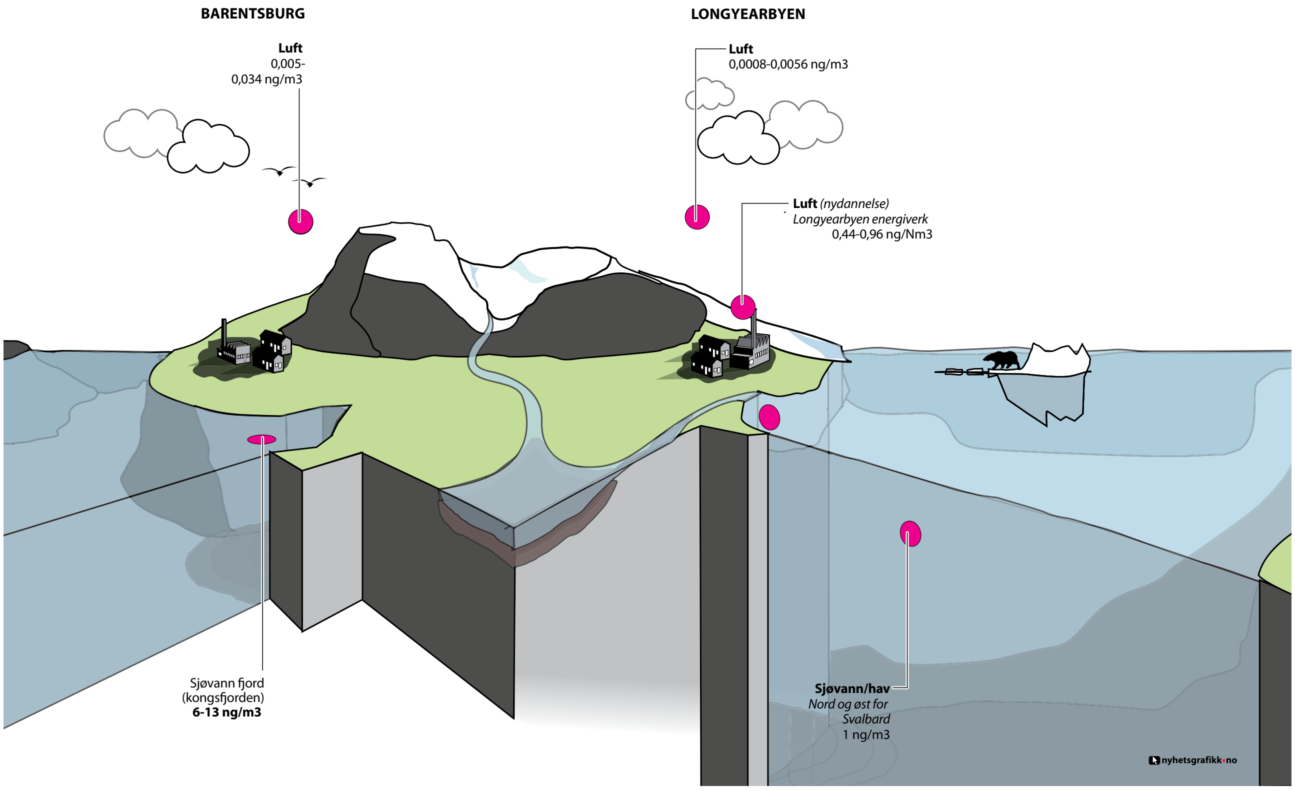
Glaucous Gulls collected from Barentsburg (2001) had a different combination of PCBs than that found in Glaucous Gulls from Bjørnøya. It is likely that Glaucous Gulls in Barentsburg have accumulated local PCB contamination.

PCB levels in eggs from Black-legged Kittiwakes indicate no local impact: Analyses of PCB levels in eggs from Barentsburg, Pyramiden and Ny-Ålesund show that Black-legged Kittiwakes are not affected by local sources. Since Black-legged Kittiwakes obtain their food from the sea it is unlikely that they would be affected by local PCB sources.

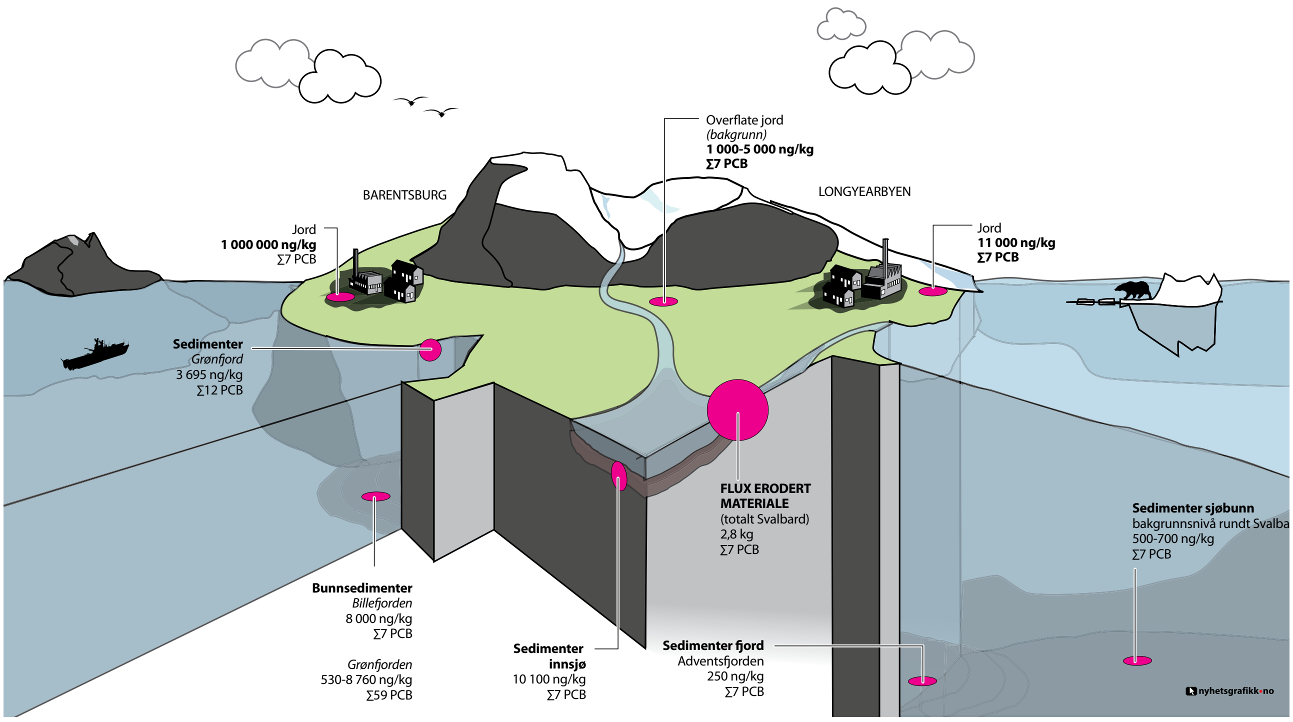
PCB levels in eggs from a number of seabird species show a decrease: A decrease in PCB levels has been measured from the middle of the 1990s to the present day in the eggs of various seabird species. PCB levels in Glaucous Gulls from Bjørnøya have stabilised in the last 5 years.

PCB levels in Northern Fulmars have increased: Analyses of samples from the period 1975 to 1993 show that concentrations in Northern Fulmars have increased. ∑32PCB for Northern Fulmars from Bjørnøya varied between 4873-9164 µg/kg ww. PCB congeners # 153, 118 and 180 dominate. These account for 60% of ∑PCB.

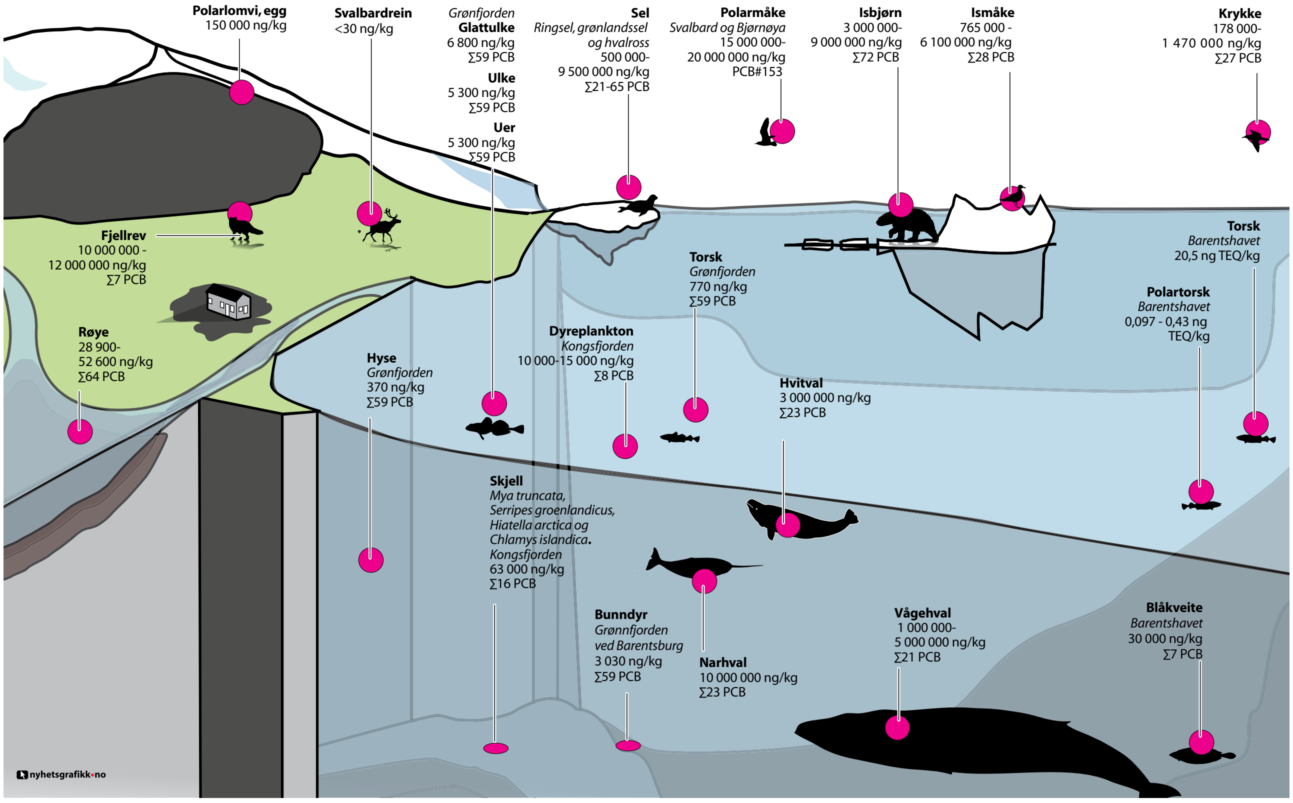
SVALBARD: **PCB-forurensing til luft og vann**



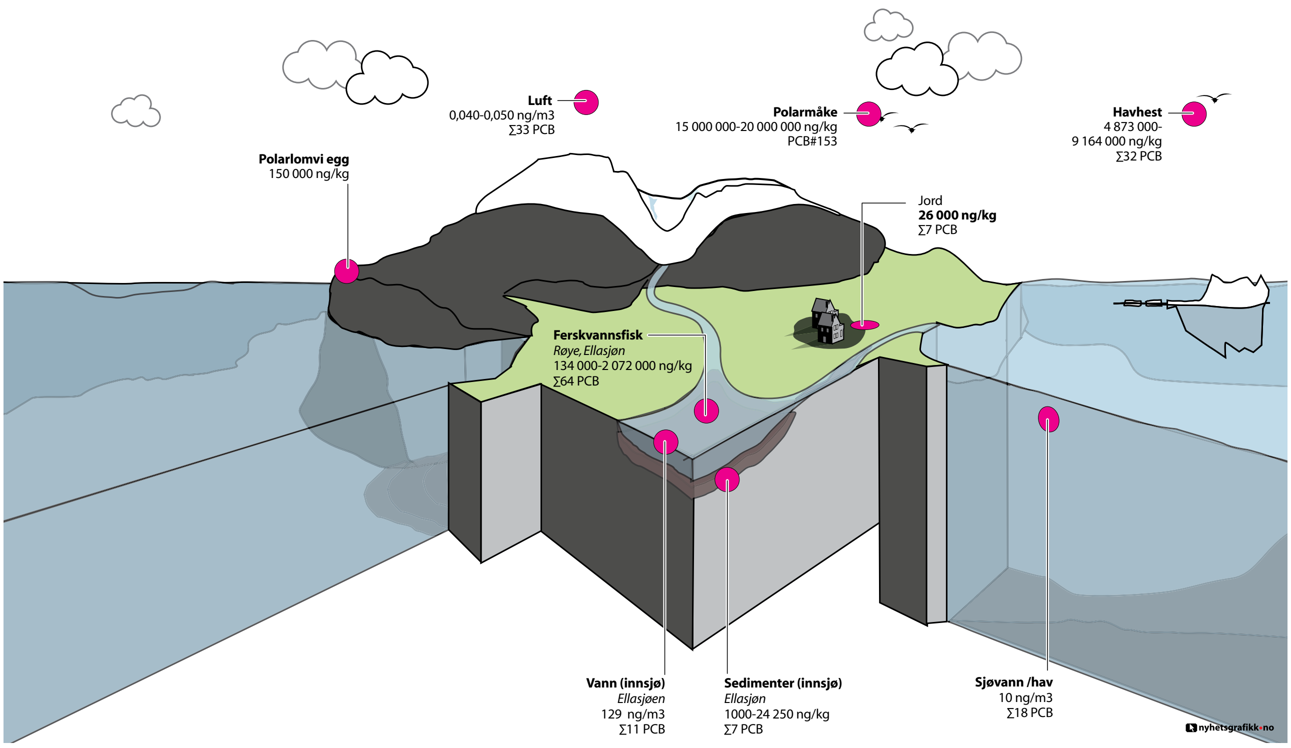
SVALBARD: **PCB-forurensing i jord og sedimenter**



SVALBARD: **PCB i dyr, fisk og fauna**



BJØRNØYA: **PCB-nivåer**



1.2.2 OVERVIEW OF KNOWN PCB LEVELS IN VARIOUS MEDIA ON SVALBARD.

The levels of PCBs reported in chapter 1.2.1 are presented in table form below:

MEDIA	WHERE	REPORTED LEVEL	CONVERTED LEVEL (ng)	∑xxPCB	SOURCE/COMMENTS
AIR					
Air (background)	Zeppelin	15-20 pg/m³	**0.015-0.02 ng/m³**	∑31PCB	Kallenborn et al. 2007 Measurement period 2000-2006
Air (background)	Bjørnøya	40-50 pg/m³	**0.040-0.050 ng/m³**	∑33PCB	Kallenborn et al. 2007 Measurement period 2000-2003
Air (settlement)	Barentsburg	5-34 pg/m³	**0.005-0.034 ng/m³**	∑21PCB	Johansson- Karlsson, E. et al. 2010 Measured 2009
Air (settlement)	Longyearbyen	0.8-5.6 pg/m³	**0.0008-0.0056 ng/m³**	∑21PCB	Johansson- Karlsson, E. et al. 2010 Measured 2009
Air (regeneration)	Longyearbyen Power Station	0.44-0.96 ng/Nm³	**0.44-0.96 ng/Nm³**	∑7PCB	DnV, measured 2009
SOIL					
Surface soil (background)		1 – 5 µg/kg	**1000 – 5000 ng/kg**	∑7PCB	NGU (see NGU reports referred to in chap. 5)
Surface soil	Barentsburg	1 mg/kg	**1,000,000 ng/kg**	∑7PCB	NGU, arithmetic mean (see NGU reports referred to in chap. 5)
Surface soil	Longyearbyen	0.011 mg/kg	**11,000 ng/kg**	∑7PCB	NGU, arithmetic mean (see NGU reports referred to in chap. 5)
Surface soil	Bjørnøya	0.026 mg/kg	**26,000 ng/kg**	∑7PCB	NGU, arithmetic mean (see NGU reports referred to in chap. 5)
Flux of eroded materials to seabed	Svalbard		**2.8 kg/year**	∑7PCB	NGU (see NGU reports referred to in chap. 5)
WATER					
Water (freshwater)	Ellasjøen, Bjørnøya	129 pg/l	**129 ng/m³**	∑11PCB	Evenset et al. 2007 Ellasjøen is supplied with PCBs via guano from seabirds.
Water (freshwater)	Øyangen, Bjørnøya	23 pg/l	**23 ng/m³**	∑11PCB	Evenset et al. 2007
Seawater (sea)	Kongsfjorden	6-13 pg/l	**6-13 ng/m³**	∑8PCB	Hallanger et al. 2011 Samples taken 2007
Seawater (sea)	North and east of Svalbard	Magnitude 1000 fg/l	**1 ng/m³**	∑12PCB	Carrizo et al. 2011 Samples taken 2001
Seawater (sea)	Bjørnøya	10 pg/l	**10 ng/m³**	∑18PCB	Evenset et al. 2002
ICE AND SNOW					
Ice (glacier)	Lomonosov	748 pg/l	**0.748 ng/m³**	∑100PCB	Norwegian Polar Institute (Hermanson et al. 2005)
Ice (sea ice)		30 pg/l	**0.03 ng/m³**		Gustafson et al. 2005
Snow (surface)	Ny-Ålesund	2 pg/l	**2 ng/m³**	∑31PCB	Kallenborn et al. 2010
Snow core (depth of 40-80 cm)	Ny-Ålesund	2-88 pg/l	**2-88 ng/m³**	∑31PCB	Kallenborn et al. 2010

SEDIMENTS					
Sediments (back-ground level in seabed)	Around Svalbard	0.5-0.7 µg/kg	**500-700 ng/kg**	∑7PCB	Green et al. 2010
Sediments (lake)	Ellasjøen, Bjørnøya	1-24.25 µg/kg	**1000-24,250 ng/kg**	∑7PCB	Evenset et al. 2004, 2005, 2006, 2007 a and b PCBs supplied via, among other things, guano
Sediments (lake)	Svalbard (n=5)	10.1 ng/g dw	**10,100 ng/kg**	∑7PCB	Christensen et al. 2008 Average
Sediments (fjord)	Grønfjorden, Barentsburg	0.53-8.76 µg/kg dw	**530-8,760 ng/kg**	∑59PCB	Evenset et al. 2009
Sediments (Russian settlements)	Barentsburg, Pyramiden (n=12)	3695 ng/kg dw	**3695 ng/kg**	∑12PCB	NGU/NVE (unpubl. data)
Sediments (fjord)	Billefjorden	8 µg/kg dw	**8,000 ng/kg**	∑7PCB	Evenset et al. 2009 Average
Sediments (fjord)	Adventsfjorden	0.25 µg/kg dw	**250 ng/kg**	∑7PCB	Evenset et al. 2009 Average
MAMMALS					
Svalbard reindeer *(Rangifer tarandus zplatyrhynchus)*		Lower than the detection limit <0.03 ng/g	**<30 ng/kg**		
Seals	Ringed seals, harp seals and walruses	0.5-9.5 mg/kg	**500,000-9,500,000 ng/kg**	∑21-65PCB	Kleivane et al. 2000; Wolkers et al. 2006b; Wolkers et al. 2008 Average. Highest levels measured in harp seals, followed by walruses and ringed seals
White whale		3 mg/kg lw	**3,000,000 ng/kg**	∑23PCB	Blubber samples (Letcher et al. 2010; Wolkers et al. 2006a)
Narwhal		10 mg/kg lw	**10,000,000 ng/kg**	∑23PCB	Wolkers et al. 2006a blubber samples
Minke whale		1-5 mg/kg lw	**1,000,000-5,000,000 ng/kg**	∑21PCB	Kleivane and Skaare 1998
Polar Bear *(Ursus maritimus)*		3-9 mg/kg lw	**3,000,000-9,000,000 ng/kg**	∑72PCB	McKinney et al. 2011
Arctic fox *(Vulpes lagopus)*		10-12 mg/kg lw	**10,000,000-12,000,000 ng/kg**	∑7PCB	Norheim, 1978; Wang-Andersen et al. 1993; Severinsen and Skaare, 1997; AMAP, 2004; Fuglei et al. 2007
AQUATIC INVERTE-BRATES (marine invertebrates)					
Zooplankton	Kongsfjorden	10-15 ng/g lw	**10,000-15,000 ng/kg**	∑8PCB	Hallanger et al. 2011
SALTWATER FISH					
Polar cod *(Boreogadus saida)*	Barents Sea	0.097-0.43 ng TEQ/kg ww	**0.097-0.43 ng TEQ/kg**		Institute of Marine Research 2010b Pooled samples of whole fish, caught in 2006-2009
Atlantic cod *(Gadus morhua)*	Barents Sea	20.5 ng TEQ/kg ww	**20.5 ng TEQ/kg**		Institute of Marine Research 2010b Average Liver samples from fish caught in 2009
Atlantic cod *(Gadus morhua)*	Grønnfjorden near Barentsburg	0,77 µg/kg vv	**770 ng/kg**	∑59PCB	Evenset et al. 2009 Pooled sample

Greenland halibut *(Reinhardtius hippoglossoides)*	Barents Sea	30 µg/kg vv	**30,000 ng/kg**	∑7PCB	NIFES 2010a
Arctic staghorn sculpin	Grønnfjorden near Barentsburg	6.8 µg/kg vv	**6,800 ng/kg**	∑59PCB	Evenset et al. 2009 Pooled sample
Scorpion fish	Grønnfjorden near Barentsburg	5.3 µg/kg vv	**5,300 ng/kg**	∑59PCB	Evenset et al. 2009 Pooled sample
Redfish	Grønnfjorden near Barentsburg	Similar values to scorpion fish	**Similar values to scorpion fish**	∑59PCB	Evenset et al. 2009 Pooled sample
Haddock	Grønnfjorden near Barentsburg	0.37 µg/kg vv	**370 ng/kg**	∑59PCB	Evenset et al. 2009 Pooled sample
FRESHWATER FISH					
Char *(Salvelinus alpinus)*	Arresjøen, Richardvatn, Annavatn, Spitsbergen	52.6 ng/g ww 32.9 ng/g ww 28.9 ng/g ww	**52,600 ng/kg 32,900 ng/kg 28,900 ng/kg**	∑64PCB	Christensen et al. 2011
Char *(Salvelinus alpinus)*	Ellasjøen, Bjørnøya	134-2072 ng/g ww	**134,000-2,072,000 ng/kg**	∑64PCB	Christensen et al. 2011
BIVALVES AND BENTHIC FAUNA					
Bivalves *(Mya truncata, Ser-ripes groenlandicus, Hiatella arctica and Chlamys islandica)*	Kongsfjorden	63 ng/g lw	**63,000 ng/kg**	∑16PCB	Vieweg 2010 Average four species
Benthic fauna	Grønnfjorden near Barentsburg	3,03 µg/kg vv	**3,030 ng/kg**	∑59PCB	Evenset et al. 2009
PLANTS					
Moss	Land outside Barentsburg	589.7 µg/kg	**589,700 ng/kg**	∑15PCB	Typhoon 2004 Average
Vascular plants	Land outside Barentsburg	97.5 µg/kg	**97,500 ng/kg**	∑15PCB	Typhoon 2010 Average
BIRDS					
Brünnich's Guillemots *(Uria lomvia)*	Kongsfjorden and Bjørnøya	Magnitude of 150 ng/g ww	**150,000 ng/kg**		Fisken og havet, special edition 1b-2010 Eggs taken 2007
Glaucous Gull *(Larus hyperboreus)*	Svalbard and Bjørnøya	15,000-20,000 ng/g ww	**15,000,000-20,000,000 ng/kg**	PCB#153	MOSJ
Northern Fulmar *(Fulmarus glacialis)*	Bjørnøya	4,873-9,164 µg/kg ww	**4,873,000-9,164,000 ng/kg**	∑32PCB	Knudsen et al. 2007 Gabrielsen et al. 2005
Black-legged Kit-tiwake		178-1470 ng/g ww	**178,000-1,470,000 ng/kg**	∑27PCB	Miljeteig and Gabrielsen 2009
Ivory Gull		7770-62700 ng/g lw	**756,000-6,100,000 ng/kg**	∑28PCB	Miljeteig et al. 2009

1.2.3 AND AS IF THAT IS NOT ENOUGH...

Climate change could result in more PCBs in the Arctic. Despite the intentions of, and work on, the Stockholm Convention that these compounds will be phased out and properly destroyed, climate change could result in more PCBs in the Arctic. Arctic regions appear to be affected faster and with greater impact by climate change compared with other parts of the globe.

The average temperature of seawater is rising and there is less sea ice. This has been linked to man-made climate change and warming, and this trend is expected to continue. An increase in water temperature could result in PCBs stored in ice or unbound in water being remobilised and gradually being released into the atmosphere again. The Zeppelin station has registered an increase in levels of atmospheric PCBs compared with the measurements made in 2004. This effect is reinforced by the fact that the extent of the ice cover, which works as a natural barrier against evaporation into the atmosphere in the sea area around Svalbard, has shrunk noticeably. This trend is also confirmed by an academic study that shows that evaporation from the surface of the sea in combination with reduced sea ice in the central Arctic will contribute to the greater evaporation and remobilisation of PCBs in the Arctic and Svalbard in the future (Ma et al. 2011)

Climate change that results in more run-off and transport of sediment and surface soil could also result in a greater supply of PCB contamination from glaciers and polluted ground from, for example, earlier settlements to the local marine environment. along the coast. In addition to this, climate change that affects temperature-dependent processes like absorption and accumulation could influence the effects PCBs have on ecosystems. The result could be direct or indirect changes in sources, transport processes and pathways, and degradation patterns.

Climate change and changes in sea temperatures will change the composition of animal species. Arctic waters are home to a unique composition of species compared with Atlantic waters. Atlantic water from the south has higher levels of environmental pollutants compared with Arctic water. A change of diet due to changes in sea temperatures could affect nutrient take up and the composition of environmental pollutants in birds and marine mammals in the Svalbard region.

Given what we currently know, it is not possible to predict the effect of all the changes. Therefore, it is important to commence research and environmental monitoring to acquire knowledge about how changed pollutant loads, temperature changes and other stress factors in aggregate are affecting individuals, species and ecosystems. Such new knowledge is crucial if we are to predict the effect of the changes and implement measures to counter the most pernicious influences where applicable.

PCBs are just one of many hazardous pollutants: PCB contamination has resulted in these chemicals now being found in people, animals and organisms around the world. However, neither we nor the environment are exposed to one environmental pollutant at a time. Instead we are exposed to a mixture of them and also their decomposition products, which can have just as pernicious effects. We know very little about the consequences exposure to a mixture of lower concentrations of multiple pollutants can have with respect to adverse effects on the environment and people. Nonetheless, it is known that exposure to a mixture of pollutants can have serious additional effects and that when a combination of multiple environmental pollutants is present, the levels required to trigger the same effects or health disorders in individuals are lower. Experiments NIFES has conducted show, among other things, that non-dioxin-like PCBs and dioxins are more toxic together than alone.

PCBs are not just hazardous pollutants out of the pages of history, they are also formed today: Under certain circumstances PCBs can be formed in incineration processes. The formation of new PCBs has been documented in the coal power station in Longyearbyen on Svalbard. It has also be demonstrated that these compounds can be formed in the production of pigments that are used, for example, in paint on the market today.

1.3 MANAGEMENT STATUS (MEASURES)

1.3.1 WHAT HAS BEEN DONE?

Local sources of PCBs have been surveyed and removed: Supervisory actions have taken place in all the settlements to follow up the PCB regulations (see chapter 7.2 about the regulations). In addition to heavy high voltage electrical equipment, a total of 4,762 capacitors from light fittings and smaller electrical/electronic equipment has been collected. This waste has been sent for destruction. PCB-containing sealed panes can be found in some buildings in Longyearbyen and the panes have been marked with a PCB label. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen.

PCB data from buildings in Russian settlements and Longyearbyen are now available. The buildings are registered in the Governor's digital map system.

Trust Arktikugol is going to produce a waste plan for Barentsburg. The plan will specify, among other things, what should be done with PCB-containing building materials. Some of the façades are now protected by plates that reduce degassing from PCB-containing paint.

Polluted ground and landfill sites have been surveyed, fenced off and registered in the Governor's digital map system, see chapter 3.2.2.2.

1.3.2 WHAT SHOULD BE DONE?

The PCB contamination is significant. Studies of PCBs in organisms have shown declining trends but the content of selected PCB congeners in the atmosphere, measured at the Zeppelin station, has increased. The current monitoring of PCBs in Svalbard's environment is moderate in scope and provides only a minimum overview.

PCBs are an 'old' environmental pollutant and generally quite a lot is known about PCBs, although this knowledge is fragmented. There is a particular need for further multidisciplinary research efforts and a focus on how PCBs affect things such as public health, including via the decomposition products of PCBs.

The major challenge for Svalbard is long range transported pollutants. Measures in other countries to counter sources of pollution will over time reduce the supply of these compounds into the Svalbard region, Arctic and other vulnerable environments. In our experience it is particularly important to focus on measures aimed at countering the primary sources, but work on limiting secondary sources is also important. Norway's national action plan for reducing emissions of PCBs should play an active and vital role in achieving a binding international partnership working to ensure the prompt, preventive phasing out and destruction of those PCBs that can still be found in places such as buildings, structures and electrical equipment.

Monitoring environmental pollutants on Svalbard and in the Arctic is strategically important and existing programmes should be continued, developed and strengthened. Environmental monitoring data should be secured in order to assess and possibly implement measures.

Systems should be established for Arctic status classes, standard values and threshold values for soil, sediments, etc. Such classification systems would make it easier to assess the degree of contamination and make decisions based on scientific data.

The need for measures contributed by the research communities that prepared this report. The researchers in the project group believe the initiative should be taken to put together a comprehensive, coordinated programme of monitoring environmental pollutants, research and measures that integrates:

- measuring and calculating emissions, supply and dispersal, including knowledge about the compounds' origins and how they are transported and converted (transferred/'diluted' into other media or degrade)

- monitoring of their status in the environment and people with clarification of the need for measures (including climate effects)
- knowledge about PCBs' chemical properties and decomposition products (metabolites)
- comparing measured concentrations in the environment with knowledge about effect levels to obtain information about the potential risk of harm
- monitoring the effect of the measures

PCBs have complex effects and cause-effect relationships . Even though as a group of compounds PCBs have been researched for more than 50 years, a lot of scientific work is required to assess long-term developments. There is a need for coordinated multidisciplinary:

- research and monitoring efforts to provide a thorough expert assessment. This includes modelling, monitoring, climate effects, human toxicology and ecotoxicology. A comprehensive programme such as this would benefit by being administered by the University Centre in Svalbard (UNIS) or the Norwegian Polar Institute (NP) and could, for example, be based on following up the polluted areas in the Russian settlements.
- a stronger effort to achieve the intentions of the Stockholm Convention concerning the proper global phasing out of PCBs

The project group has identified the following gaps in our knowledge and need for initiatives:

Reduction of PCBs in use internationally

- Take the initiative concerning a partnership on reducing emissions of PCBs with countries that contribute to PCB contamination on Svalbard via air and oceanic currents
- It is recommended that the results from the project and report "PCBs on Svalbard" be actively used to provide information about the need to reduce the quantities of PCBs in the primary sources and the effects of hazardous pollutants like PCBs. Examples of relevant forums include AMAP/ACAP, the Stockholm Convention, the LRT Convention, etc., as well as bilateral collaborations with countries that contribute long range transported pollutants to Svalbard and the rest of the Arctic
- Take the initiative to arrange an international conference to contribute to the proper phasing out and destruction of equipment and materials that contain PCBs
- Take the initiative to continue the reporting and PCB work under the auspices of, for example, UNIS and NP
- REACH (the EU's chemicals regulation) has recently come into force on Svalbard, and the pollution authorities should have a goal of ensuring that chemicals listed on the Candidate List in REACH or that are on the Norwegian Priority List are not used on Svalbard

Monitoring of environmental status and effect of measures

- Continue long-term studies to clarify the relationship between climate change and the level of environmental pollutants
- Develop classification systems and toxicity tests for Arctic conditions (e.g. soil, water and sediment) and organisms
- Monitor developments in marine sediments off settlements with samples being taken every 5 years (2010, 2015…), including new sampling points
- The contact with Typhoon should be maintained, and Norwegian and Russian monitoring coordinated to achieve good utilisation of limited resources on both sides of the international border
- Annual monitoring of PCBs in the air in settlements to see how PCB concentrations change after PCB-containing waste is removed. Could perhaps be integrated as part of UNIS' course "Techniques for the detection of organo-chemical pollutants in the Arctic environment".

Research, knowledge about PCBs's chemical properties and decomposition products (metabolites)

- Research into the synergistic and any antagonistic effects of various environmental pollutants should be carried out
- Increase knowledge about how PCBs affect organisms at lower trophic levels.
- Surveys of sediment toxicity and bioaccessibility of PCBs in sediments and potential for dispersal further along the food chains through analyses of benthic fauna collected off the Norwegian and Russian settlements (comparison of levels and congener profiles)
- Surveys of PCBs in vegetation
- New environmental pollutant surveys should be conducted for Arctic foxes on Svalbard since it is now 10-15 years since the last surveys were conducted
- Monitoring/research on polar bears should continue. The link with effect parameters is important and any population effects should be documented.
- Some species of whale have high levels of environmental pollutants. New surveys should be conducted for white whales and minke whales from the Barents Sea area.
- Monitoring of environmental toxins in eggs from various seabird species should continue with regular collections every 5 years.
- Glaucous Gull monitoring/research should continue. The link with effect parameters is important and any population effects should be documented.
- PCB analyses of MAREANO samples from the Svalbard region
- Measurements of PCBs in sea ice and freshwater
- Adults on Svalbard have largely lived most of their lives in other places in Norway and the world, although there are people who were born, grew up and have spent most of their lives here. It would be interesting to look at the PCB levels of those who have spent the most time on Svalbard and compare different groups (e.g. from Longyearbyen and Barentsburg) or compare the settlements to see if there are major differences.

Following up local sources

- Supervision and verification in relation to remaining local sources (including PCB-containing sealed panes and façade materials)
- Reduce emission of newly formed PCBs
- Updating of ground pollution database with all surveys that contain documentation of polluted ground

1.3.3 NATIONAL ENVIRONMENTAL TARGETS AND PCBS ON SVALBARD

The Governor's compilation of the follow-up status of national environmental goals[9] for PCBs and PCB-containing waste on Svalbard is presented in the table below:

NATIONAL ENVIRONMENTAL GOALS	STATUS OF PCBS ON SVALBARD
Reduce emissions of prioritised environmental pollutants (3.3.1) *Emissions of prioritised environmental pollutants must be stopped or reduce significantly by 2010.*	We assume that emissions of PCB oil do not occur locally on Svalbard since PCB-containing equipment has been surveyed, removed and delivered for destruction. Old oil stores have also been removed. In the case of PCBs as chemicals and as covered by this goal, the situation on Svalbard is that the primary local sources such as larger equipment and 4,700 capacitors containing PCB oil have been removed. Measures have been implemented for any remaining PCB-containing equipment and materials that ought to ensure that the waste is properly managed (marking of PCB panes and waste plan in Barentsburg). Emissions from primary local sources have been prevented and this greatly reduces the risk of emissions. ☺ The goal can be regarded as fulfilled for primary local sources. ☹ The goal has not been fulfilled for buildings with PCB façades and secondary sources such as contaminated soil in the settlements. ☹ The goal has not been fulfilled for primary or secondary sources in other parts of the Arctic. For example, serious PCB contamination has been demonstrated on Franz Josef Land. This will continue to supply PCBs to the Barents Sea and Svalbard. This is not a local Svalbard source, but it is close by and requires immediate measures to prevent the leakage of more PCB pollutants. 😐 The goal can be regarded as partially fulfilled with respect to communicating the lessons learned from the measures implemented to counter primary sources and surveys and measures for secondary sources through active communication at international conferences and multilingual websites and reports. The proposed future measures could contribute to even better goal attainment.
Eliminate releases by 2020 (3.3.2) *Releases and use of substances that pose a serious threat to health or the environment will be continuously reduced with a view to eliminating them by 2020.*	The generation goal is very ambitious. In the case of Svalbard it would be natural to look at the goal in light of primary and secondary PCB sources. As far as: 😐 primary sources are concerned, fulfilling the goal is regarded as feasible assuming that the remaining PCB-containing equipment and materials are managed in line with the prepared requirements. ☹ secondary sources are concerned, fulfilling the goal is regarded as difficult for the same reasons provided in the comments on polluted ground and sediments below.
Least possible risk of harm due to chemicals (3.3.3) *The risk of releases and the use of chemicals causing harm to public health and the environment must be minimised.*	Status and reasons same as above. The absence of PCB-containing equipment will also help to prevent harm to public health and the environment in the future. ☺ The goal can be regarded as fulfilled.
Stop pollution from contaminated soil (3.3.4) *The dispersal of substances from contaminated soil will be stopped or substantially reduced. Steps to reduce the dispersal of other substances that may cause injury to health or environmental damage will be taken on the basis of case-by-case risk assessments.*	Landfill sites and other areas polluted by primary local sources have been surveyed. Many surveys have been conducted that show that PCBs are leaking from polluted ground, especially in the Russian settlements. If mitigating measures are not implemented the PCB contamination will disperse into the marine environment and the seabed in the fjords. Over time, the natural supply of eroded materials by spring floods and melting snow will cover this contamination. As long as the sediments are not disturbed by bioturbation, currents or human activity, the contamination will remain in the sediments. To avoid contaminated surface soil in Russian settlements dispersing, measures that reduce water-based particle transport can be implemented, e.g. maintaining the ditch system and courses of streams in a settlement. In the event of construction or building activities, contaminated materials ought to be secured in relation to snow melting and flood water. ☹ The goal has not been fulfilled.
Stop pollution from contaminated seabed sediments (3.3.5) *Contamination of seabed sediments with substances that are hazardous to health or the environment will not give rise to serious pollution problems.*	Many surveys have been conducted that show that PCBs are taken up by organisms and introduced into the food chains via water and sediments. Bioaccumulation and biomagnification mean that the substances then move up the food chains and result in harm to the top predators. Svalbard's seabed is constantly covered over by materials from land via large rivers and glacial systems. This dilutes the contamination and covers it over time. It is recommended that no measures be taken in relation to contaminated seabed areas. They should be left to lie undisturbed. ☹ The goal has not been fulfilled since PCBs in contaminated seabed sediments are mobilised into the ecosystem by being taken up by benthic fauna.

WASTE

NATIONAL ENVIRONMENTAL GOALS	STATUS OF PCBS ON SVALBARD
Dispose of hazardous waste safely (3.4.3) *Hazardous waste will be dealt with in an appropriate way, so that it is either recovered or sufficient treatment capacity is provided within Norway.*	All PCB-containing materials that are collected are delivered to approved reception facilities and sent to the mainland for destruction in Finland (incineration) at a special plant. Remaining PCB panes are marked for proper management when they are replaced. This should ensure less PCB waste goes astray in the future. The goal can be regarded as fulfilled. A special waste plan for Barentsburg will help ensure that PCB-containing façades, buildings and polluted soil are properly managed in the future. The plan remains to be put into action. The goal can be regarded as partially fulfilled.
Reduce hazardous waste generation (3.4.4) *The generation of each type of hazardous waste will be reduced by 2020 compared with the 2005 level.*	The surveying, phasing out of equipment and removal of PCB-containing mining waste and equipment will result in less PCB-containing waste to deal with in the future. Knowledge about PCBs in paint, among other things, has made us aware of a new source of PCBs that is difficult to deal with. Renovating and demolishing buildings could generate a lot of PCB-containing building waste in the future, especially in Barentsburg. The goal can be regarded as partially fulfilled.

THE POLAR REGIONS

NATIONAL ENVIRONMENTAL GOALS	STATUS OF PCBS ON SVALBARD
Circumpolar cooperation: The cooperation in the Nordic region, in neighbouring regions and in the Arctic is intended to help improve the environmental situation, protect natural and cultural heritage values in these areas and reduce and prevent cross-border pollution that can affect the environment, public health and commercial activities in Norway.	The goal has not been fulfilled for primary or secondary sources in the Arctic. Work should continue on achieving a mutual boost based on existing knowledge about primary and secondary sources and the harmonisation of regulations that prevent washing out and contribute to removal measures. The goal can be regarded as partially fulfilled through contact with experts and the authorities in a number of the Nordic countries, sharing experiences directly and at conferences, and contributing to surveys in, for example, Greenland.
Cooperation with Russia *The cooperation is intended to ensure the authorities and business in Russia are better able to gain proper control over their environmental problems and integrate environmental protection management in Russia into international and regional partnerships.*	The goal can be regarded as fulfilled through a good, close partnership with the Russian mining company Trust Arktikugol on surveying, removal and further measures in the Russian settlements. The available knowledge about PCB contamination is actively shared between the Russian and Norwegian actors who perform environmental monitoring on Svalbard. There has also been cooperation between the Norwegian and Russian environmental monitoring actors on surveys of the seabed off the settlements. The objective has not been met for thelarge oil stores and PCB contamination on Franz Josef Land. These could increasingly supply the Barents Sea and Svalbard with PCBs in the future. This is not a local Svalbard source, but it is close by and requires immediate measures to prevent PCB contamination.
Svalbard should stand as one of the best managed wilderness areas in the world and the settlements should be run in an environmentally-friendly way to protect the environment and ensure prosperity. Norway must work to ensure that nearby Arctic sea areas are preserved as some of the world's most pristine and that resources are utilised within a framework that ensures biodiversity is sustained in the short-term and the long-term.	The removal of primary sources of PCBs and fencing off and following up the management of secondary sources enables us to provisionally say that the goals has partially been fulfilled with respect to PCBs and the Governor's area of responsibility. The goal has been partially fulfilled. The biggest challenge associated with PCBs is not the remaining local sources, it is the long range transported pollutants that arrive via air and oceanic currents and sea ice. The environmental management must strive to promote active, bilateral and international cooperation that can help to reduce PCB emissions. A good knowledge-base is a prerequisite for success in such processes. This reinforces the need for research and monitoring in relation to the effects of long range transported pollutants on the natural environment. The goal has not been fulfilled.

OFFICE OF THE AUDITOR GENERAL OF NORWAY STUDY OF THE MANAGEMENT OF SVALBARD

Office of the Auditor General of Norway study of the management of Svalbard, report 3:8 (2006-2007)	The Office of the Auditor General pointed out deficiencies in the environmental monitoring and associated basis for making decisions. ☺ The work on systematising PCB efforts on Svalbard is one example of a measure that was designed to follow up the Office of the Auditor General's observations. The environmental monitoring has been used to put measures in place and establish management routines.

FOOTNOTES CHAPTER 1

1 Convention on Long-range Transboundary Air Pollution for the ECE area.

2 Primary sources: Equipment and materials containing PCBs are potential primary sources if they are not managed properly.

3 Secondary sources: These are PCBs that have left the primary source and are present in soil, water, air, flora and fauna and have not been broken down.

4 Which monitors background concentrations in the Arctic.

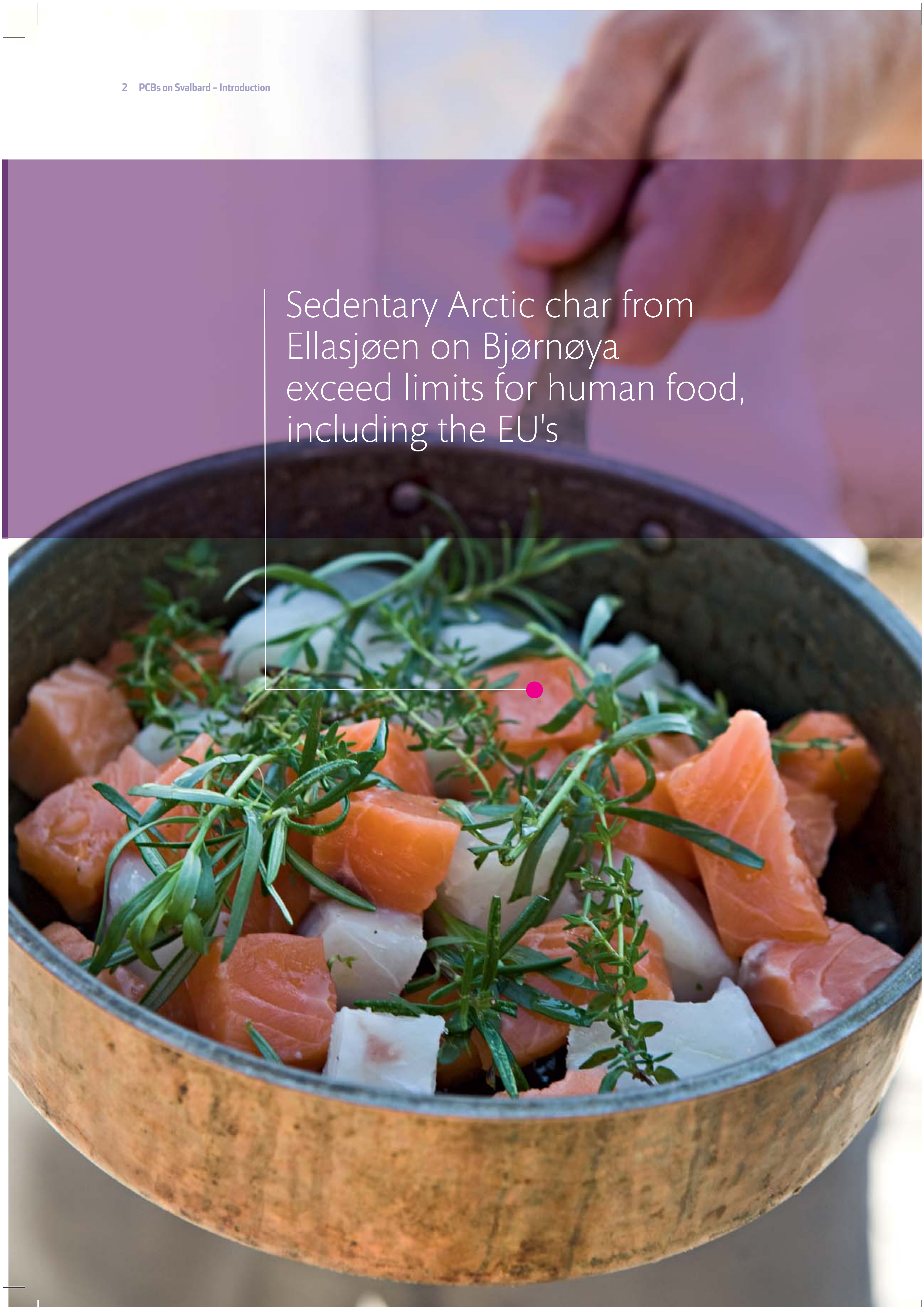
5 ∑31PCB means the total quantity of the 31 congeners/types of PCB analysed for. Correspondingly, ∑7PCB means the total quantity of seven forms of PCBs, also see chapter 2.7 of the report.

6 Dioxin-like PCBs are the congeners that have a flat conformation and therefore properties and effects like the environmental pollutants dioxins.

7 Dioxin-like PCBs are often reported using the unit TEQ (Toxic Equivalency Quotient). TEF (Toxicity Equivalency Factors) indicates how toxic a dioxin-like environmental pollutant is in relation to the dioxin compound 2,3,7,8-TCDD (which has been assigned a toxicity value of "1"). When mixtures of multiple dioxin-like environmental pollutants are assessed, the concentration of the various environmental pollutants is multiplied by a factor (TEF value). The total value, toxic equivalent, is used as a measure of the potential toxicity of the mixture.

8 POP = Persistent Organic Pollutant (resistant to environmental degradation).

9 The Ministry of the Environment's Proposition 1 S (2010–2011). Proposition to the Storting The goals have been systematised and communicated via State of the Environment: www.environment.no/Goals-and-indicators/.



Sedentary Arctic char from Ellasjøen on Bjørnøya exceed limits for human food, including the EU's

The Constitution - Article 110 b

Every person has a right to an environment that is conducive to health and to a natural environment whose productivity and diversity are maintained. Natural resources should be managed on the basis of comprehensive long-term considerations whereby this right will be safeguarded for future generations as well.

In order to safeguard their right in accordance with the foregoing paragraph, citizens are entitled to information on the state of the natural environment and on the effects of any encroachment on nature that is planned or carried out.

The authorities of the State shall issue specific provisions for the implementation of these principles.

(Appended by a constitutional amendment of 19 June 1992 no. 463)

Svalbard encompasses the islands between 74° and 81° north and 10° and 35° east, as well as the surrounding sea areas. The territory covers an area of more than 61,000 square kilometres, 60% of which is covered by glaciers.

2. PCBS ON SVALBARD – GENERAL CONDITIONS

"The levels of dioxin-like PCBs in Arctic char in Ellasjøen on Bjørnøya are so high they exceed the EU's limits for human consumption. Arctic char from a number of lakes on Svalbard also contain relatively high levels of PCBs."

Anita Evenset, Manager, Arctic R&D, Akvaplan-niva

Svalbard encompasses the islands between 74° and 81° north and 10° and 35° east, as well as the surrounding sea areas. The territory covers an area of more than 61,000 square kilometres, 60% of which is covered by glaciers. Svalbard has three Arctic bioclimatic zones, as well as the Polar Front and the marginal ice zone. Air temperatures on Svalbard are generally low and so are precipitation levels. Svalbard has permafrost and only a thin layer of soil.

PCBs and the challenges these hazardous substances present on Svalbard and in the Arctic are well-documented in a number of scientific reports, including Oehme et al. 1996, AMAP 2004a, AMAP 2009, Letcher et al. 2010 and Verreault et al. 2010.

Norway has high ambitions for the environmental management on Svalbard. This is also reflected in section 1 of the Svalbard Environmental Protection Act: *"The purpose of this Act is to preserve a virtually untouched environment in Svalbard with respect to continuous areas of wilderness, landscape, flora, fauna and cultural heritage. Within this framework, the Act allows for environmentally sound settlement, research and commercial activities."*

The goal is for Svalbard to be one of the best managed wilderness areas in the world. The framework has been laid by papers such as Report No. 22 to the Storting (2008-2009) "Svalbard", Report No. 12 to the Storting (2001–2002) "Protecting the riches of the seas", and for PCBs also by the "National action plan for reduced emissions of PCBs".

2.1 PURPOSE OF THE REPORT

The Governor and Climate and Pollution Agency carried out a project in the period 2008-2010 to compile, supplement and document knowledge about PCBs in the archipelago. The project has also identified and removed as many of the local sources of PCB contamination as possible, identified a further need for research and drawn up measure-oriented management routines. The project was funded by the Ministry of the Environment.

This report summarises and documents the project's results. A number of institutions and research communities participated in and contributed to systematising, compiling and updating the information. The project was carried out in the form of seminars, subprojects and field work.

The first edition of the project report[10] was published by the Governor in 2008. The purpose of this report is to point out the serious effects the compounds and their decomposition products have, and to identify gaps in our knowledge and any need for measures. It is also important to show how the results of environmental monitoring must be used as a basis for making decisions concerning management measures and plans[11]. The report also aims to facilitate the wide-ranging dissemination of what we know about PCBs on Svalbard.

Proposed measures:
- It is recommended that the results from the project and report "PCBs on Svalbard" be actively used to provide information about the need to reduce the quantities and effects of hazardous substances. Examples of relevant forums include AMAP/ACAP, the Stockholm Convention, the LRT Convention, etc., as well as bilateral collaborations with countries that contribute long range transported pollutants to Svalbard and the rest of the Arctic.
- Take the initiative to arrange an international conference to contribute to the proper phasing out and destruction of equipment and materials that contain PCBs.
- Take the initiative to continue the reporting and work under the auspices of, for example, UNIS and NP.

2.2 PCBS - THEIR PROPERTIES

PCBs (polychlorinated biphenyls) are a group of hazardous substances that have very serious effects on human health and nature. These substances are so-called POPs (Persistent Organic Pollutants). A PCB molecule can have 1-10 chlorine atoms located at different positions on the molecule's phenyl rings, see figure 2.2-1. Therefore, there are 209 possible different variants, so-called congeners of the PCB molecule, see figure 2.2-2 that shows the congener PCB#153. The individual congeners have different physical and chemical properties (see AMAP 1998 and others). A small group of PCBs have a flat structure (non-ortho PCBs) or a partially flat structure (mono-ortho PCBs) and are referred to as dioxin-like PCBs (dl-PCB) because they have similar effects to dioxins.

The biological effects of the various congeners differ in strength and the effects they can have (Li et al. 2003). For example, these chemicals can affect:
- reproduction
- hormone systems
- the immune system
- the nervous system
- development in the early stages of life/foetuses
- the development of cancers

In general, resistance to degradation decreases as the degree of chlorination increases (number of chlorine atoms). The resistance to degradation also depends on the positions of the chlorine atoms on the phenyl rings.

PCBs with a chlorine content of between 19–43% have a crystalline form, from 43–56% they are oily, from 57–69% they are semi-solid, and between 67–70% they are crystalline again.

Properties such as low water solubility and vapour pressure strongly influence how the congeners disperse and are distributed in the natural environment (air, water, sediments and soil). In particular, those with a low chlorine content can easily be transported in a gaseous phase via the air (volatile PCB congeners) and they can bind to particles/aerosols (so-called semi-volatile PCBs) in air. Even though PCBs generally have low water solubility, many Arctic food chains are affected by exposure to unbound PCBs or those available via particulate bound PCBs in seawater. Emissions of PCBs have resulted in these chemicals now being found in people, animals and organisms around the world.

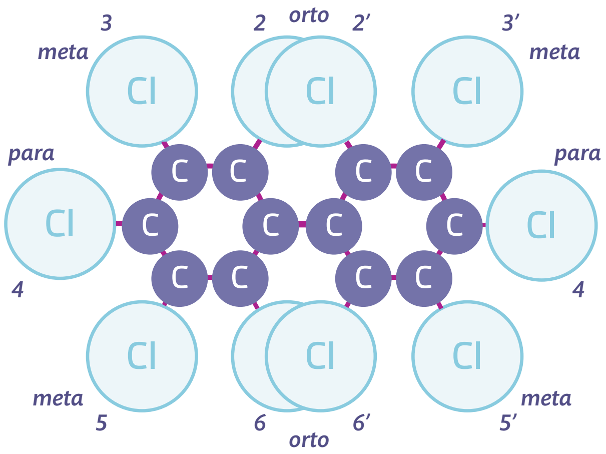


FIGURE 2.2-1 The structure of a PCB molecule with phenyl rings encircled by chlorine atoms (Cl).

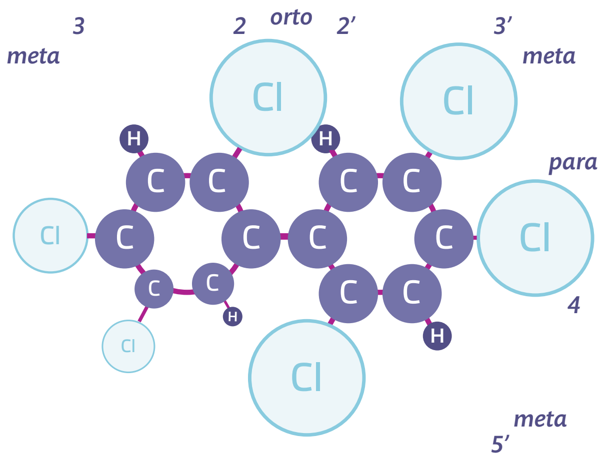


FIGURE 2.2-2 The figure shows the structure of the PCB#153 congener.

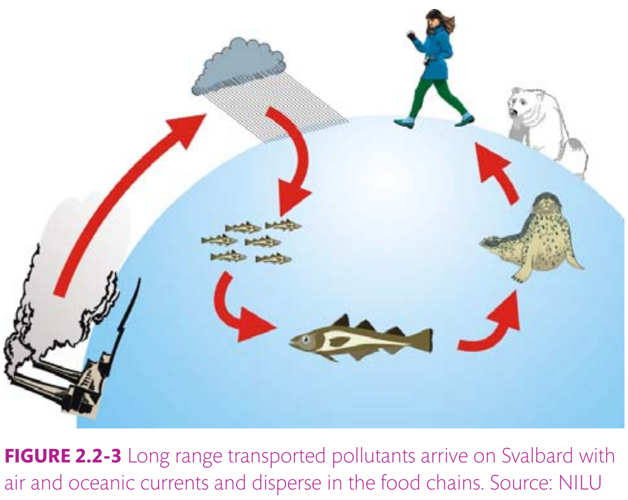


FIGURE 2.2-3 Long range transported pollutants arrive on Svalbard with air and oceanic currents and disperse in the food chains. Source: NILU

Climatic conditions and Svalbard's geographical location means that air and oceanic currents carry PCBs from industrialised and other areas in Europe, the USA, Russia and Asia into the Arctic ecosystems and food chains (long range transported pollutants), see figures 2.2-3 and 2.2-4.

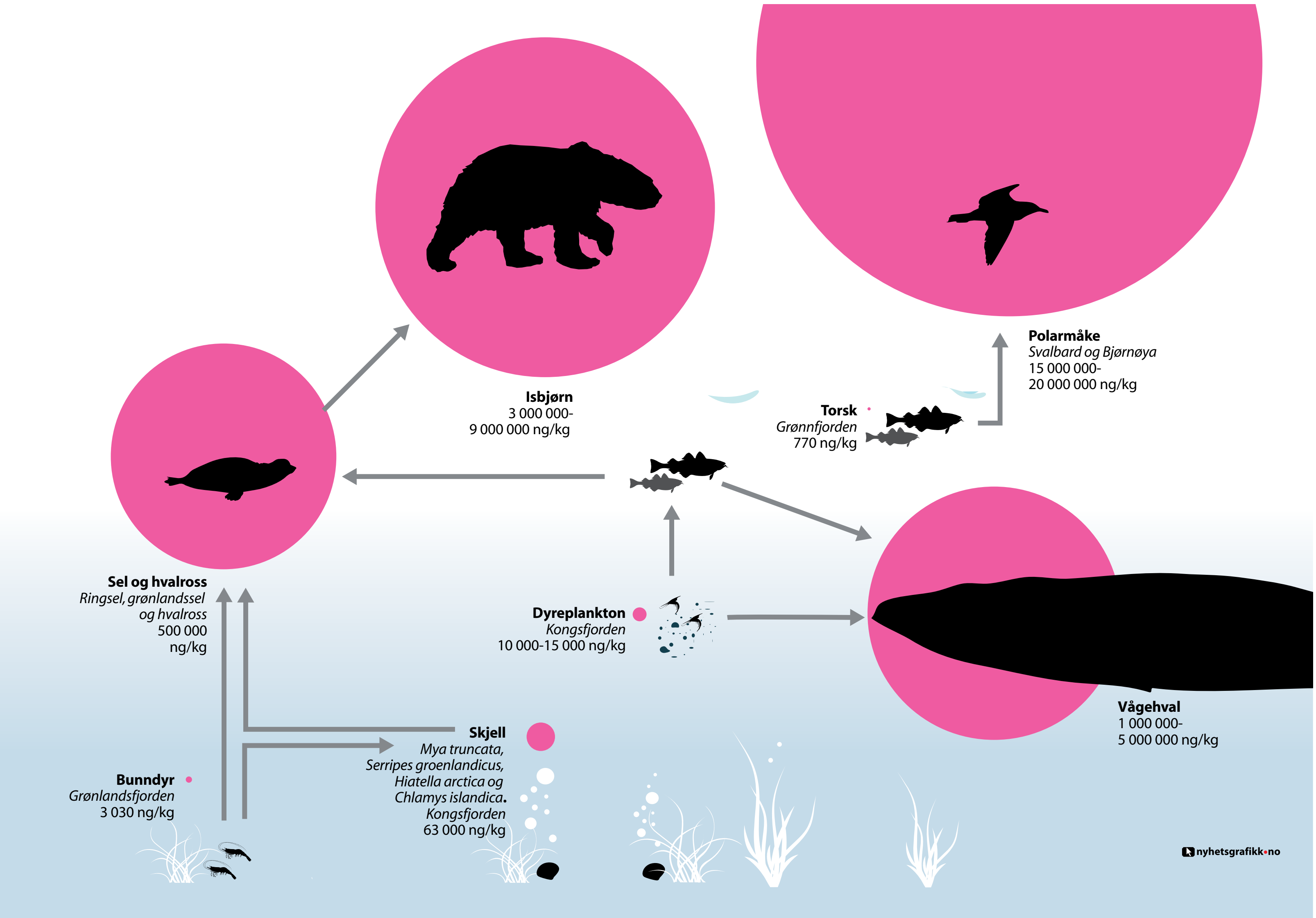
Environmental monitoring in the form of analyses of ice cores from Lomonosovfonna shows a clear reduction in the supply of PCBs to Svalbard via air currents in the period 1970–2000 (Hermanson et al. 2005). Sediment analyses from Ellasjøen on Bjørnøya show that supplies of the compounds were highest in the period 1960–1972 (Evenset et al. 2007). This indicates that phasing out the active global use of PCB oil has had an effect. A major challenge now is to speed up the proper management and possible destruction of existing PCB-containing products and materials that are still in use around the world.

Arctic ecosystems are vulnerable to hazardous substances due to (AMAP 2002, AMAP 2009 and Jenssen 2006):

- biodiversity is low
- life cycles are long
- reproduction potential is low
- the production period is short and intensive
- Arctic animals experience great seasonal variations (periods of hunger) in lipid deposits (fat)
- the offspring of Arctic mammals receive fat-rich breast milk
- seabirds transfer fat from the mother bird to eggs
- lipids transfer from primary producers to top predators quickly

The compounds have complex effect mechanisms. Even though research has been carried out into this group of chemicals for more than 50 years, a lot of scientific work is still needed on the effects of PCBs, including on human health.

FIGURE 2.2-4 PCBs are highly resistant to degradation and very liposoluble. These properties contribute to PCB compounds being stored (bioaccumulation) in fat-rich parts of organisms and concentrations increasing as they move up the food chains (biomagnification). (NB! The analysis results may be related to different types of tissue, which means that the figures are not directly comparable.)



In general PCBs are highly resistant to degradation and very liposoluble. These properties contribute to PCB compounds being stored (bioaccumulation) in fat-rich parts of organisms and concentrations increasing as they move up the food chains (biomagnification) (Borga et al. 2001), see figure 2.2-4. This particularly impacts animals at the top of Arctic food chains. These rely on building up large fat reserves as food stores and insulation for survival (Jenssen)

The decomposition products/metabolites from PCBs in mammals primarily consist of hydroxylated (OH) and methyl sulfone ($MeSO_2$) compounds of PCB. The conversion (biotransformation) that occurs is directed towards greater water solubility (polarity) but does not always result in detoxification (decontamination) because the metabolites that are formed are often also toxic (reactive intermediate product).

The properties of PCB congeners with respect to degradation (persistence), bioaccumulation and effects depend on their concentration. Long-term exposure, even to small quantities, can result in changes, including to the immune system, reproductive ability and hormone balance (see for example Stølevik 2011).

PCBs are transferred to the next generation, including via food reserves in eggs, via the uterus to the foetus *(in utero)*, and via breast milk. People and animals, which are high up in the food chain, primarily take them up via food. Fish and organisms that live in water can also take up significant amounts of PCBs that are unbound in the water, especially of the smaller hydrophobic congeners.

In general, the pattern of PCB contamination in organisms is normally as follows:

- the content of the compounds in plants and herbivores on land is normally low
- the levels of the compounds in different species depend on their diet, habitat use and how they break down environmental pollutants
- the capacity of different species to break down PCBs varies greatly
- levels increase with age and are higher in males than females
- sedentary species that live in close contact with sediments have higher concentrations of PCBs than species that swim freely in bodies of water

Arctic conditions affect the processes that control the natural degradation of environmental pollutants like PCBs (Mohn et al. 1997; Kuipers et al. 2003; Snape et al. 2007) and management measures in the Arctic environment must be risk assessed and adapted to local conditions (Menzie and Coleman 2007; Snape et al. 2003).

Further information on PCBs and the challenges related to environmental pollutants can be found in chapter 7.

2.3 PCBS IN FOOD

The Norwegian Institute of Public Health, 2008 found that approx. 10% of Norway's population have a higher than average intake of dioxin-like PCBs and dioxins than the weekly tolerable level (based on Norwegian diets). Foetuses and children are particularly exposed (see for example Stølevik et al. 2011).

The Institute of Marine Research, 2010a, generally concluded that levels of environmental pollutants in seafood from the Barents Sea are low, but some factors indicate that the Barents Sea could be so affected by human activity that the safety of seafood could come under pressure. This applies, for example, to Atlantic cod liver in which levels of dioxin-like PCBs and dioxins have been found that are close to the limit of 25 ng TEQ/kg wet weight (ww) that has been set for human consumption. Four stations in the Barents Sea exceeded this limit in the 2009 survey.

NIFES, 2010a, found that Greenland halibut from sampling stations off Svalbard and other places had concentrations of total dioxin-like PCBs and dioxins above the EU's upper limit, see chapter 3.4.5.1.3.

Levels of organic environmental pollutants in Arctic char from lakes on Svalbard that are used for angling have been surveyed in a project funded by the Svalbard Environmental Protection Fund (Christensen et al. 2011). Fish from Ellasjøen on Bjørnøya have the highest concentrations of most of the organic environmental pollutants covered by the survey. The levels of PCBs and dioxin-like PCBs calculated as TE (toxicity equivalents) exceed limits for human consumption set by the US Environmental Protection Agency and the EU. Fish from Richardvatn, Arresjøen and Annavatn also had elevated levels of environmental pollutants compared with fish from Laksvatn, Ratjørna, Diesetvatn, Linnévann, Straumsjøen and Liefdefjorden. The levels of environmental pollutants in anadromous Arctic char caught in the sea (Liefdefjorden) and Arctic char from anadromous Arctic char rivers (Linnévann, Straumsjøen, Dieset) were lower than in fish from lakes with only sedentary Arctic char.

The amounts of PCBs in eggs from Glaucous Gulls are about the same as in seagull eggs (Great Black-backed Gull and Herring Gull) from the coast of the mainland. In relation to eating a seagull egg, eating 10 eggs would double one's annual intake of dioxin-like PCBs and dioxins (Pusch et al. 2005). The dietary advice from the Norwegian Food Safety Authority is that children, young women, pregnant women and breastfeeding women should not eat seagull eggs. Other people should restrict their intake.

2.4 OTHER ENVIRONMENTAL POLLUTANTS AND NEW CHEMICALS

2.4.1 PCBS IN INTERACTION WITH OTHER HAZARDOUS SUBSTANCES

PCBs are just one of many groups of hazardous substances. Neither we nor the environment are exposed to one environmental pollutant at a time. Instead we are exposed to a mixture of them, e.g. PCBs, dioxins, chlorinated pesticides, brominated flame retardants, perfluorinated compounds and heavy metals. In addition to this come decomposition products that can have the same harmful effects as the 'parent product' (Gilman et al. 2009).

Our knowledge about how PCBs interact with other hazardous substances and decomposition products/metabolites is full of gaps, including about:

- how the total load of substances affects species and ecosystems
- the effects of decomposition products

Nonetheless, it is known that exposure to mixtures of substances can have strong additional effects (AMAP 2009, AMAP 2011). When multiple environmental pollutants interact, lower levels of the individual substances can trigger the same effects or health disorders. Experiments conducted by NIFES showed that non-dioxin-like PCBs and dioxins in combination are more toxic together than individually (NIFES 2010b).

2.4.2 REACH (REGISTRATION, EVALUATION, AUTHORISATION AND RESTRICTION OF CHEMICAL SUBSTANCES)

REACH, which is the EU's regulation on chemicals, will provide new knowledge about hazards, as well as the risk of using and releasing commercial substances. However, the system is not adapted to Arctic regions and this means that screening and monitoring potential environmental pollutants in the High North will continue to be important. No system has been developed for assessing the total effect of multiple chemicals in REACH.

PROPOSED MEASURES:

- Because some hydroxy metabolites of PCB (OH-PCB) have demonstrated strong bonds with the transport protein TTR, a vivo exposure experiment with PCBs is required with a view to gaining a greater insight into the mechanisms behind the distribution of PCBs and metabolism process in animals, and especially in Arctic species.
- More research into synergistic and any antagonistic effects of various environmental pollutants should be carried out.

- Methods for toxicity tests on Arctic organisms should be developed.
- REACH recently came into force on Svalbard. The pollution authorities should stipulate requirements for activities on Svalbard that prohibit the use of chemicals listed on the Candidate List in REACH or that are on the Norwegian Priority List.

2.5 REGULATIONS AND CONVENTIONS

An overview of the regulations and conventions that, directly or indirectly, regulate PCBs nationally, internationally and on Svalbard is provided in chapter 7.2.

2.6 INSPECTIONS

The Governor and Climate and Pollution Agency, in coordination with the project, have carried out inspections in all settlements on Svalbard to follow up the PCB regulations. The results of these inspections show that many sources of PCBs have been properly removed. The remaining PCB-containing materials and equipment have been identified and measures for their proper management and phasing out have been implemented, see chapter 4.1.6.4.

The pollution control authorities have planned an action for 2011/ 2012 to verify that the phasing out of PCB-containing electrical equipment has been completed.

PROPOSED MEASURES:

- Following up that PCB-containing sealed panes and façade materials in buildings are being managed according to the regulations.
- Verification of the final phasing out of capacitors from light fittings in Barentsburg and Pyramiden.
- Inspections in relation to the waste plan for Barentsburg.

2.7 SAMPLES, ANALYSES AND INTERPRETING RESULTS

2.7.1 MONITORING STRATEGY

One important purpose of monitoring levels of environmental pollutants is to detect trends. The goal should be formulated clearly enough to ensure that the magnitude of the trends the monitoring should be able to detect can be quantified. This will have a major impact on the choice of monitoring strategy, e.g. how many samples must be taken and how often. The issue is illustrated by a statistical analysis conducted by the Norwegian Polar Institute of 8 years of environmental pollutant samples in polar bears (Henriksen et al. 2001). Samples were taken of blood, fatty tissue and milk, and initially indicated no time trends because of the great variation in the data. The first task therefore was to find the tissue with the least variance. This proved to be blood serum. Thereafter, all the samples in serum were analysed to find which causes other than pollutant levels could explain the variation between years. It was shown that the animal's nutritional situation, reproductive status and the time and place of the sampling all played a part. It was not before one had materials that were standardised for these factors that it was possible to establish a trend - in fact the first time series for contamination in polar bears. However, no more than half of the samples that had been collected were needed for this. The main conclusion was that in order to establish a time trend new samples need to be taken every year, and not every third or fifth year as is often the case in monitoring programmes. The study clearly showed that sampling for time trend studies must be standardised.

2.7.2 SAMPLING AND ANALYSES

A number of factors may play a role in determining the outcome of the measurements and how they are interpreted, for example:

1. Sample type and sampling variability in the field and population
2. Differing methods for processing the samples
3. Problems related to different analysis batches
4. Problems in connection with detection limits and how to manage values below the detection limit
5. Contamination from sample containers
6. Problems associated with weighing heterogeneous sample material

These points at looked at in more depth in chapter 7.3.

Analyses often only look for a limited number of the 209 congeners. The reason for this is partly economic and partly the fact that PCBs are selectively enriched in different media. It is therefore not always necessary to analyse for all 209 congeners in all sample types. In air and water the focus is on di-tetra PCB, in biota it is on tetra-hexa/hepta, and in sediments/soil it is on penta-octa.

2.7.3 REPORTING RESULTS

The content of PCBs in various samples from Svalbard has been determined by various sampling and analysis methods by many different laboratories and over many years. One of the factors one must be aware of when assessing research and monitoring reports is that PCBs are reported in different ways that are not directly comparable.

- Wet weight (ww) versus dry weight (dw). PCBs are liposoluble and samples with different fat contents will therefore contain different quantities. In order to compare the content of environmental pollutants in samples with different fat contents, the concentrations of environmental pollutants is usually normalised by fat content, lipid/fat weight (lw)
- Reporting form for data; single congeners of PCB, e.g. PCB#153, or the sum of multiple congeners, e.g. ∑7PCB, ∑33PCB, etc. (means the sum of 7 and 33 individual and predetermined congeners respectively). ∑7PCB covers the normal congeners PCB#28, PCB#52, PCB#101, PCB#118, PCB#138, PCB#153 and PCB#180.
- Dioxin-like PCBs are often reported using the unit TEQ (Toxic Equivalency Quotient). TEF (Toxicity Equivalency Factors) indicates how toxic a dioxin-like environmental pollutant is in relation to the dioxin compound 2,3,7,8-TCDD (which has been assigned a toxicity value of "1"). When mixtures of multiple dioxin-like environmental pollutants are assessed, the concentration of the various environmental pollutants is multiplied by a factor (TEF value). The total value, toxic equivalent, is used as a measure of the potential toxicity of the mixture. There are several TEF models, including the one designed by the World Health Organisation, WHO-TEQDFP, that include PCBs.

A measurement for, for example, Glaucous Gulls reported as ∑7PCB ww can as a measurement be directly compared with something else that is reported in the same way, i.e. ∑7PCB ww. Crude comparisons between, for example, ∑7PCB and other ∑xxxPCB or total PCBs (=∑209PCB) can be made with the aid of a factor by which the results are multiplied. The use and interpretation of PCB profiles with ∑7PCB data in sediments can be found in Konieczny and Mouland, 1997, and others.

2.7.4 INTERPRETING RESULTS

Concentrations of PCBs and other organic environmental pollutants increase as they move up the food chain (see figure 2.2-4) and the levels therefore are often highest in animals that are high up in the food chain (high trophic level). Therefore, it is important to know organisms' trophic level in order to interpret results from analyses of environmental pollutants. Trophic level can be determined by analysing biota samples for the stable isotopes of nitrogen (14N/15N) and carbon (12C/13C).

To interpret the result it is important to know when the sampling was carried out (e.g. whether water and snow samples were taken in the spring/summer when snow is melting and whether animals samples are from "periods of hunger", etc.).

A high content of PCB#118 and low content of PCB#153 and #180 characterise the Soviet PCB mixture Sovol. It might be possible to detect the take up of local PCBs and differentiate these from long range transported PCBs when analyses differentiate between the different variants of PCB (congener profile).

2.7.5 CLASSIFICATION SYSTEMS

There are no established systems for Arctic status classes, standard values and limits for soil, sediments, etc. Such classification systems make it easier to make assessments on a common basis and take decisions in cases to do with, for example, polluted ground and contaminated sediments.

Standardised classification systems will be important for the predictable and science-based environmental management of Svalbard.

Classifications systems have been developed for things such as polluted ground, see table 2.7.5-1 (Hansen et al. 2009), sediments and water (Bakke et al. 2007, TA-2229/2007) that apply to mainland Norway. However, these are not directly transferable to Arctic conditions.

PROPOSED MEASURES:

- Develop classification systems for Arctic conditions.
- "Arctic standard sample bank" in which large volumes of typical sample media are deposited and to which researchers can have access. This will make it possible to compare different studies.

2.8 RUSSIAN ENVIRONMENTAL SURVEYS ON SVALBARD AND INTERCALIBRATION

2.8.1 TRUST ARKTIKUGOL'S ENVIRONMENTAL MONITORING

The "Centre for Environmental Chemistry SPA "Typhoon", North-Western branch" has for many years conducted environmental surveys (air, soil, sediments, water and biota) in Barentsburg and Pyramiden on behalf of Trust Arktikugol. Samples have been collected and analysed for PCBs and other environmental pollutants.

Reports, translated into Norwegian, of results from Typhoon's environmental monitoring are available for 2002-2009 and 2010. These results are referred to in this report "PCBs on Svalbard".

STATUS CLASS/ SUBSTANCE	1	2	3	4	5
	VERY GOOD	GOOD	MODERATE	POOR	VERY POOR
Arsenic	<8	8-20	20-50	50-600	600-1000
Lead	<60	60 -100	100-300	300-700	700-2500
Cadmium	<1.5	1.5-10	10-15	15-30	30-1000
Mercury	<1	1-2	2-4	4-10	10-1000
Copper	<100	100-200	200-1000	1000-8500	8500-25000
Zinc	<200	200-500	500-1000	1000-5000	5000-25000
Chromium (III)	<50	50-200	200-500	500-2800	2800-25000
Chromium (VI)	<2	2-5	5-20	20-80	80-1000
Nickel	< 60	60-135	135-200	200-1200	1200-2500
∑7PCB	< 0,01	0.01-0.5	0.5-1	1-5	5-50
DDT	<0.04	0.04-4	4-12	12-30	30-50
PAH16	<2	2-8	8-50	50-150	150-2500
Benzo(e)pyrene	< 0,1	0.1-0.5	0.5-5	5 -15	15-100
Aliphatics C8-C10[1)]	<10	≤10	10-40	40-50	50-20000
Aliphatics > C10-C12[1)]	<50	50-60	60-130	130-300	300-20000
Aliphatics > C12-C35	<100	100-300	300-600	600-2000	2000-20000
DEHP	<2.8	2.8-25	25-40	40-60	60-5000
Dioxins/furans	<0.00001	0.00001-0.00002	0.00002-0.0001	0.0001-0.00036	0.00036-0.015
Phenol	<0.1	0.1-4	4-40	40-400	400-25000
Benzene [1)]	<0.01	0.01-0.015	0.015-0.04	0.04-0.05	0.05-1000
Trichloroethylene	<0.1	0.1-0.2	0.2-0.6	0.6-0.8	0.8-1000

1) In the case of volatile substances, gas as an exposure pathway will result in low limits for human health. If gas in a building is not a relevant exposure pathway, a location specific risk assessment should be conducted to calculate location specific acceptance criteria.

TABLE 2.7.5-1 Classification system for polluted ground. The quantity unit for PCBs is mg/kg. Source: Klif TA-2533

Coordinated Norwegian-Russian sampling was conducted off the settlements of Pyramiden and Barentsburg in 2009. Sediment samples were collected but these have not been analysed due to a lack of funding.

2.8.2 INTERCALIBRATION

By way of information it should be mentioned that many Russian laboratories, NILU and EMEP (European Monitoring and Evaluation Programme) laboratories have participated in intercalibration (ArcticIntercal: 2010) on parameters including PCB, PAH, OCP, and BFR in air. An AMAP/EMEP report on this is being prepared.

2.8.3 INTERCALIBRATION IN THE PCBS ON SVALBARD PROJECT – SAMPLING AND ANALYSIS METHODOLOGY

To assess whether Norwegian and Russian data can be compared, an intercalibration process was conducted in 2008 in which Norwegian (Akvaplan-niva) and Russian (Typhoon) sampling and analysis methodologies for soil and sediments were compared.

Both Akvaplan-niva and Typhoon took five soil and five sediment samples each (total 20 samples) from locations in/off Barentsburg in autumn 2008. Each of the samples were homogenised and split into two equal parts, one of which was analysed for ∑7PCB by Typhoon and the other by ALS Scandinavia (which is an accredited laboratory often used by Akvaplan-niva).

The analysis results, see table 2.8.3 -1 below, indicate that the laboratories arrived at comparable results, in other words the variation apparent lies within what can be expected when analytical uncertainty and variations in the sample material are take into account. However, it is necessary to be aware when interpreting results from analyses of soil and sediments that different layers of sediments and soil are sometimes used in the monitoring. The results from the intercalibration study are reported in Evenset and Ottesen 2009.

In February 2009, a working seminar was arranged in St. Petersburg in which representatives from Klif, NGU, Akvaplan-niva and Typhoon met to discuss the joint use of data and any future collaboration.

PROPOSED MEASURES:

- The contact with Typhoon should be maintained, and Norwegian and Russian monitoring coordinated to achieve good utilisation of limited resources on both sides of the international border.

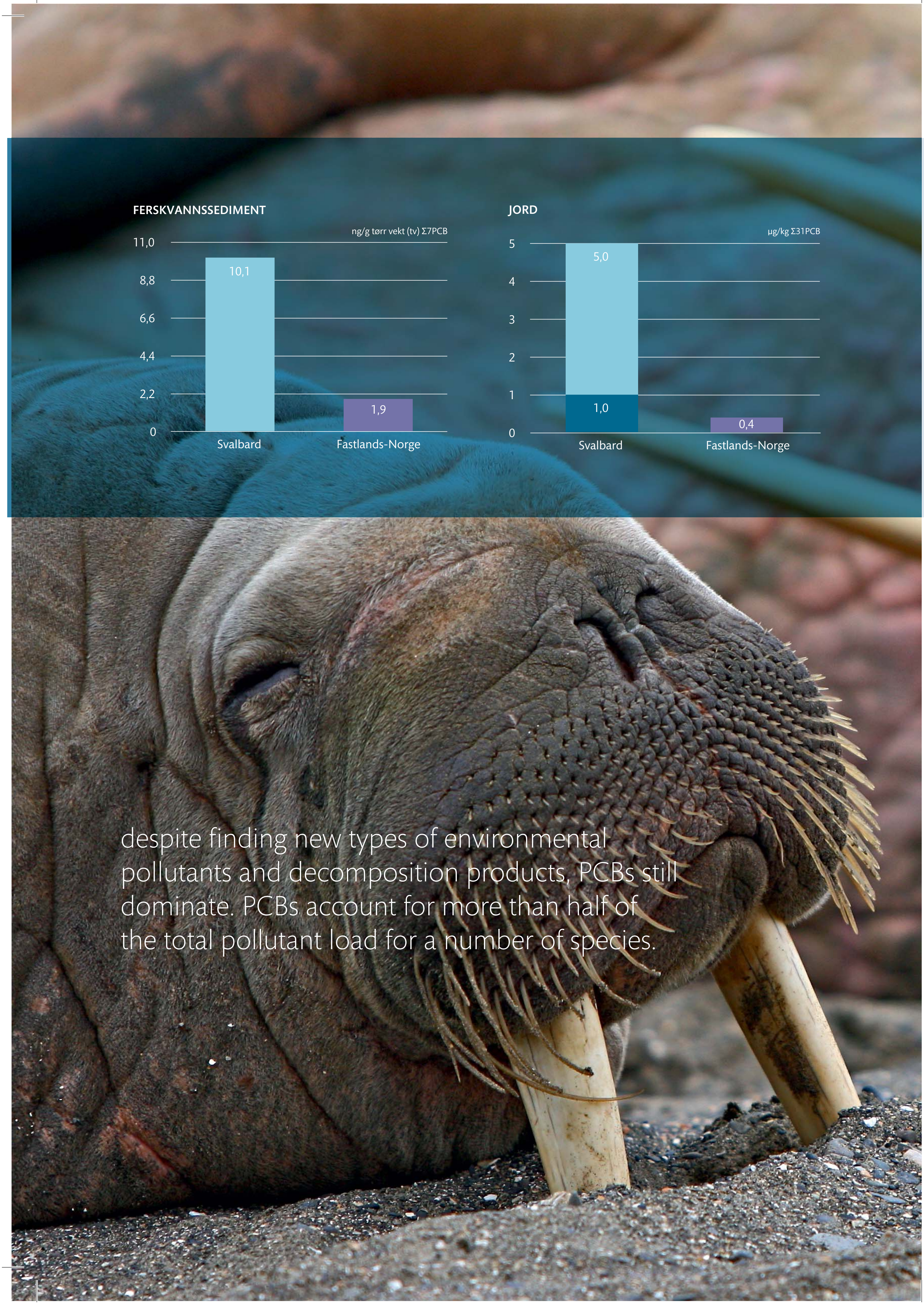
Station	Sampler	∑7PCB - Typhoon µg/kg ts	∑7PCB -als µg/kg ts
Bar-1	Akvaplan-niva	126.5	72
Bar-7	"	527.3	313
Bar-9	"	282.5	190
Bar-13	"	I.A.	63
Bar-16	"	152.2	171
Soil 1	Typhoon	38.9	120
Soil 2	"	13873	16700
Soil 3	"	3.64	<Lod
Soil 4	"	91.4	65
Soil 5	"	74.6	39

TABLE 2.8.3-1 ∑7PCB in soil samples analysed by both ALS Scandinavia and Typhoon, 2008. ts = solid matter. Source: Evenset and Ottesen 2009.

FOOTNOTES CHAPTER 2

[10] Report 1/2008; PCBs on Svalbard; status of knowledge and management, April 2008.

[11] Office of the Auditor General of Norway's study of the management of Svalbard, report 3:8 (2006–2007) points out deficiencies in the environmental monitoring and the associated basis for making decisions. The work on systematising PCB efforts on Svalbard can be seen as one example of a measure that was designed to follow up the Office of the Auditor General's observations.



despite finding new types of environmental pollutants and decomposition products, PCBs still dominate. PCBs account for more than half of the total pollutant load for a number of species.

THE LEVELS OF PCBS IN SVALBARD'S ENVIRONMENT ARE ALREADY HAVING ADVERSE EFFECTS ON A NUMBER OF ANIMAL SPECIES: PCBs, together with other environmental pollutants, have negative effects on Arctic foxes, polar bears, orcas, Northern Fulmars, Glaucous Gulls, Great Skuas and Ivory Gulls. The PCB concentrations now in top predators can cause physiological, immunological and reproductive stress, which in turn can have a negative impact at an individual and population level.

3. PCBS IN SVALBARD'S ENVIRONMENT – THE KNOWLEDGE-BASE

"The high levels of PCBs in animals such as polar bears, Arctic foxes, Glaucous Gulls, Ivory Gulls and Great Skuas are disturbing. PCBs are the dominant environmental pollutants in these species."

Professor Geir W Gabrielsen. Norwegian Polar Institute, Tromsø.
Adjunct professor of marine biology at the University Centre in Svalbard, Longyearbyen

3.1 ATMOSPHERIC

3.1.1 IN GENERAL

The transport of PCBs to Svalbard depends on the physical-chemical properties of the various PCB congeners and environmental factors such as weather, hydrology and geology, etc. Variations in transport, both throughout the year and regionally, have been found for some PCB congeners in air samples from the Zeppelin station in Ny-Ålesund (MOSJ, AMAP 2004a and 2009).

Understanding and predicting the dispersal, distribution and effects of PCBs on Svalbard is a very complex task due to factors such as the large seasonal variations in supplies via air and oceanic currents and in ambient temperature. Local topography and meteorological conditions also have a big effect on how much of the long range transported pollutants are deposited on the ground or in water.

3.1.2 BACKGROUND LEVEL OF PCBS IN THE ATMOSPHERE AT THE ZEPPELIN STATION

The background level in atmospheric samples for ∑31PCB was 15-20 pg/m^3 at the Zeppelin station in the period 2000-2006 (Hung et al. 2010; Kallenborn et al. 2007).

3.1.3 INCREASING QUANTITIES OF PCBS IN THE ATMOSPHERE ABOVE SVALBARD

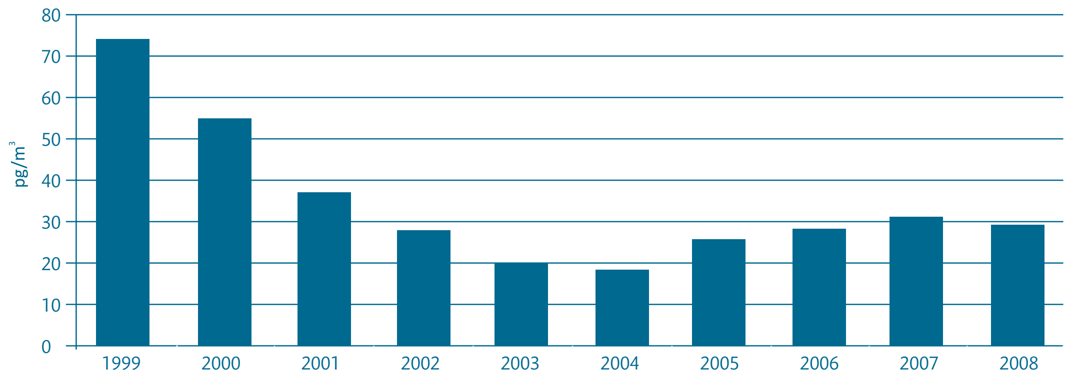
After a downwards trend, an increased level of PCB congeners was detected in the atmosphere above Svalbard in the period 2004-2008 (figure 3.1.3-1).

There may be several possible explanations for this, including changes in climate, air and oceanic currents, and the extent of ice. The most probable explanation is that the transport pathways and transport mechanisms for environmental pollutants have changed (Hung et al. 2010, Ma et al. 2011).

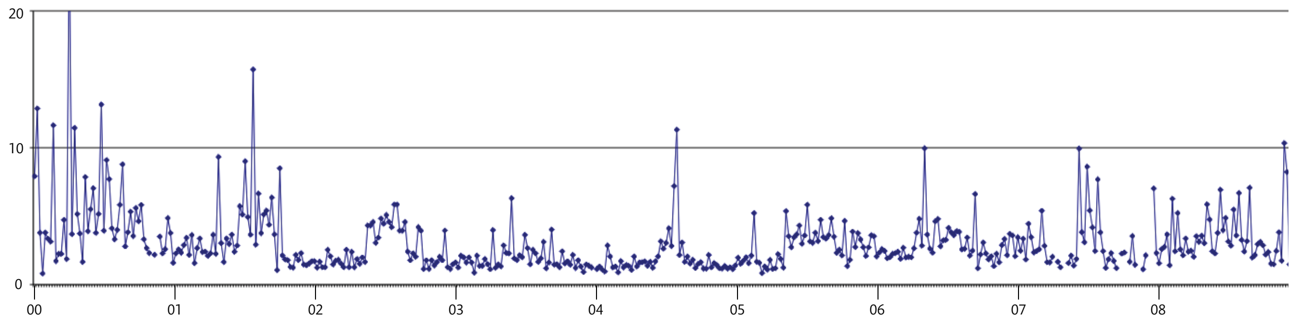
Data from the Zeppelin station for PCB#28, which is primarily transported in a gaseous phase, shows that the number of long range transport episodes has increased in the last few years, see figure 3.1.3-2.

3.1.4 SEASONAL PCB DISTRIBUTION

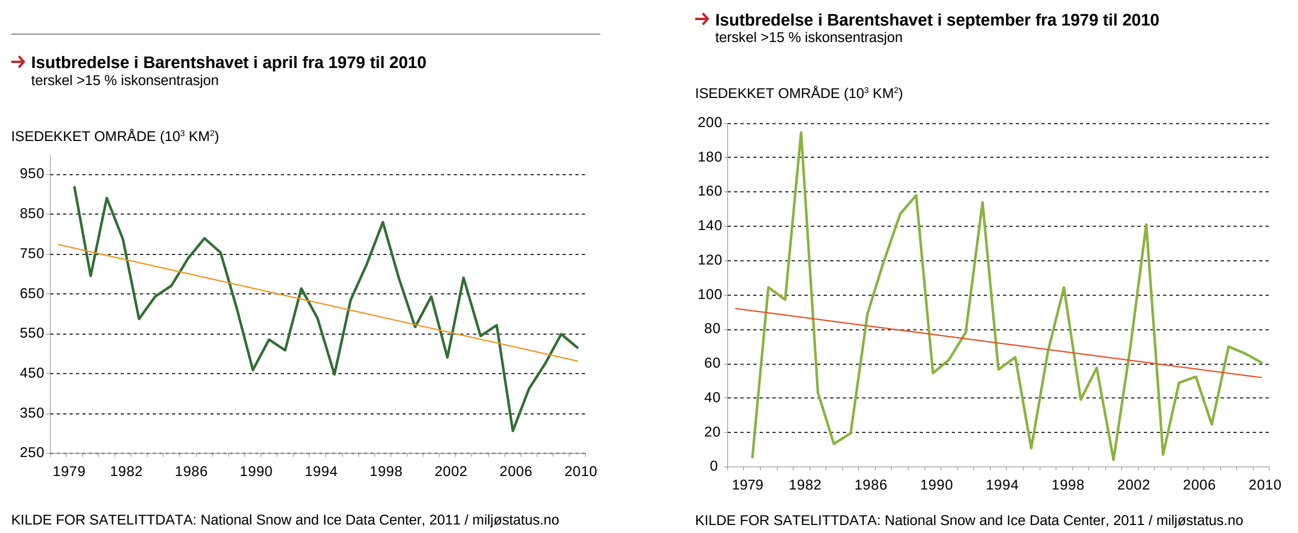
Analyses of PCBs in air samples collected during the period



PICTURE 3.1.3-1 The graph shows the average annual concentrations of PCBs in the air at the Zeppelin station. A break in the trend is clearly visible from 2004. Source NILU.



PICTURE 3.1.3-2 The graph illustrates the results of weekly measurements of PCB#28 in the air recorded at the Zeppelin station during the period 2000-2008. PCB#28 is principally transported in the gas phase and the graph shows that the number of long range transport episodes has risen in recent years. Source R. Kallenborn.



PICTURE 3.1.4-1 The graph illustrates the extent of sea ice in the Barents Sea during the period 1979-2010 while it is at its maximum (April) and its minimum (September) (threshold: >15% ice concentration; data are based on observations from passive microwave satellites). The middle values for each month and the linear trend have been depicted. The interannual variation is large, but the trends for maximum and minimum extents are also clear. Source: www.miljostatus.no/tema/ hav-og-vann/havomrader/Barentshavet/indikatorer-barentshavet/indikator-Isutbredelse-i-Barentshavert/7.

2000-2008 indicate that the distribution of PCBs in air masses over Svalbard varies according to the time of year (figure 3.1.3-2). One reason for this may be increased evaporation from the sea surface during the summer months (Ma et al. 2011). This may be associated with changes in large-scale weather phenomena, e.g. oceanic current systems that have exhibited irregular patterns in recent years. Nonetheless, this alone cannot fully explain the changed concentrations in some seasons and years. There are recent indications that the sea itself may be a source of environmental pollutants in the form of unbound PCBs in the water (Ma et al. 2011). The environmental pollutant is now gradually being released back into the atmosphere. This process is steered by periods of upheaval in the sea and contact between the surface of the sea and atmosphere (AMAP 2004 and 2009; Hung et al. 2010). This contact varies throughout the year and from year to year because of the variation in the extent of sea ice. Ice forms a protective cap over the sea, which counters emissions of environmental pollutants to air (SWIPA, 2011). With less extensive sea ice, see figure 3.1.4-1, evaporation and thus the release of environmental pollutants to air have increased.

Another possible source of environmental pollutants are the large boreal forests in Eurasia and North America. Trees can absorb environmental pollutants, which in turn can be released to air when biomass burns (Eckhardt et al. 2007). This theory is supported by measurements that show increasing levels of penta and hexachlorinated PCBs in the air in the summer, levels that can be linked to forest fires in Alaska. Such an event occurred at the end of April 2006 when heavily polluted air from burning biomass in Eastern Europe was transported to Svalbard where it caused smog (fog mixed with and polluted by smoke), Eckhardt et al. 2007. Following this, significantly higher levels of PCBs were measured in Svalbard's air (Øyseth 2009; NorACIA 2009).

3.1.5 BJØRNØYA

The background level in atmospheric samples for ∑33PCB on Bjørnøya was 40-50 pg/m^3 in the period 2000-2003. The levels on Bjørnøya reflect a significant contribution from neighbouring areas (evaporation from the sea, PCBs bound to particles of guano, etc.) compared with data from the Zeppelin station, where long range transported PCBs are primarily measured in the air (Kallenborn et al. 2007).

Average concentrations of ∑33PCB in samples taken on Bjørnøya (Evenset et al. 2007) linked to a defined catchment area represent on an annual basis:

- Fog results in 7.4 g PCBs
- Rain results in 11.6 g PCBs
- Snow results in 8.4 g PCBs

PROPOSED MEASURES:

- Take the initiative concerning a partnership on reducing emissions of PCBs with countries that contribute to PCB contamination on Svalbard via air and oceanic currents In the case of countries that have ratified the Stockholm Convention this could, for example, be presented as a joint activity following up the convention:
  - Klif's partnership with countries like China, Poland and other countries represented on NySMAC (NySMAC = Ny Ålesund Science Manager Committee)
  - AMAP and the bilateral environmental protection partnerships with Russia
  - Partnership for removing PCB contamination on Franz Josef Land

3.1.6 AIR MEASUREMENTS IN THE SETTLEMENTS ON SPITSBERGEN

3.1.6.1 Air measurements taken by the University Centre in Svalbard (UNIS)

UNIS (Johansson-Karlsson, E. et al. 2010) has carried out air measurements with active and passive meters in Barentsburg and Longyearbyen. These settlements are only 50 km from each other and it is assumed that the supply of long range transported PCBs are of the same magnitude both places. However, differences in local topography may have a major influence on local deposits (Evenset et al. 2007).

The samples were analysed for the congeners PCB#18, 28, 31, 44, 52, 77, 81, 95, 99, 101, 105, 114, 118, 128, 138, 146, 149, 153, 156, 157 and 167. The measurements show that the levels in air in Longyearbyen are on a par with the background levels measured at the Zeppelin station in Ny-Ålesund. ∑7PCB measured in Barentsburg was higher:

- Longyearbyen: the measurements were carried out in November and the concentrations in the samples varied between 0.8-5.6 pg/m^3. PCB#95 dominated in the samples.
- Barentsburg: the measurements were carried out in September-October. The concentrations in the samples varied between 5-34 pg/m^3. PCB#52 and #95 dominated in the Barentsburg samples.

Since the measurements were not made at the same time in both places it cannot be safely concluded that it is the PCB contamination present in Barentsburg that causes the elevated levels of PCBs in the air. Tetra and pentachlorinated PCBs dominated in the samples from Barentsburg, which indicates local sources. The significantly large variations in the Barentsburg measurements compared with those from Longyearbyen and Zeppelin also provide grounds for assuming that local sources of PCBs in

Passive air measuring equipment located in the area around Barentsburg. Photo: Halvard R. Pedersen

SPRING 2002-2004				(pg/m³)	
BARENTSBURG TOWN AND ITS VICINITY		HELIPAD AREA		NEIGHBOURHOOD	
VARIATION	AVERAGE	VARIATION	AVERAGE	VARIATION	AVERAGE
11.7-31.5	24.9	13.6-13.8	13.7	9.86-25.2	17.2

TABLE 3.2.6.2.1-1 ∑18PCB in atmospheric air, Barentsburg, spring 2002-2004. Source Typhoon, 2004.

SUMMER/AUTUMN 2002-2004				(pg/m³)	
BARENTSBURG TOWN AND ITS VICINITY		HELIPAD AREA		NEIGHBOURHOOD	
VARIATION	AVERAGE	VARIATION	AVERAGE	VARIATION	AVERAGE
9.61-25.6	20.4	11.5-13.7	12.9	8.67-19.9	13.3

TABLE 3.2.6.2.1-2 ∑18PCB in atmospheric air, Barentsburg, summer/autumn 2002-2004. Source Typhoon, 2004

Barentsburg explain the elevated measurements, ref. Hung et al. 2010.

3.1.6.2 Air measurements carried out by Typhoon

3.1.6.2.1 Surveys 2002-2004

The air in Barentsburg and surrounding areas was also sampled and analysed by Typhoon as part of Trust Arktikugol's survey of environmental pollutants (Typhoon, 2004). The sampling points were the meteorological observatory in Barentsburg, Selisbukta, the mouth of the Grøndalselva river and Stemmevatn. The samples cover dust and the gaseous phase. The measurements, measured in pg/m3 in outdoor atmospheric air, are shown in table 3.2.6.2.1-1 and table 3.2.6.2.1-2.

3.1.6.2.2 Survey 2010

Measurements made in 2010 (Typhoon, 2010) show ∑18PCB levels[12] in air of up to 40 pg/m³ (spring, measurements in the period 13-28 May), with an average of 20 pg/m³. In the summer and autumn seasons (measurements taken in the period 26 August-9 September) concentrations of ∑18PCB were significantly higher and reached a value of 181 pg/m³, with an average value of 103 pg/m³. The highest content was measured for congener PCB#105, and was 53 pg/m³.

3.1.7 LOCAL SOURCES OF EMISSIONS OF PCBS TO AIR

PCBs that temporarily exist in secondary sources, such as polluted ground and sediments, can be re-emitted and redistributed to other media such as water, air, snow and soil. New PCBs can under certain circumstances also be formed in incineration processes such the burning of coal, etc. (Lee et al. 2005; NERI Technical Report No. 786; Grochowalski et al. 2008). Little Norwegian data exists on emissions of newly formed PCBs from industrial sources, incineration and heating plants, motorised traffic and fires. Possible sources of newly formed PCBs on Svalbard are:

- Power stations (Longyearbyen and Barentsburg). Verification measurements of PCB formation in the power station in Longyearbyen show emissions of around 2-3 g of ∑7PCB/year (Bydrift Longyearbyen, 2007). PCBs cannot be detected in the ash from the power station (Governor's archive no. 20 09 00 971).
- Fires in ore landfills and stone tips. Some air sampling (passive and active) was conducted on Svalbard close to burning ore dumps in Barentsburg in 2007 (Kallenborn, NILU report for SMS) and in Svea 2005 (report for SNSK).
- Internal combustion engines (Stanmore 2004) (vessels, vehicles, shipping (Cooper et al. 1996 and 2005)).

PROPOSED MEASURES:

- Identify causes of PCB emissions and if possible change the processes such that PCBs are not formed, alternatively assess the need for purification
- Annual monitoring of PCBs in air to see how PCB concentrations change after the removal of PCB-containing waste. Could perhaps be integrated as part of UNIS' course "Techniques for the detection of organo-chemical pollutants in the Arctic environment".

3.2 ON LAND (TERRESTRIAL ENVIRONMENT)

3.2.1 BACKGROUND CONTAMINATION

Table 3.2.1.1-1 summarises known surveys of background PCB contamination in the soil in Svalbard. Background samples of soil on Svalbard typically have ∑7PCB levels of 1-5 µg/kg.

In the case of the atmospheric long range transport of compounds, there is a perception that deposition is quite uniform across large areas. A survey of the area around Forlandsundet shows that the levels between four locations within a radius of 15 km (figure 3.2.1.1-1) vary (Eggen et al. 2010a). Possible explanations for the differences could be dissimilarities in soil (e.g. organic content and particle size) and/or different precipitation patterns between the locations. Local differences in deposits of PCBs have been documented on Bjørnøya (Evenset et al. 2007). Similar local variations were also observed after the Chernobyl accident in 1986 where the levels of long range transported radioactive fallout varied strongly over relatively shorts distances (Lindahl and Håbrekke, 1986).

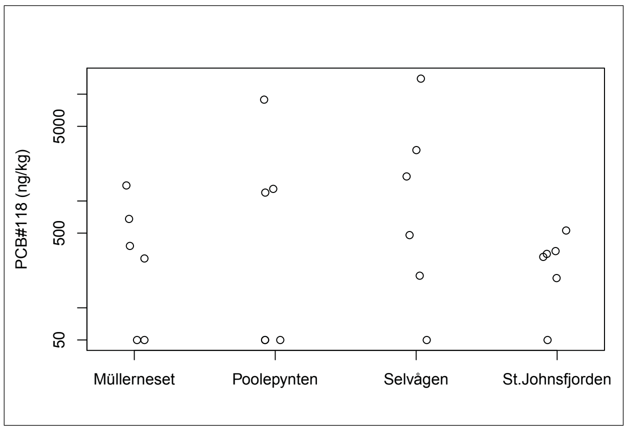
Figure 3.2.1.1-2 compares three surveys of background PCB contamination of soil on Svalbard. Again the range of concentrations varies widely for all congeners (figure 3.2.1.1-2A), but the three surveys show more or less the same trend. The difference between the surveys will be a combination of variation in analyses and decomposition, and variation out in the field.

NGU has, in cooperation with Professor Keri Hornbuckle of Iowa State University, analysed 23 background samples of soil from Svalbard for all 209 congeners. More than 80 PCB congeners were detected (ref. figure 3.2.1.1-3). The median value was 7.11 µg/kg ∑209PCB. The congeners included in ∑7PCB often occur in relatively high concentrations compared with congeners with the same degree of chlorination, but it is the congeners PCB#78 and PCB#79 that have the very highest median values (NGU, unpublished data). A thorough interpretation of the results remains to be carried out.

3.2.1.1.1 Background contamination per km² and source

A rough calculation, based on background level data, results in an estimate for PCB contamination on Svalbard of 0.4 kg/km^2 ∑7PCB.

Based on NGU's surveys and studies of Arctic sea areas (Carrizo and Gustafson, 2011) similarities between the distribution of congeners around Svalbard and the surface soil on Svalbard were pointed out (figure 3.2.1.1-2B). The other Arctic sea areas have a different type of signature. This may indicate that PCBs on Svalbard and in the sea areas around Svalbard are from the same source.



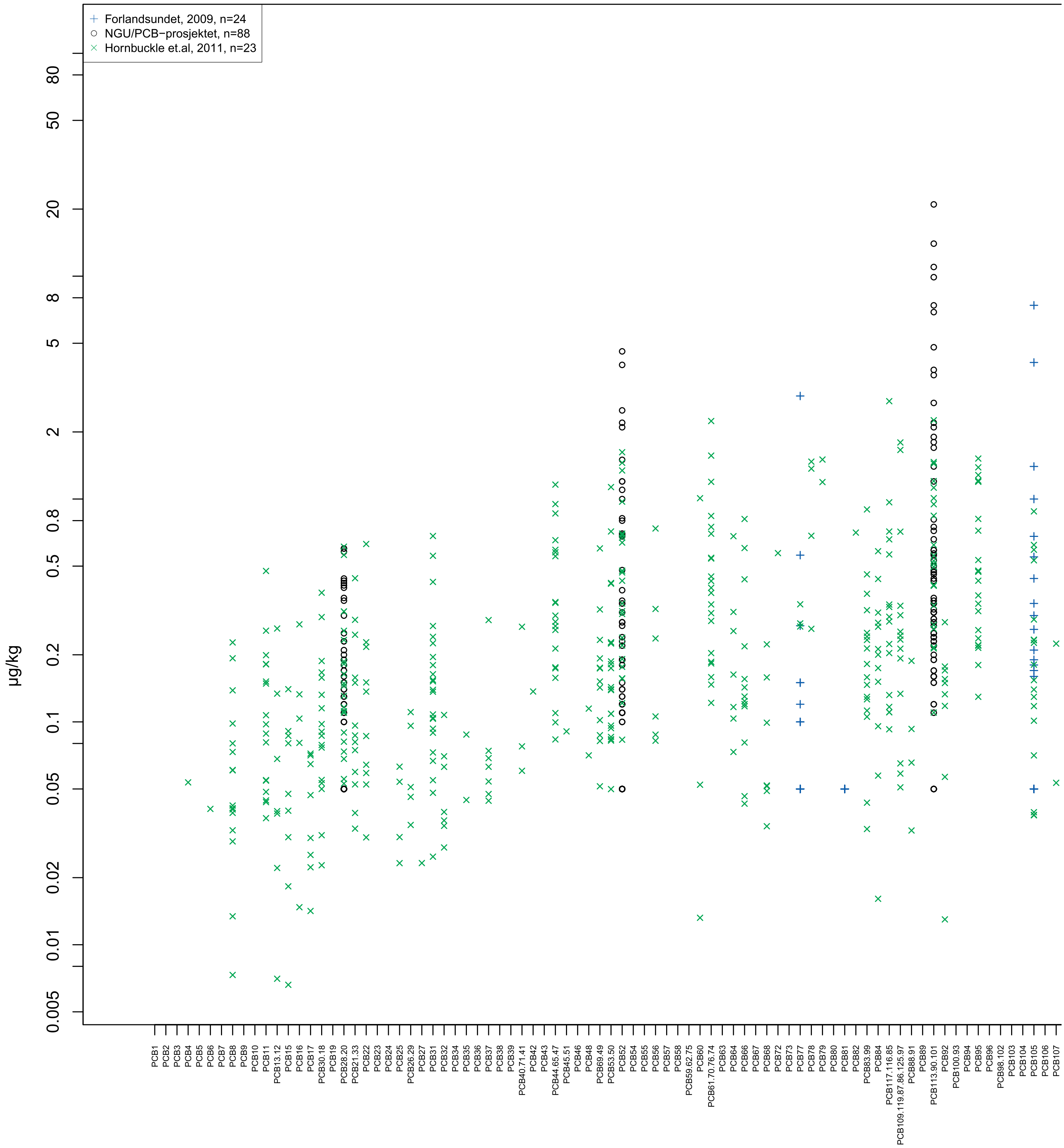
PICTURE 3.2.1.1-1 Background level from four sites around Forlandssundet varies even over short distances. Source Eggen et al. 2010a.

	DESCRIPTION	MEDIAN CONCENTRATION (µg/kg)
Schlabach and Steinnes, 1999	9 sites (n=9), 24 congeners	1.01 ∑24PCB (0.43 ∑7PCB)*
Breedveld, 2000	1 site: Platåfjellet, subsample of 7 individual samples	< 0.4 ∑7PCB
Harris, 2008	Kinnvika, 4 background samples	< 1 ∑7PCB
Eggen et al., 2009	4 sites around Forlandssundet (n=24), 12 congeners	1.07 ∑12PCB*
NGU/The PCB project, unpubl.	24 sites (n=83), 7 congeners	1.96 ∑7PCB*
The PCB project/Iowa State Univ.	23 sites (n=23), 209 congeners	7.11 ∑209PCB

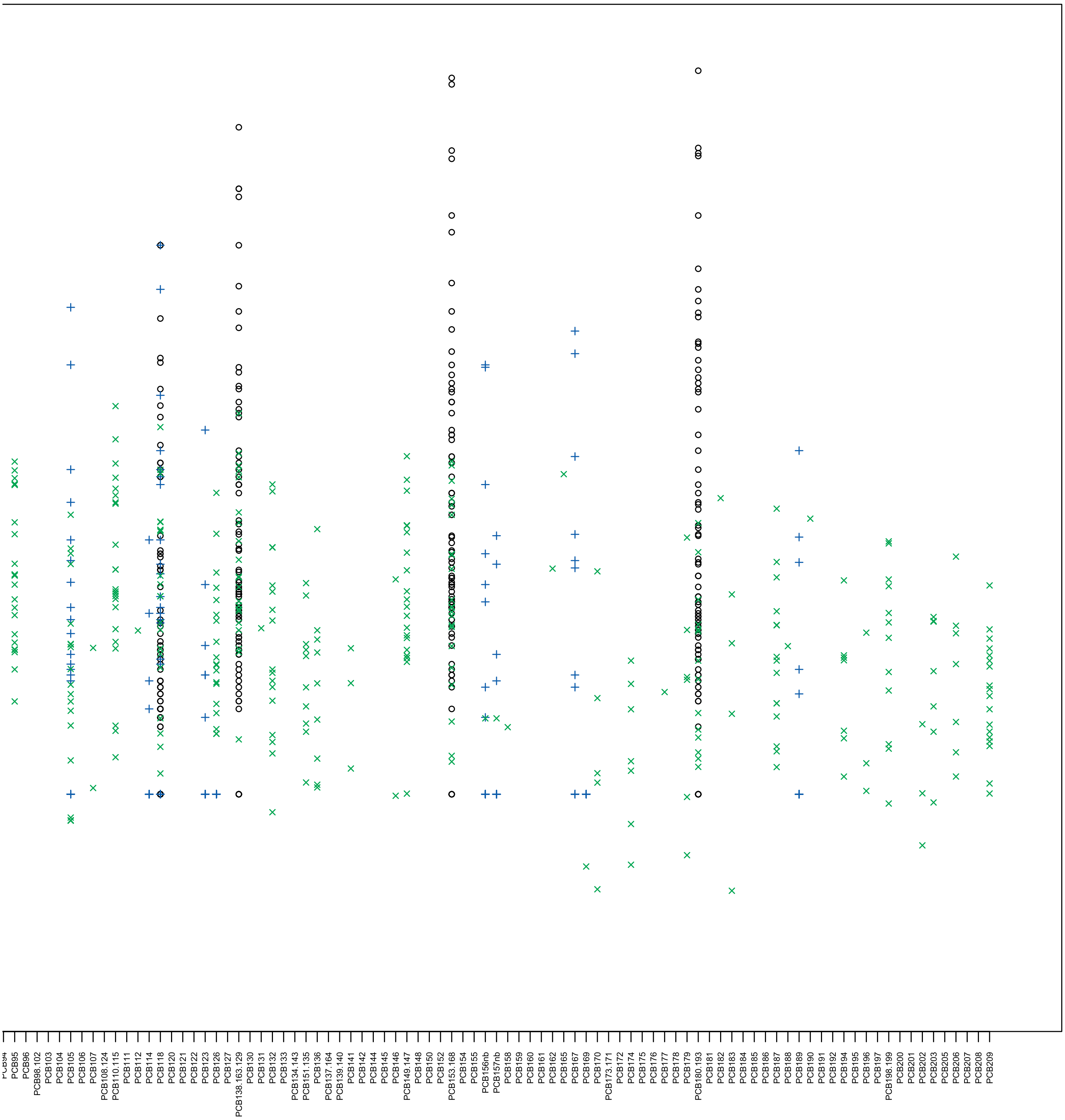
* When calculating the median, samples below the detection limit are assigned half the value of the detection limit

TABLE 3.2.1.1-1 Studies of background contamination of PCBs in the soil in Svalbard.

The funicular station and Power station chimney in Longyearbyen. Measurements have been taken of the emissions of newly-formed PCBs from the combustion of coal in the Power station. Photo: Halvard R. Pedersen.



PICTURE 3.2.1.1-3 The graph illustrates the results from analysis of all the 209 PCB congeners in 23 background samples of soil from Svalbard. Over 80 PCB congeners have been found. Source: The Geological Survey of Norway (NGU):


PCB95
PCB96
PCB98.102
PCB103
PCB104
PCB105
PCB106
PCB107
PCB108.124
PCB110.115
PCB111
PCB112
PCB114
PCB118
PCB120
PCB121
PCB122
PCB123
PCB126
PCB127
PCB138.163.129
PCB130
PCB131
PCB132
PCB133
PCB134.143
PCB151.135
PCB136
PCB137.164
PCB139.140
PCB141
PCB142
PCB144
PCB145
PCB146
PCB149.147
PCB148
PCB150
PCB152
PCB153.168
PCB154
PCB155
PCB156nb
PCB157nb
PCB158
PCB159
PCB160
PCB161
PCB162
PCB165
PCB167
PCB169
PCB170
PCB173.171
PCB172
PCB174
PCB175
PCB176
PCB177
PCB178
PCB179
PCB180.193
PCB181
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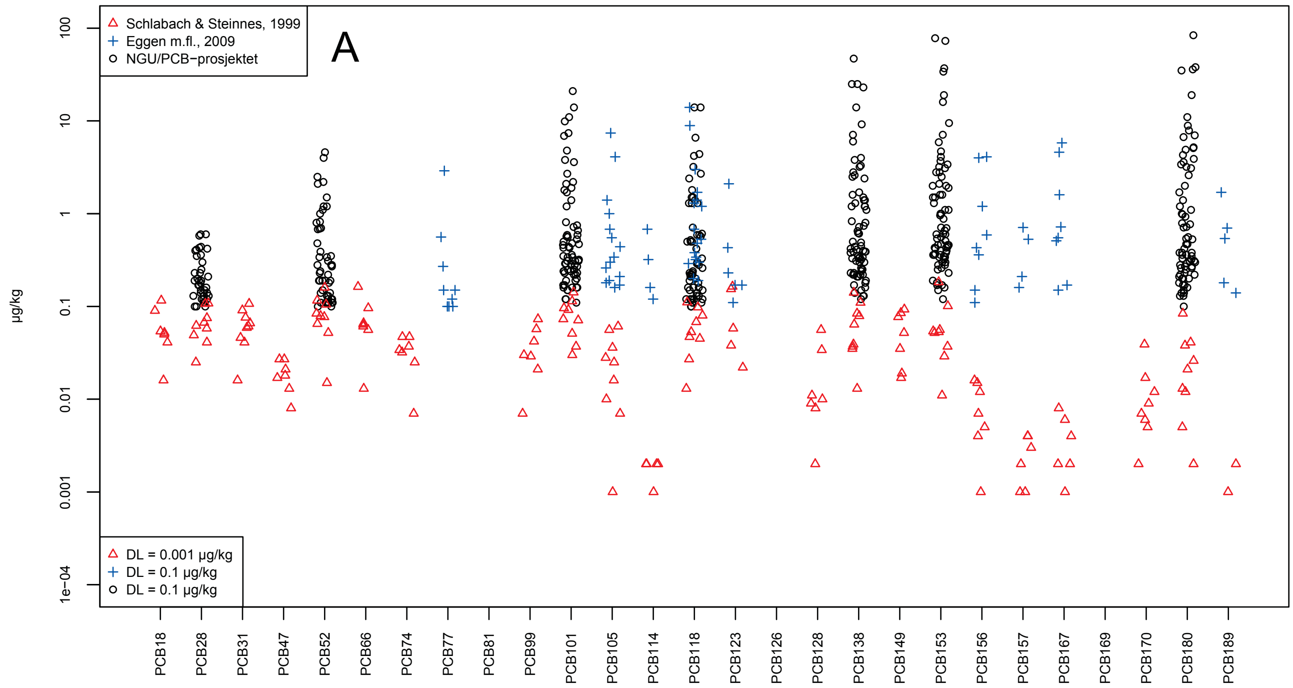
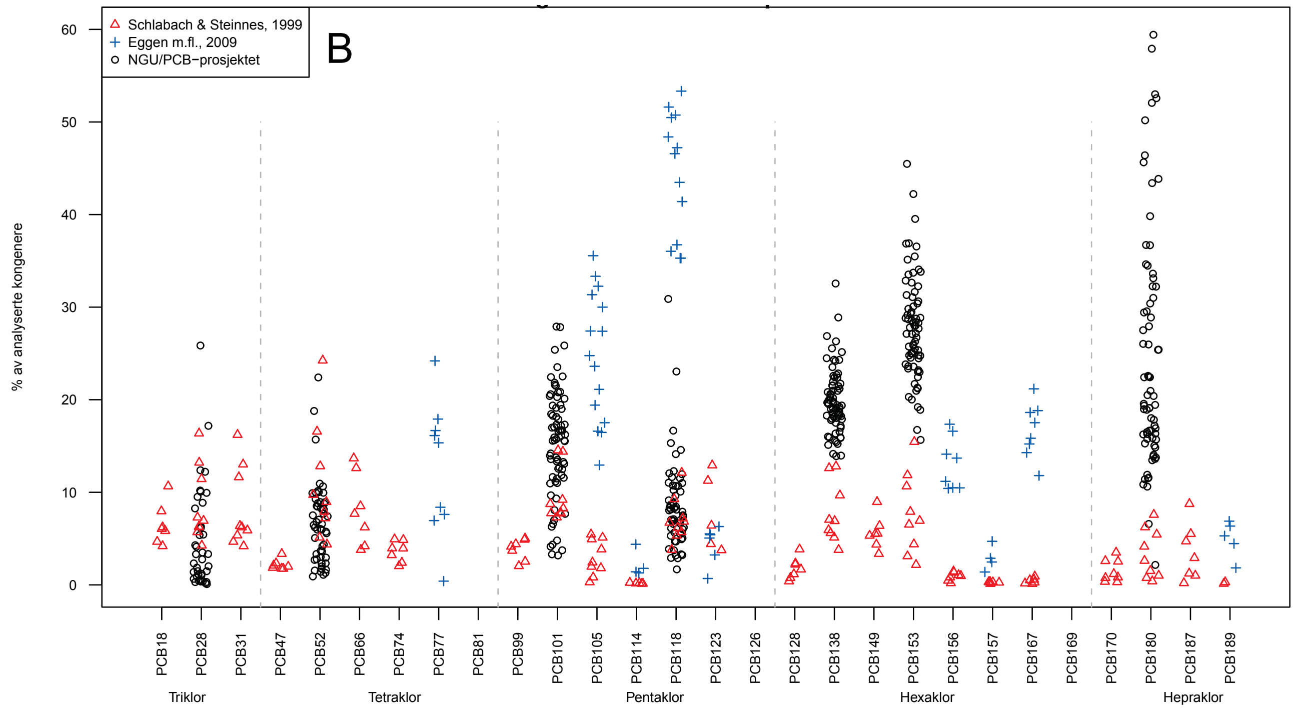
PCB207
PCB208
PCB209





PICTURE 3.2.1.1-2 The graphs show the wide spread in concentrations of all congeners in the background contamination of PCBs in soil in Svalbard. Samples below the detection limit have not been included. Source NGU.

3.2.2 SURFACE SOIL IN SETTLEMENTS, LANDFILL SITES AND POLLUTED GROUND

3.2.2.1 Surface soil

3.2.2.1.1 Surveys carried out by NGU

PCBs in soil were surveyed in all settlements on Spitsbergen in the field seasons of 2007-2009 (Jartun et al. 2007; Eggen et al. 2008; Eggen and Ottesen 2008; Jartun et al. 2009; Jartun et al. 2010). A total of 12 different locations were surveyed and 369 samples of surface soil analysed for ∑7PCB. The results are summarised in table 3.2.2.1.1-1. The table specifies the number of samples within each category, arithmetic average concentration, median value and concentration distribution (min.- max.). There is also a category showing the relationship between the median value in each settlement and the entire data set. This gives an indication of the degree of contamination in each settlement. Results below the detection limit are counted as half the detection limit in the statistics. The extent of PCB contaminated soil is greatest in Barentsburg and Pyramiden. Sources of PCBs in surface soil could be, for example, flakes of paint, contamination from electrical waste, leaks, and earlier spills of PCB oil.

3.2.2.1.3 Surveys carried out by Akvaplan-niva

Akvaplan-niva took soil samples in Barentsburg in connection with a project funded by the Svalbard Environmental Protection Fund (Evenset and Christensen 2009). The samples were analysed for 59 PCB congeners, including dioxin-like congeners. Dioxin-like PCBs accounted for 9 – 34% of ∑59PCB in the soil samples. The soil samples' dioxin toxicity based on dioxin-like PCBs is higher than that measured previously for dioxins/furans in soil from Norwegian or other European cities (Andersson et al. 2006).

3.2.2.1.4 Surveys carried out by Typhoon

In the period 2003-2009, Typhoon carried out measurements of surface soil in the bare ground period in Barentsburg and neighbouring areas (Typhoon 2009). The content of ∑7PCB at fixed measuring points, see figure 3.2.2.1.4-1, linked to the settlement and helicopter station/Kap Heer (stations 2, 7, 16, 18) and neighbouring areas (stations 3, 6, 8, 20) varies greatly in places.

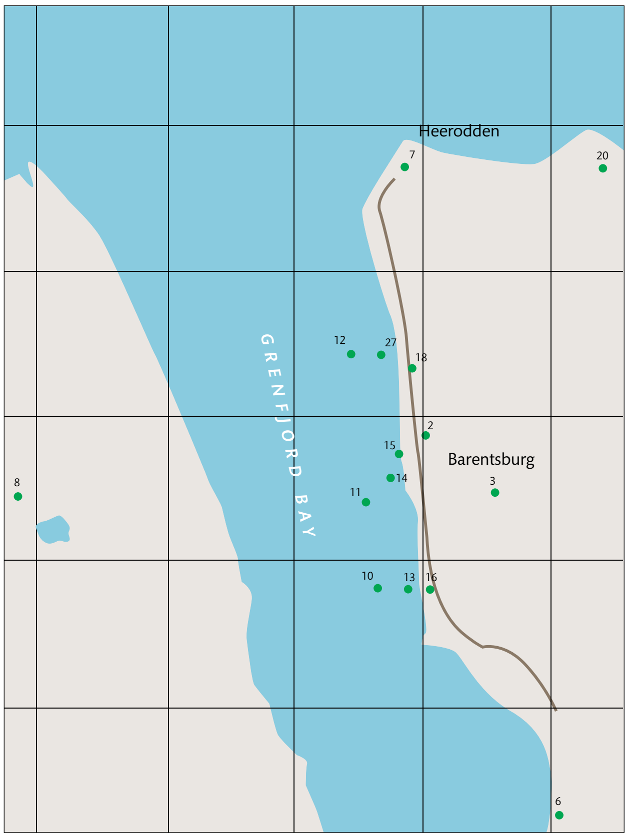
Typhoon explains the variation by the distance from possible local pollution sources (station 16 is an old waste dump and station 2 is the helicopter station). Typhoon believes the relatively high values measured in 2007 were linked to the prolonged ore fire in the area. The elevated values can also been seen in the samples from the neighbouring areas and are also assumed to explain the somewhat elevated levels of PCBs in 2008-2009.

In corresponding surveys in 2010 (Typhoon 2010) the highest concentrations of PCBs were established in samples from

Location	Number of samples N	Arithm. average ∑7PCB (mg/kg)	Median ∑7PCB (mg/kg)	Min – max ∑7PCB (mg/kg)	$Median_{settlem}$ / $Median_{total}$
Total	**369**	**0.677**	**0.046**	**<0.004-28.7**	**-**
Barentsburg*	127	0.992	0.217	<0,02 - 28,7	4.7
Bjørnøya	9	0.026	<0.02	<0,02 - 0,121	0.21
Colesbukta	13	0.365	0.025	<0,02 - 1,89	0.54
Fuglehuken lighthouse	1	0.039	0.039	0.039	0.85
Grumant	5	<0.02	<0.02	<0.02	0.21
Hopen	1	<0.02	<0.02	<0.02	0.21
Hornsund	1	<0.02	<0.02	<0.02	0.21
Isfjord Radio	16	<0.02	<0.02	<0.02	0.21
Longyearbyen*	79	0.011	<0.02	<0,004 - 0,130	0.21
Ny-Ålesund*	20	0.011	<0.02	<0,004 - 0,042	0.21
Pyramiden*	83	1.40	0.290	<0,004 - 18,4	6.3
Svea	14	<0.02	<0.02	<0.02	0.21

*Lower detection limit in 2007 (<0.004 mg/kg)

TABLE 3.2.2.1.1-1 Overview of the concentration of ∑7PCB (mg/kg) in surface soil from the settlements in Svalbard. Source NGU.



PICTURE 3.2.2.1.4-1 Locations of Typhoon's fixed monitoring stations. Source Typhoon

the areas near the helicopter pad, and ∑15PCB[13] amounted to 328 ng/g. Similarly, high values were also found in the settlement's soil: 172 ng/g ∑15PCB at the hydro-meteorological observatory, 198 ng/g ∑15PCB in the sloping stream area near the consulate, and 178 ng/g ∑15PCB at the rubbish tip for household waste. All 15 congeners were detected in the surveyed areas. The maximum concentrations were: PCB#28 – 0.94 ng/g, PCB#31 – 4.51 ng/g, PCB#52 – 13.8 ng/g, PCB#99 – 30.0 ng/g, PCB#101 – 39.5 ng/g, PCB#105 – 47.0 ng/g, PCB#118 – 81.2 ng/g, PCB#128 – 15.7 ng/g, PCB#138 – 48.6 ng/g, PCB#153 – 28.7 ng/g, PCB#156 – 10.4 ng/g, PCB#170 – 4.32 ng/g, PCB#180 – 4.25 ng/g, PCB# 183 – 1.17 ng/g, PCB#187 – 1.28 ng/g. ∑15PCB was in the range 0.05 – 328 ng/g, with an average of 49.9 ng/g dw.

3.2.2.1.5 Calculated quantity of pollutants in the settlements

NGU has made a rough calculation of how much PCB is present in the surface soil in the settlements based on soil samples taken by NGU in Pyramiden, Barentsburg and Longyearbyen (Jartun et al. 2010), see figure 3.2.2.1.5-1.

3.2.2.2 Landfill sites and other polluted ground

Ground contamination, including PCB contamination, has been surveyed and documented (Kovacs 1996; Danielsberg 1998, and Eggen et al. 2010b). Recent contamination surveys of soil and sediments were summarised in Evenset 2010.

The locations were in Longyearbyen, Ny-Ålesund, Isfjord Radio, Barentsburg and Pyramiden. In the period 1999-2003, the Norwegian Geotechnical Institute (NGI) conducted a number of

PICTURE 3.2.2.1.5-1 Amount of PCBs in contaminated soil in the settlements and background level in the wilderness. Source Jartun et al. 2010. Photo: Halvard R. Pedersen.

	KLIF'S LOC. NO.	NUMBER OF SAMPLES	MEDIAN (mg/kg)	AVERAGE (mg/kg)	MAX (mg/kg)
Longyearbyen, mine 3	2110022	2	< DL	< DL	< DL
Longyearbyen, mine 3, tip 3	2110024	5	0.0003	0.0009	0.0025
Longyearbyen, mine 7	2110031	7	< DL	< DL	< DL
Longyearbyen, old landfill	2110032	3	< DL	< DL	< DL
Longyearbyen, new landfill	2110033	2	< DL	< DL	< DL
Pyramiden, waste disposal site at the river delta	2110060	9	0.0172	0.1112	0.5500
Isfjord Radio, tip at the cliffs	2110069	5	< DL	< DL	< DL
Barentsburg, mining tip south of the town	2110071	1	0.0650	0.0650	0.0650
Barentsburg, mining tip at the airport	2110079	3	0.0023	0.0025	0.0034

TABLE 3.2.2.2-1 PCBs in surveyed waste disposal sites and landfills. Source Eggen et al. 2010b.

surveys of the environmental status of ore landfills, fuel storage areas, and dumps on Svalbard (Breedveld et al. 1999 a, b, c; Breedveld and Skedsmo 2000 a, b and c; Breedveld 2000; Børresen and Sørlie 2002; Børresen 2003). The surveys covered locations in Longyearbyen, Ny-Ålesund, Svea, Colesbukta, Pyramiden and Barentsburg. The results from the surveys showed that acid run-off was the main problem in areas with waste from mining activities. The surveys established the presence of PCBs in the following locations:

- **Ny-Ålesund:** location 6003 (Thiisbukta), 6013 (shaft 6) and 6014 (shaft 7) where small quantities of PCBs drain into Tvillingvatn. A subsequent survey did not find PCBs in Thiisbukta.
- **Sveagruva:** 0003 closed dump Svea.
- **Barentsburg:** 0080 Kapp Heer, 0066 laths in Colesbukta, and low levels of PCBs at location 0075 fuel tanks and 0079 dump from mines between Kapp Heer and the city boundary.

NGU surveyed nine landfill sites and dumps on Svalbard for PCBs (Eggen et al. 2010b). ∑7PCB was established in four of these, see table 3.2.2.2-1. In those cases where PCBs were established the levels were low. All the landfill sites are open and exposed to wind and weather. Measures have been taken to prevent leakages in Pyramiden.

3.2.2.2.1 Kinnvika

A research station was established in 1957-58 at Kinnvika on Nordaustlandet. In 2008, a student from the University of Tasmania, in cooperation with researchers from UNIS, conducted a survey of the contamination around the research station (Harris 2008). The analyses of the soil samples showed high concentrations of PCBs at some of the sampling points.

In 2011, Svalbard Environmental Protection Fund's granted funding for surveys of any dispersal of PCBs into sediments in the neighbouring area. Field work in 2011, which has been reported by Akvaplan-niva, showed low contamination levels. The results indicate that no further risk assessments or measures are required in the area (Evenset and Christensen 2012a and b).

3.2.2.3 Registration of contaminated ground and landfill sites

Contaminated ground and landfill sites are to some extent registered in Klif's Polluted Ground database. A digital map of areas with contaminated ground in Barentsburg and Pyramiden has been produced based on the PCB project's data.

PROPOSED MEASURES:

- Update the polluted ground database with all the surveys/locations in which polluted ground has been documented.

3.2.3 FLUVIAL SEDIMENTS - TRANSPORT OF EARTH AND ROCK IN FRESHWATER AND RIVERS

3.2.3.1 Wash-out of materials from land to the sea

Erosion processes and sediment transport in High Arctic rivers are very different from the processes on mainland Norway. The sparse vegetation and permafrost affect run-off conditions and erosion processes on slopes.

Sediment production in the rivers on Svalbard varies greatly, both between rivers and from year to year in individual rivers (Elverhøi et al. 1983; Kostrewski et al. 1989; Svendsen et al. 1989; Krawczyk and Opolka-Gadek 1994; Barsch et al. 1994; Hodson and Ferguson 1999). In the event of heavy precipitation, weathered materials are washed down mountainsides around glaciers and into rivers.

Precipitation floods and episodes of flooding linked to melting ice and rain usually result in short-term, high sediment content in river water, typically between 2,500 – 5,500 mg/l. Concentrations seldom exceed 500 mg/l during normal snow melting.

60% of Svalbard is covered by glaciers. There are glaciers in most catchment areas and the sediment budgets are determined by glacier erosion. NVE has carried out calculations of how much earth and rock/sediments rivers and glaciers on Svalbard transport out to sea. For catchment areas outside glaciers (based on Londonelva) this amounts to 82.5 tons/km^2/year, while in glacier areas (based on the Brøgger glaciers) it could be as much as 586 tons/km^2/year. In total this transport of earth and rock on Svalbard could thus total around 16 million tons per year (Hasholt et al. 2006).

ELEMENT	UNIT	SETTLEMENTS			BACKGROUND		
		MIN	MEDIAN	MAX	MIN	MEDIAN	MAX
PCB[1]	mg/kg	<0.004	0.046	28.7	<0.0001	0.0018	0.03
Arsenic (As)	mg/kg	<2	4.8	68	<1	6.8	108
Barium (Ba)	mg/kg	16	292	5260	9.4	107	860
Cerium (Ce)	mg/kg	<1	32.5	82.5	5	36	325
Chromium (Cr)	mg/kg	0.8	41.5	2340	4.1	22	174
Copper (Cu)	mg/kg	0.8	32.5	37900	0.92	20	163
Lanthanum (La)	mg/kg	3.4	17.5	41.8	3.1	18	189
Nickel (Ni)	mg/kg	0.8	26.6	1460	5	28	158
Lead (Pb)	mg/kg	1.6	27.2	13600	<1	12	85
Zinc (Zn)	mg/kg	11.5	153	14400	11	68	169

[1] Number of samples in which PCBs have been found: soil samples in densely populated areas (n=378) and background (n=83)

TABLE 3.2.3.2-1 Overview of PCB, arsenic and metal content in 378 soil samples from existing and abandoned settlements in Spitsbergen compared with natural background levels in 650 samples of flood sediments from Spitsbergen. Source Ottesen et al. 2010.

3.2.3.2 Annual flux of PCBs from land to the marine environment

NVE has carried out calculations of how much earth and rock is transported by individual rivers/streams in Barentsburg and Pyramiden. It is estimated that these can transport around 100 tons of earth and rock out into the fjord every year. The vast majority of this is transported during the spring flood and other flooding peaks in the summer (Benjaminsen 2009).

NGU has analysed the PCB content of soil from background areas and settlements, see table 3.2.3.2-1. The total annual flux of PCBs to marine areas has been calculated as 2.8 kg for ∑7PCB, 44.8 kg for mercury (Hg) and 19.8 kg for lead (Pb) (based on the figures from NGU and NVE above).

Finds of high PCB content in the samples on land in Pyramiden (see chapter 3.3.3.3.4) and verification of the transport of PCB contaminated soil from land may indicate that this is a possible source of the increased PCB content that has been measured in sediments off Pyramiden in 2005.

3.2.4 SNOW AND ICE

3.2.4.1 Svalbard

The snow cover and glaciers on Svalbard are steadily shrinking and surveys conclude that considerable quantities of PCBs and other POPs are deposited in the ice and snow masses (Hermanson et al. 2005). These substances are released when ice and snow melt, and can enter food chains (Jenssen, 2007).

3.2.4.1.1 Snow from Ny-Ålesund

Kallenborn et al. 2010 reported on ∑31PCB levels in surface snow and snow cores taken at the Zeppelin station:

- 2 pg/l in surface snow (0-40 cm)
- 2 - 88 pg/l in snow cores taken from a depth of 40-80 cm

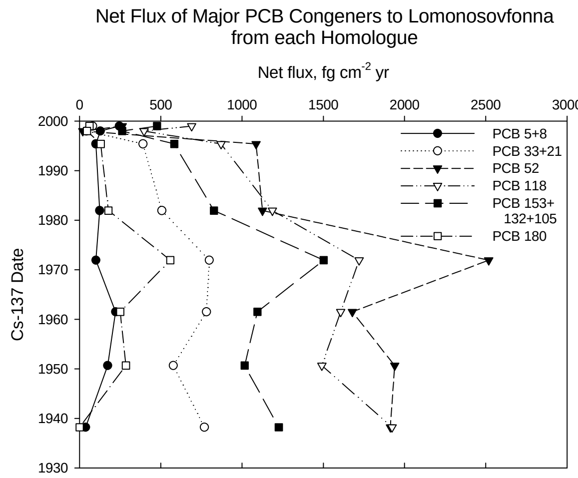
The concentrations correlated with surface snow temperatures. The highest values were registered during periods of high humidity and low sun radiation, and in connection with precipitation. The concentrations decreased in periods of strong sun, which indicates that the substances may have been remobilised.

An analysis of spring snow sampled in 2001 in Ny-Ålesund showed a PCB content of 742 pg/l. The studies support observations that PCB congeners with a low molecular weight can remain in a gaseous phase under the climatic conditions that prevail on Svalbard (Hermanson et al. 2005).

3.2.4.1.2 Ice from glaciers

The Norwegian Polar Institute takes samples of winter snow and ice from a number of glaciers (Lomonosovfonna, Holtedahlfonna, Austfonna, Linnebreen), and has done so for many years, to analyse PCBs and organic pesticides. Ice from ice cores from Lomonosovfonna (taken in 2000) have been analysed and a time series for PCBs established (Hermanson et al. 2005), see figure 3.2.4.1.2-1. The maximum PCB concentration (> 100 congeners) was 748 pg/l.

The analysis shows a clear reduction in the supply of PCBs via air currents after 1970. Little change has been seen in the composition of congeners, which indicates the presence of an effective atmospheric distillation process above Svalbard.



PICTURE 3.2.4.1.2-1 The graph shows the supply of PCBs after 1930, as these can be detected in measurements in ice from Lomonosovfonna. The measurements document a clear reduction in the supply of PCBs via air currents after 1970.
Source Norwegian Polar Institute.

In spring 2011, the Svalbard Environmental Protection Fund awarded funds to UNIS to carry out analyses of PCBs in ice from Lomonosovfonna.

3.2.4.1.3 Snow samples from Barentsburg
Typhoon has surveyed ∑15PCB[14] in snow in and around Barentsburg (Typhoon 2010). All 15 congeners could be detected. The maximum concentrations of individual congeners was for: PCB#118 – 29.1 ng/l meltwater; PCB# 138 – 19.0 ng/l; PCB#105 – 12.9 ng/l. The total average content of ∑15PCB amounted to 9.15 ng/l, while the maximum concentration was around 105 ng/l meltwater, and it was measured in snow samples taken from the areas by the helicopter pad.

3.2.4.2 Bjørnøya
Evenset et al. 2007 examined the supply of PCBs on Bjørnøya via precipitation, which included collecting and analysing snow samples. The result from the relevant catchment area (6.1 km^2) was that 8.4 g of PCBs arrived via snow per year.

3.2.5 WATER
It is not known whether any Norwegian measurements have been made in relation to freshwater from Spitsbergen. Typhoon has analysed freshwater in the area around Barentsburg. The analyses were based on samples of 2-3 litres of water. This indicates that there is a great deal of uncertainty concerning the analysis results.

3.2.5.1 Barentsburg
3.2.5.1.1 River and lake water
Since 2002, Typhoon has regularly sampled water from Stemmevatn, which is the source of drinking water for Barentsburg and Grøndalselva. The lake lies on the west side of Grønfjorden, while Grøndalselva lies on the east side of the fjord, just south of the buildings in Barentsburg. Based on water samples (which were a few litres in size) the analysis results indicate relatively large variations in PCB concentrations between the different years. The concentrations in the river water from Grøndalselva are generally slightly higher (1.5-3.6 times) than the concentrations in the lake. The reason for the variations from year to year is not known, but Typhoon indicates that fires in some ore landfills in 2006 – 2007 could be the reason why levels are higher in 2007 than in the other years.

In corresponding measurements conducted in 2010 (Typhoon 2010) analyses were conducted for ∑15PCB[15], and these detected the presence of congeners PCB#28, 31, 52, 101, 99, 118, 153, 105 and 138 in the river water. The following congeners were detected in the lake water:PCB #99 and 118 (spring[16]), and in the summer/autumn[17] they detected: PCB#28, 31, 52, 101, 99, 118, 153, 105 and 138.

The average concentration in the river water was ∑15PCB – 0.98 ng/l. The average concentration in Stemmevatn's surface water amounted to 0.16 ng/l ∑15PCB in the spring period. In the summer and autumn periods it was 1.79 ng/l.

3.2.5.1.2 Groundwater
Typhoon took 10 samples of "groundwater" in the summer and autumn of 2010 (Typhoon 2010). Of the 15[18] congeners they analysed for, only PCB#187 could not be detected. PCB#52, 99, 101, 105, 118, 138 and 153 were detected in 90-100% of the analysed samples. The highest detected concentrations were PCB#105 – 1.02 ng/l, PCB#101 – 0.87 ng/l, PCB#118 – 0.63 ng/l, PCB#128 – 0.60 ng/l. ∑15PCB was within the range 0.82 – 5.71 ng/l, with a mean value of 2.22 ng/l. The highest concentration of ∑15PCB was found in samples from the area around the sloping stream near the consulate.

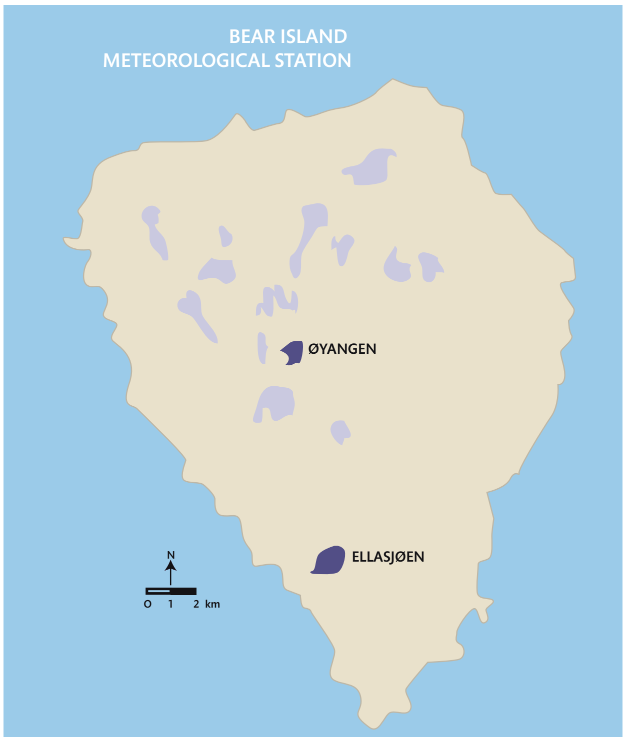
PROPOSED MEASURES:
- Measurements of PCBs in freshwater

3.2.5.2 Bjørnøya
Evenset et al. 2007 has analysed water samples from Ellasjøen and Øyangen on Bjørnøya for PCBs, see figure 3.2.5.2-1. The concentration was highest in Ellasjøen: 129 pg/l ∑11PCB compared to 23 pg/l in Øyangen. Part of the PCBs Ellasjøen receives is supplied via guano from seabirds (Evenset et al. 2007a).

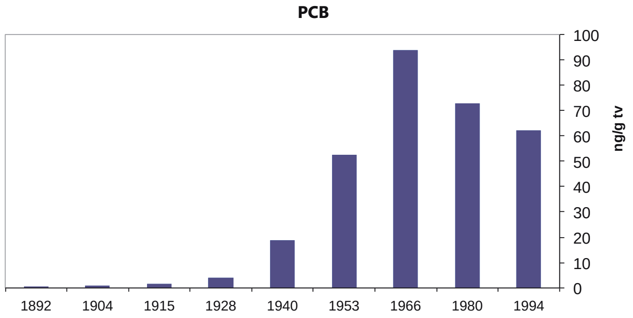
3.2.6 FRESHWATER/LACUSTRINE SEDIMENTS
3.2.6.1 Norwegian measurements
All lake sediments on Svalbard that have been surveyed: Kongressvatn, Linnévann, Barentsvatn, Arresjøen, Åsøvatn and Richardvatn, as well as Ellasjøen and Øyangen on Bjørnøya, contain PCBs (Christensen et al. 2008). The survey showed that the content of persistent organic pollutants in sediments is relatively high and significantly higher than what has been found in other areas of the Arctic and Northern Norway. The average concentration of ∑7PCB in sediments from the lakes on Svalbard (n=5) was 10.1 ng/g dw, while the average for the mainland (n=49) was around 1.9 ng/g dw.

The highest level was found in Ellasjøen on Bjørnøya (24.25 ng/g dw ∑7PCB). It has been established that Ellasjøen is affected by PCBs supplied via bird guano (Evenset et al. 2004, 2005, 2006, 2007 a and b), also see chapter 3.2.5.2. Kongressvatn, which is close to Barentsburg, has the next highest measurement, 15,79 ng/g dw. Relatively high values were also demonstrated in Åsøvatn (6.09 ng/g dw). The measurements, which were carried out in 2004-2006, indicate somewhat lower values than earlier measurements (Skotvold et al. 1997).

3.2.6.2 Russian measurements
Sediments from Stemmevatn and Grøndalselva were analysed for PCBs as part of Trust Arktikugol's surveying of environmental pollutants. The measurements made by Typhoon show that the trend for ∑7PCB in bed sediments (ng/g dw) in Stemmevatn and Grøndalselva has been sinking since the measurements started in 2002 (Typhoon 2009). Typhoon assumes the increase was related to a fire in some of the old ore landfills in 2006- 2007.



PICTURE 3.2.5.2-1 The map shows Ellasjøen and Øyangen which are situated in Bjørnøya. Source Evenset et al. 2007.



PICTURE 3.2.6.3-1 Concentrations of ∑18PCB in a dated sediment core from Ellasjøen in Bjørnøya. Supply was at its highest in the period from 1960-1972. Source Evenset et al. 2007b.

In corresponding measurements in 2010 (Typhoon 2010) ∑15PCB were analysed for and congeners PCB#28, 52, 101, 105, 118, 138, 153, and 180 were detected. The levels of PCBs in Grøndalselva were – 2,14 ng/g, in bed sediments in Stemmevatn – 3,72 ng/g.

3.2.6.3 Time variations

Trümper et al. 2012 (in prep.) document annual variations of PCBs in freshwater sediments near Barentsburg from 1930 up to the present day.

Variations in supply rates of PCBs to sediments have been determined in Ellasjøen on Bjørnøya. The results (∑18PCB dw) showed that the supply rates were highest in the period 1960-1972, see figure 3.2.6.3-1 (Evenset et al. 2007b).

Akvaplan-niva has sediment cores from some of the other lakes in Svalbard. These can be used for studies of time trends for PCBs and other environmental pollutants, as well as estimating background values.

3.3 IN THE SEA (MARINE ENVIRONMENT)

3.3.1 SEAWATER

3.3.1.1 In general

The intake of, and resulting levels of PCBs in species lower down in the Arctic food chain, is governed by exposure to unbound PCBs in seawater (MacDonald et al. 2000; Fisk et al. 2001; Schwarzenbach et al. 2003; Borgå et al. 2004; Sobek et al. 2006; Sobek et al. 2010).

Around 30% of long range transported particulate PCBs arrive in Svalbard via oceanic currents (Roland Kallenborn, personal statement).

Long range transported PCBs enter the sea areas around Svalbard via atmospheric deposition, sea ice and oceanic currents. There are also local sources that supply the seawater and fjords with PCBs via rivers, snow, dust, etc.

3.3.1.2 Svalbard's fjords

Some studies of PCBs in seawater have been conducted, including AMAP/Olsson 2002.

3.3.1.2.1 Kongsfjorden

PCB concentrations were measured in seawater from Kongsfjorden as part of COPOL (see chap. 7.4). The levels varied between 13.1 ∑8PCB pg/l in May and 6.0 pg/l in October. Seasonal variations in PCB quantities were found in which the highest concentrations were found before and during the spring bloom (Hallanger et al. 2011). It is believed that the reason concentrations decrease as the season passes is that the organisms take up environmental pollutants from bodies of water and that these then evaporate or degrade photochemically as the ice disappears and the water warms up (Hallanger et al. 2011).

3.3.1.2.2 Grønfjorden

Typhoon has carried out measurements of PCBs in seawater in Grønfjorden in the spring and autumn. Typhoon, 2009, established the the Russian limit was exceeded by a factor of 8.3 in the spring measurements

3.3.1.3 Bjørnøya

Seawater collected near Bjørnøya shows concentrations of 10 pg/l ∑18PCB (Evenset et al. 2002).

3.3.1.4 Sea areas around Svalbard

Little data exists for PCBs in seawater. Carrizo et al. 2011 carried out measurements of unbound and particulate PCBs in seawater in the Arctic mixed layer (AML) in the areas surrounding Svalbard. The measurements were between 352 and 2624 fg/L ∑12PCB (unbound + particulate). They highest values were found off the east coast of Spitsbergen. Unbound ∑13PCB varied between 94 – 1748 fg/L and particulate between 222 –876 fg/L.

3.3.1.5 Barents Sea

3.3.1.5.1 Atmospheric deposition of PCBs in seawater

Green et al. 2010 calculate the supply and dispersal of environmentally hazardous substances in Norwegian sea areas, including the Barents Sea. The supply of ∑7PCB from the air to the sea area east of Svalbard in 2007, taking dry deposition into account, was calculated as 610 kg. It should be emphasised that net supplies from air to sea are expected to be smaller because the substances/congeners can also evaporate back from the sea into the atmosphere. Evaporation varies from congener to congener and also depends on, for example, external physical conditions. Air measurements and meteorological data from 2007 from the Zeppelin station (Aas et al. 2008) and Bjørnøya (www.met.no), respectively, was used in the calculations. Observations made in the Barents Sea show that particulate bound PCBs account for a higher proportion in water than the unbound proportion of PCBs (Gustafson et al. 2005; Detlef et al. 1991).

The supply of PCBs to the sea surface from the atmosphere was calculated as a constant flux covering the entire surface of the sea and the supply data was obtained from Molvær et al. 2008 and new calculations from NILU.

3.3.1.5.2 Supply of PCBs via oceanic currents

The supply of PCBs to the Norwegian sector of the Barents Sea by oceanic currents has been calculated using the ECOSMO model (Schrum et al. 2005; Green et al. 2010). The information about background concentrations used in the model simulations was largely obtained from the data Inventory (http://www.ices.dk) of the International Council for the Exploration of the Sea (ICES), available reports and information from the Oslo Paris Commission (OSPAR, http://www.ospar.org) and scientific publications (e.g. Gustafson et al. 2005; Schulz-Bull et al. 1998).

3.3.1.5.3 The ECOSMO model

The model (Green et al. 2010) describes the transport pathways and concentrations for substances including PCBs, and provides the spatial variation in the Barents Sea in various hydrodynamic situations. The circulation model for the Barents Sea was used in the calculations (Schrum et al. 2005). This hydrodynamic model has been validated (Årthun and Schrum, 2010) and can reproduce the annual variations in hydrological conditions.

3.3.1.5.4 Model calculations of variations of PCBs in the Barents Sea

The results from the ECOSMO model simulations show that the atmosphere is the most important source of PCBs with respect to quantity (Schrum et al. 2005; Green et al. 2010). The model results also show that the distribution of PCBs and subsequent concentrations in surface water and bottom water of between 0-65 pg/l. There are large variations between seasons, especially around Svalbard. An increased supply of PCBs with melt water from sea ice, layer formation in the ocean due to warming, and increased melt water in the summer will result in higher concentrations of PCBs in surface water in the northern part of the Barents Sea.

The results show that at times of intense sea circulation one can expect higher concentrations of PCBs that propagate far in the sea and higher concentrations in water at the bottom than at times of weak circulation.

The results may indicate higher concentrations of PCBs in the surface layer in the western part of the Barents Sea when there is little wind and weak circulation. The calculated PCB concentrations span the entire range from 0 to 40 pg/l, which indicates a large degree of spatial variation for PCBs in the Barents Sea. Concentrations of PCBs in bottom water can especially vary a lot between close-lying areas.

3.3.2 SEA ICE

There is little data about concentrations of PCBs in ice, and those that exist show great variations. The Pollution Monitoring Programme's calculations, see chapter 3.3.1.5 above, use a PCB concentration of 30 pg/l, a value consistent with published observations (Gustafson et al. 2005).

PROPOSED MEASURES:

- Measurements of PCBs in sea ice

3.3.3 MARINE SEDIMENTS

3.3.3.1 In general

Long range transported PCBs bound to particles can sink to the bottom and supply the bottom sediments with substances. PCBs can also be supplied to sediments from local sources on Svalbard via rivers, melting snow, dust, etc. The layers of sediment constitute an 'environmental archive' that shows the development of PCB transport, also see chapter 3.2.6.3.

The substances are usually bound to fine grain sediments that are rich in organic carbon (e.g. organic residues from algae and organic materials transported from land). The reservoir of substances/congeners that over time are stored in the bottom sediments depend on two factors:

1) concentrations of environmental pollutants in materials that sediment, and
2) sedimentation speed

Dating sediment cores enables you to determine sedimentation speed in different areas. Information about PCB levels in different core segments combined with information about sedimentation speed can be used to calculate the supply rate in different periods.

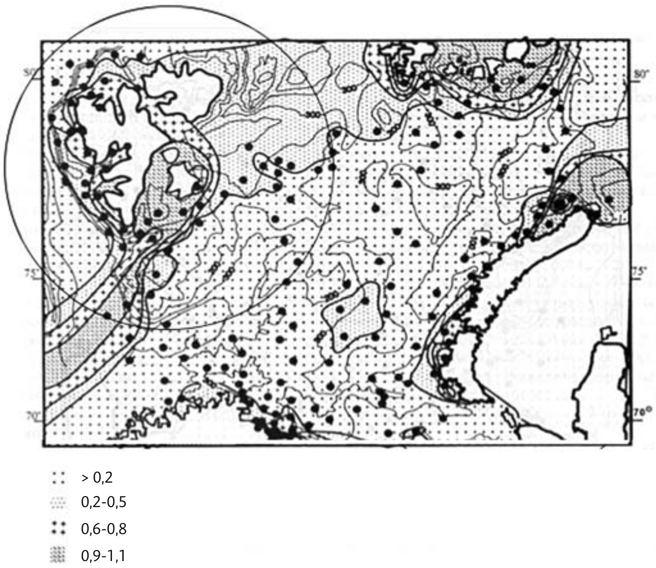
Sediment-dwelling invertebrates are exposed to the bioaccessible portion of the contaminants in the sediments. As prey for organisms higher in the food chain, they can therefore act as a link in the transfer of PCBs between sediment and animals higher up the food chain.

3.3.3.2 The Barents Sea and immediate area around Svalbard

PCB contamination in sediments in the Barents Sea has been surveyed by Sevmorgeo, and in connection with the Barents Sea Management Plan, (Green et al. 2010).

3.3.3.2.1 Sevmorgeo

Figure 3.3.3.2.1-1 shows the collated results from Russian surveys of PCB contamination in sediments in Barents Sea (Ivanov 2006).



PICTURE 3.3.3.2.1-1 Russian compilation of older PCB measurements in marine sediments from the Barents Sea Unit ng/g. Source Ivanov 2006.

3.3.3.2.2 Barents Sea Management Plan

Green et al. 2010 documents average concentrations in surface sediments in the sea area east of Svalbard. The concentrations lie in the range 0.5-0.7 µg/kg ∑7PCB dw.

If one compares measured sediment concentrations with modelled summer concentrations in bottom water, (ref. chapter 3.3.1.5.4) an explanation for the observed sediment concentrations emerges. The sediment measurements show sediment concentrations increase from the south to the north and from the west to the east. This pattern can be explained by increasing summer concentrations in the bottom water in the north due to increasing PCB supply from melting sea ice, and increasing sedimentation in the summer due to biological activity.

3.3.3.2.3 The MAREANO project

The MAREANO project (see chap. 7.4) has taken sediment samples in the area between Spitsbergen and Bjørnøya. The samples have not been analysed for PCBs. The MAREANO samples are used to verify and supplement the surveys conducted by Sevmorgeo and modelling carried out in the Pollution Monitoring Programme to gain a better understanding of the quantities and distribution of PCBs.

PROPOSED MEASURES:

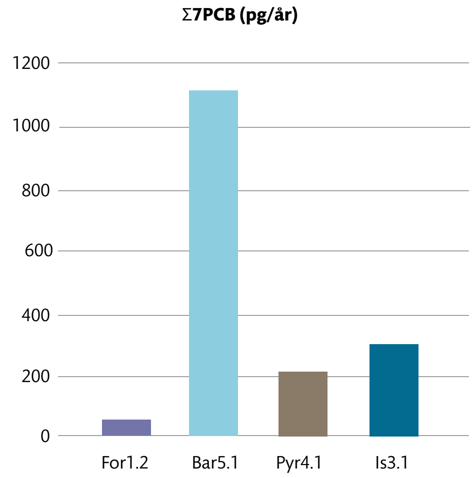
- PCB analyses of MAREANO samples from the Svalbard region

3.3.3.3 Svalbard's fjords

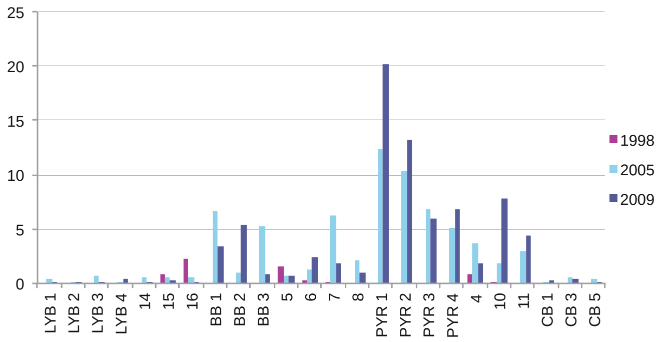
A number of surveys of marine sediments have been conducted in Svalbard's fjords: Kongsfjorden, Liefdefjorden, Adventfjorden, Grønfjorden, Billefjorden, Colesbukta, Isfjorden and Hornsund (Skei 1993; Holte et al. 1994; Cochrane et al. 2001; Hop et al. 2001; Evenset et al. 2006 and 2009; Tessmann 2008).

In general , the surveys of the marine sediments show that the levels of organic environmental pollutants, including PCBs, are higher outside the settlements than in other marine areas around Svalbard. This indicates that the marine environment in these areas are affected by local sources.

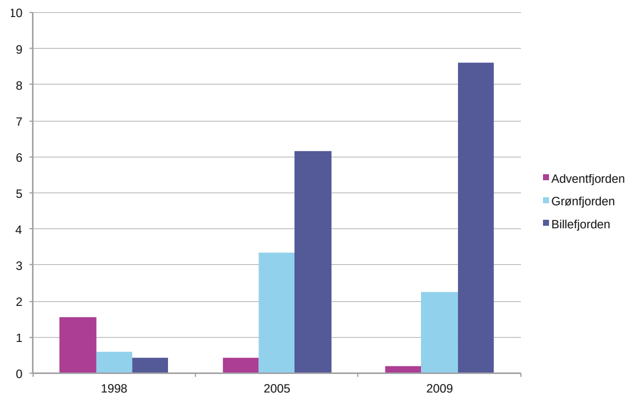
The PCB contamination in Grønfjorden and Billefjorden have a different range/composition of congeners to that in Adventfjorden, Isfjorden and Kongsfjorden. This indicates that the contamination comes from local sources (Hop et al. 2001; Evenset et al. 2009).



PICTURE 3.3.3.3-1 Calculated supply of ∑7PCB to the bed sediments at Forlandsundet, Barentsburg, Pyramiden and Isfjorden in the period from 1988-1998. Source Cochrane et al. 2001.



PICTURE 3.3.3.3-2 Time trends for ∑7PCB in sediment from Isfjorden (unit µg/kg dw). Data from 1998 Cochrane et al. 2001, from 2005 Evenset et al. 2006, and 2009 from Evenset et al. 2009. LYB1=16 stations in Adventfjorden, BB1=8 in Grønfjorden, PYR1=11 in Billefjorden, CB1–CB5=Colesbukta.



PICTURE 3.3.3.3-3 Average ∑7PCB concentrations measured in µg/kg dw in sediment from Adventfjorden, Grønfjorden and Billefjorden in 1998 (Cochrane et al. 2001), 2005 (Evenset et al. 2006 and 2009). The figures for 1998 are based on fewer stations than the figures from 2005 and 2009.

Cochrane et al. 2001 calculated the supply of various environmental pollutants, including PCBs, to sediments in Forlandsundet, Grønfjorden, Billefjorden and Isfjorden. The sedimentation speed was highest in Barentsburg, followed by Isfjorden, Pyramiden and Forlandsundet. The supply of environmental pollutants to the seabed was highest in the area off Barentsburg, due to sedimentation speed and relatively high concentrations of environmental pollutants in the supplied materials, see figure 3.3.3.3-1. A comparison between the areas shows that the supply of chloro-organic compounds in the period 1988-1998 was 3-5 times higher in the area outside Barentsburg than to areas off Pyramiden, Isfjorden and Forlandsundet. This indicates an active source of PCBs. As follow-up to the results from the environmental monitoring, large quantities of PCB-containing equipment have been removed from Barentsburg, see chapter 4.1.6.4.

Marine sediments off abandoned and active settlements are covered by a monitoring programme run by the Governor and samples are taken every 5 years (Cochrane et al. 2001; Evenset et al. 2006 and 2009). Some stations have been sampled several times and this has made it possible to make a gross assessment of time trends, see figure 3.3.3.3-2. As figure 3.3.3.3-3 shows, the concentration of PCBs in Billefjorden increased from 1998 up to 2009, while the levels in sediments off Barentsburg decreased during the same period. Sediments from Adventfjorden and Colesbukta have low PCB concentrations and no large changes over time have been detected (Evenset et al. 2009).

3.3.3.3.1 Kongsfjorden

The COPOL project has taken sediment samples from Kongsfjorden (May, July, October 2007, July 2008 and July 2009) and from Liefdefjorden (July 2008 and 2009). The samples have been analysed for a large number of organic environmental pollutants, including PCBs. The analysis results show low levels of PCBs are present in sediment from Kongsfjorden (Tessmann 2008).

The results from other surveys (Olsson et al. 1998 and Skei 1993) also showed that there were low concentrations of PCBs in sediments from Kongsfjorden, off the coast of Ny-Ålesund, but they were slightly elevated near Kullhamna (Thiisbukta, where polluted ground has also been registered. Also see chapter 3.2.2.2).

3.3.3.3.2 Isfjorden

Hop et al. 2001 documented local PCB contamination off the settlement in Isfjorden by measuring bottom-dwelling marine organisms. The concentrations were generally relatively low. Because the concentrations in benthic fauna were higher in the areas close to settlements than in the areas further out in the fjords it was concluded that local sources were more important than long range transport sources.

3.3.3.3.3 Grønfjorden

Norwegian surveys

A number of surveys (Holte et al. 1994; Hop et al. 2001; Evenset et al. 2006 and 2009) show that the marine environment in Grønfjorden is affected by local PCB contamination and other organic environmental pollutants from Barentsburg. The levels of chloro-organic compounds in sediments from Grønfjorden vary, but they are higher than those measured in sediments from areas without local sources. The PCB concentrations are, for example, up to 5 times higher than what has been measured in sediments from Kongsfjorden (Tessmann 2008).

PCBs are the dominant environmental pollutants in the samples from Grønfjorden and dioxin-like PCBs constitute a significant proportion of ∑PCB in many of the samples (from 0 – 43% in 2008). However, the samples' total dioxin toxicity (TEQ) was nonetheless low. The concentrations in the sediments varied from 0.53 – 8.76 µg/kg ∑59PCB dw. ∑7PCB varied from 0.33 – 3.29 µg/kg dw.

Russian surveys
Typhoon has conducted surveys of sediments in Grønfjorden in the areas near Barentsburg (Typhoon 2009 and 2010). Samples have been taken from fixed stations, see figure 3.3.3.3.3-1.

The annual variation in the average values for sampling points 14 and 15 are shown at the top of figure 3.3.3.3.3-2. After decreasing from 2003 to 2007, there was a large increase in 2008 (Typhoon 2009). The measurements for 2009 show a decrease again. Typhoon concludes that the increase in 2008 was due to the washing out of PCB-containing materials from the ore landfill fire in 2006-2007. The variation in sampling points 10 – 12, which lie further out from the shoreline, are shown at the bottom of the figure 3.3.3.3.3-2.

Since the stations used in the Russian and Norwegian surveys are not the same, the results cannot be directly compared, but the PCB levels Typhoon measured in sediments from Grønfjorden are of the same magnitude as those measured by Akvaplan-niva in the same area.

3.3.3.3.4 Billefjorden
Evenset et al. 2006 concluded that the area off Pyramiden was affected by PCBs. Concentrations here increased from 1998 to 2005 and again up to 2009 (see figure 3.3.3.3-3), which indicates an active source of PCBs in the area. Large quantities of PCB-containing equipment have now been removed from Pyramiden as part of the follow-up of the results from environmental monitoring, see chapter 4.1.6.4.

3.3.3.3.5 Colesbukta
Samples were taken at three stations in Colesbukta in 2005 and 2009 (Evenset et al. 2006 and 2009). The PCB levels were low, see figure 3.3.3.3-2.

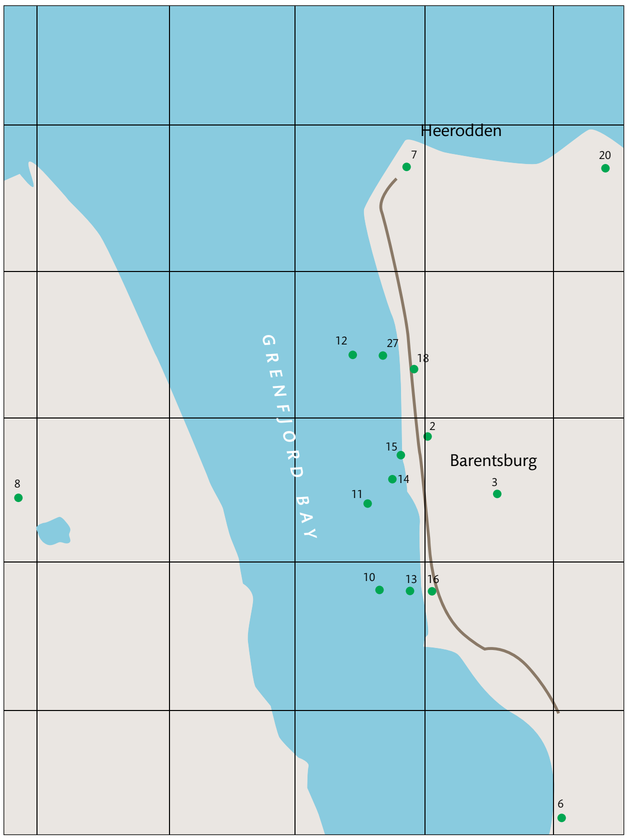
3.3.3.3.6 Van Mijenfjorden and Grumant
Akvaplan-niva has on behalf of Store Norske Spitsbergen Gruvekompani taken sediment samples in Van Mijenfjorden (Velvin and Evenset 2008; Evenset and Christensen 2009). No presence of PCBs was established in sediments from Van Mijenfjorden (the levels were below the detection limit).

There are no other surveys of PCB contamination in sediments in Van Mijenfjorden and Grumant. The area contains tips that are potential sources of contamination, ref. Klif's polluted ground database.

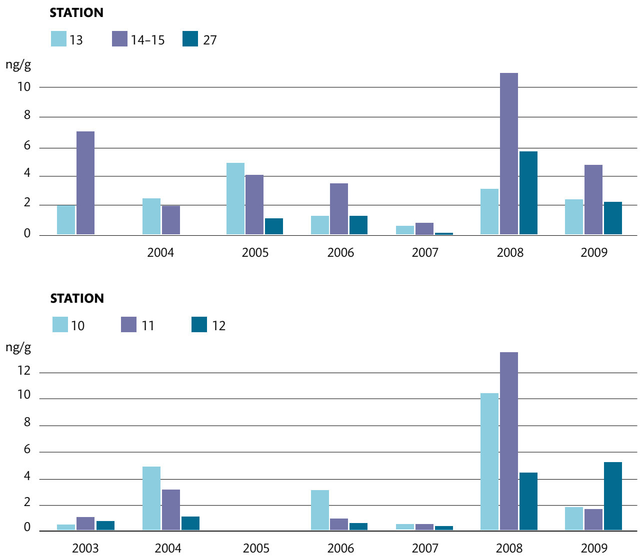
Murchisonfjorden
Surveys, based on the survey by Harris, 2008, were conducted in 2011 to delimit PCB contamination and map any dispersal to sediments off Kinnvika, see chapter 3.2.2.2.1.

PROPOSED MEASURES

- Classification system for contaminated sediments
- Monitor developments in marine sediments off settlements with samples being taken every 5 years (2010, 2015…), including new sampling points (off burning stone tips in Barentsburg)
- Surveys of the bioaccessibility of PCBs in sediments and potential for dispersal further along the food chains through analyses of benthic fauna collected off the Norwegian and Russian settlements (comparison of levels and congener profiles)
- Surveys of sediment toxicity
- In vivo (lab experiments) bioaccumulation surveys of sediments combined with estimating interstitial water concentrations with the aid of passive samplers



PICTURE 3.3.3.3.3-1 Locations of Typhoon's stationary monitoring stations. Source Typhoon.



PICTURE 3.3.3.3.3-2 ∑18PCB in sediments in Grønfjorden outside Barentsburg 2009. Source Typhoon.

3.4 PEOPLE, PLANTS AND ANIMALS

3.4.1 PEOPLE

It is not known if any measurements of PCBs in people in Svalbard exist.

PROPOSED MEASURES:

- Adults on Svalbard have largely lived most of their lives in other places in Norway and the world. There are people who were born and grew up on Svalbard and some who have spent most of their lives here. It would be interesting to look at the PCB levels of those who have spent the most time on Svalbard and compare different groups (e.g. from Longyearbyen and Barentsburg) or compare the settlements to see if there are major differences.

3.4.2 PLANTS

The content of environmental pollutants and heavy metals in plants is normally low. Moss samples from Ny-Ålesund and Bjørnøya have been analysed, including for PCBs (Tveter, 2005). The levels in moss from Ny-Ålesund were lower than those in moss from Bjørnøya, but the data was very limited.
Typhoon (Typhoon 2004) has collected samples of moss from Barentsburg. The samples have been analysed for a series of environmental pollutants, including PCBs. Typhoon concludes that the concentrations of chloro-organic pollutants are higher within the built up area of Barentsburg (average ∑18PCB 279 μg/kg, variation 70.3-132 μg/kg) than in the neighbouring areas (average ∑18PCB 116 μg/kg, variation 6.94-293 μg/kg) and so-called reference areas (average ∑18PCB 47 μg/kg, variation 15.9 – 123 μg/kg).

Samples of moss and vascular plants were collected in 2010 (Typhoon 2010). Of the 15 congeners that were analysed for, concentrations of PCB#52, 99, 101, 105, 118, 138 and 153 were detected in all samples of moss and vascular plants. The rarest two that were found in the vegetation samples were PCB#170 and 183. The average for ∑15PCB was 589.7 μg/kg in moss and 97.5 μg/kg in vascular plants.

The highest concentrations in both moss and vascular plants were found in the samples collected to the north-east and east of the settlement, and at the stone tips and slag tip for the thermal power station.

PROPOSED MEASURES:

- Surveys of PCBs in vegetation

The PCB concentrations detected in arctic foxes are up to 40% higher than the levels that were measured in polar bears (AMAP 2004a). This provides reason to believe that the contamination may affect the immune and reproductive systems in arctic foxes. Photo: Halvard R. Pedersen

3.4.3 LAND MAMMALS

3.4.3.1 Svalbard reindeer *(Rangifer tarandus zplatyrhynchus)*

Svalbard reindeer is a separate subspecies among the seven remaining subspecies of reindeer in the Arctic and is indigenous to Svalbard. Some individuals appear to have adapted to living and grazing in settlements. They can take up PCBs and other pollutants from local sources through particulate PCB pollutants that attach themselves to vegetation. Analyses of samples from Svalbard reindeer from Nordenskiöldland produced values below the detection limit for PCBs and close to the detection limit for one of the decomposition products (hydroxy metabolites) of PCBs (Polder et al. 2009).

3.4.3.2 Arctic fox *(Vulpes lagopus)*

The Arctic fox is the only wild carnivorous land mammal on Svalbard. The species is found over the entire archipelago. The Arctic fox is common in the settlements and is an omnivore (opportunist). Analyses of PCBs in tissue samples from Arctic foxes from Svalbard show concentrations of 10-12 µg/g ∑7PCB lw), (Norheim, 1978; Wang-Andersen et al. 1993; Severinsen and Skaare, 1997; AMAP, 2004; Fuglei et al. 2007). The take up of PCBs is probably related to long range transported pollutants. This is because the Arctic fox on Svalbard largely subsists on the marine food chain, e.g. carcasses of seals caught by polar bears, seal pups on the ice in spring, seabirds and eggs from bird cliffs. Only a small proportion of the population lives close to local sources of PCBs and in their case affects from local sources of PCBs cannot be excluded. No samples from Arctic foxes that live in the proximity of settlements have been analysed. NP collects samples from foxes caught in traps every year.

PCBs have been analysed for in fat and liver samples from Arctic foxes collected in the periods 1973-74, 1983-84, 1991-92 and 1998-99. The pattern of PCB congeners in Arctic foxes is similar to that found in polar bears. This is interpreted as meaning that the metabolism and possible effects on vital functions like reproduction, immune response, and endocrine "homeostasis" are the same (AMAP 2004a). The PCB concentrations detected are up to 40% higher than the levels that were measured in polar bears (AMAP 2004a). This provides reason to believe that the contamination may affect the immune and reproductive systems in Arctic foxes.

The geographical trends found in Arctic foxes match the trends founds in polar bears. The highest values for environmental pollutants were found on Eastern Greenland and Svalbard, while the values in Canada were average and the lowest were in Alaska. Recent studies have shown that the levels of environmental pollutants in Arctic foxes are strongly related to where in the food chain they find their food and the degree to which their food is marine or terrestrial. The results from Svalbard show that the highest levels of environmental pollutants can be found in Arctic foxes who eat food that is high up in the marine food chain. The geographical differences in Arctic foxes can also be linked to the two different types of habitat in which Arctic foxes live: inland and coastal. In other words, foxes that have primarily eaten animals that live on land (e.g. ptarmigan and reindeer) have lower PCB levels than foxes who have eaten animals that live in the sea (e.g. seals). The higher levels of environmental pollutants in Arctic foxes on Svalbard and Iceland can be explained by the fact that their diet is more marine compared with Arctic foxes in Canada and Alaska.

The fat reserves of Arctic foxes change dramatically over the year. The highest fat level, more than 20%, is attained in November-December and decreases over the spring to a minimum of 6% in the summer. Arctic foxes also experience extreme variations in fat reserves during the winter in periods when food is scarce, The large yearly natural fluctuations in the deposition of body fat provides an opportunity to release toxins from fat stored in tissue to organs in which effects can occur, e.g. the liver and brain. It has been shown that this seasonal variation affects the redistribution of PCBs in the bodies of Arctic fox and that this in turn affects enzyme activity in the liver (Helgason 2011). The animals in the best condition and with the highest fat content have lower levels of environmental pollutants than animals that are in poor condition. Arctic foxes have little body fat in those periods when they experience a relatively high degree of physiological stress, e.g. during the breeding period in the spring/summer and in periods of hunger during the winter.

Little is known about the effects these high levels of environmental pollutants have on, for example, nursing mother foxes and pups or on foxes that do not find food and have to drain their fat reserves during the winter. Weakened immune systems have been found in Greenland sled dogs fed on whale blubber that contains high levels of environmental pollutants (Sonne et al. 2006). There is therefore reason to believe that the current high levels of environmental pollutants may have a negative effect on the immune and reproductive systems of Arctic foxes.

PROPOSED MEASURES:

- New environmental pollutant surveys should be conducted for Arctic foxes on Svalbard since 10-15 years have now passed since the last surveys were conducted.

3.4.4 MARINE MAMMALS

In general, levels of environmental pollutants in marine mammals increase with age and are higher in males than females. This is because females flush out PCBs in breast milk. Different levels of PCBs in different species are influenced by diet and habitat use. The capacity of different species to break down PCBs also varies greatly.

Even though the available information about the various marine mammal species comes from different tissue types, genders and age groups, and is consequently not ideal for comparison, much indicates that ringed seals, bearded seals, walruses and minke whales have relatively low levels of organic environmental pollutants.

Trend studies from Canada and the European Arctic show a decrease in PCB levels (de Wit et al. 2004; Gabrielsen and Henriksen 2001; Gabrielsen 2007; Wolkers et al. 2008; Rigét et al. 2010).

3.4.4.1 Polar bear *(Ursus maritimus)*

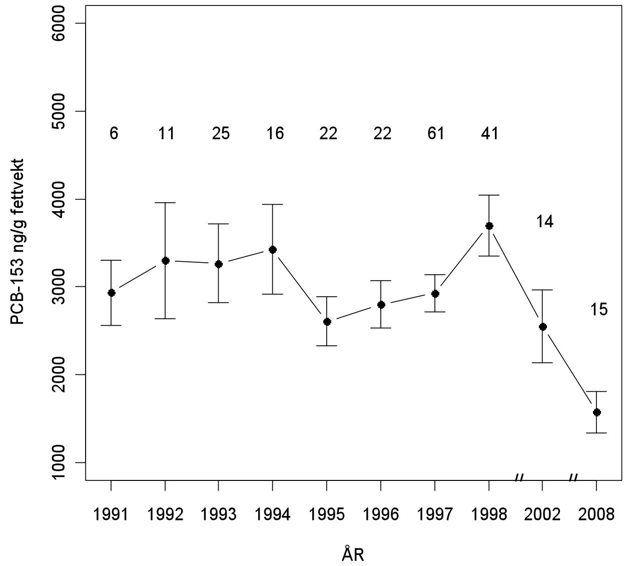
The polar bear is a top predator in the marine food chain. It primarily lives off seals and often contents itself with just blubber. This accumulates relatively high levels of PCBs and polar bears thus accumulate high levels of PCBs. Levels increase with age and are higher in adult males than females because the females effectively transfer PCBs to their offspring via breast milk. The PCB levels are higher in the body fat of the offspring than in the mother (Bernhoft et al. 2007, Lie et al. 2000).

The concentrations in blood samples from polar bears are around 100 times higher than in Norwegian women (Skaare et al. 2000).

The levels of environmental pollutants in polar bears have passed the thresholds for affecting the hormone and immune systems (Institute of Marine Research 2010b) and one can expect the reproductive ability and/or survival of certain individuals to be affected. It has been shown that the level of chlorinated organic compounds found in polar bears on Svalbard is related to hormone levels and the functionality of their immune system. Levels of the hormone thyroid were low when PCB concentrations were high and other studies show that the survivability rate of polar bear offspring on Svalbard may have developed poorly when high concentrations of chlorinated organic compounds were present (de Wit et al. 2004).

An overall assessment indicates that the polar bear must be monitored with regard to both the levels and the effects of environmental pollutants.

A study of chlorinated organic compounds in polar bears, which covers 11 different populations in Alaska, Canada, Greenland and Svalbard, shows that concentrations of ∑72PCB in fat samples on Svalbard can be compared with PCB levels from Eastern Greenland and north-east Canada (McKinney et al. 2011). ∑72PCB varied from 3 to 9 ng/g lw in samples collected from polar bears on Svalbard in 2007.



PICTURE 3.4.4.1-1 Developments from 1991 to 2008 of PCB#153 in polar bears from Svalbard measured in blood plasma. Average value with ± 1 SEM. The data in the figure specify the number of samples (from Henriksen et al. 2001; Verreault et al. 2005 and more recent data from Norwegian Polar Institute)

The levels of environmental pollutants in polar bears have passed the thresholds for affecting the hormone and immune systems and it can be expected that reproduction and/or survival are affected for certain individuals. Photo: Bjørn Franzen

Concentrations of PCBs and other chlorinated organic compounds increase from the western to the eastern populations of polar bear. This may indicate major air and sea-based long range transport of PCB compounds from Western and Eastern Europe into the Barents Sea and Svalbard region.

Surveys show that the health situation of polar bears is influenced by foreign substances. The populations in Greenland and on Svalbard are especially affected by chlorinated organic compounds (Gabrielsen 2007; Letcher et al. 2010). Polar bears are primarily contaminated by PCBs.

PCB#153 is one of the most metabolic resistant, or persistent, PCB compounds and generally has the highest concentrations in mammal and birds. Surveys of PCB#153 in polar bear blood plasma in the Svalbard area from 1990 to 2008 show stable levels in the period 1991-2002 (figure 3.4.4.1-1). Concentrations of PCB#153 fell significantly from 2002 to 2008. However, the samples from 2008 that were analysed were only from females without offspring that year. This means the average for 2008 might be slightly overestimated.

Metabolites from PCBs in mammals primarily consist of hydroxylated (OH) and methylated ($MeSO_2$) PCB compounds. Analyses of PCBs and their metabolites found OH-PCB compounds in higher concentrations than the concentrations of original PCB compounds in polar bear blood on Svalbard (Verreault et al. 2005b). This indicates that the capacity of polar bears to metabolise PCBs is high, which results in the formation of OH-PCB compounds. Nonetheless, low concentrations of $MeSO_2$ PCB compounds were measured in polar bears on Svalbard (Verreault et al. 2005a).

PROPOSED MEASURES:

- The monitoring/research on polar bears should continue. The link with effect parameters is important and any population effects should be documented.

3.4.4.2 Seals

The average PCB concentrations in the blubber of ringed seals, harp seals and walruses were 0.5-9.5 µg/g lw (Kleivane et al. 2000; Wolkers et al. 2006b; Wolkers et al. 2008). The highest levels were measured in harp seals, followed by walruses and ringed seals. Large variations in concentrations of environmental pollutants between geographic areas have been found in harp seals. The level of PCBs found in biopsy samples from fatty tissue in harp seals from the eastern ice fields (from the White Sea) were three times higher than in samples from the western ice fields (from the area around Jan Mayen) (de Wit et al. 2004; Henriksen et al. 2001; Gabrielsen 2007).

3.4.4.2.1 Ringed seal (Phoca hispida)

There is no systematic monitoring of environmental pollutants in ringed seal, but samples were taken in Kongsfjorden on Svalbard in 1996, 2004 and 2010. Samples from 1996 and 2004 show a marked decrease in PCB levels, figure 3.4.4.2.1-1. The samples collected in 2010 will be analysed in the near future as part of the COPOL project.

The decrease in environmental pollutants was most marked in adult animals, but the levels in young animals have also decreased.

Given the current level of persistent organic pollutants in ringed seal on Svalbard this is no reason to believe that pollutants exceed limits for effects on the immune, hormone and reproduction systems of animals (Letcher et al. 2010). Negative effects have been found in seals from the Baltic Sea. The levels of environmental pollutants in ringed seal and common seal collected in the Svalbard region is just 5-13% of the concentrations reported in seals from the Baltic Sea and North Sea (Wolkers et

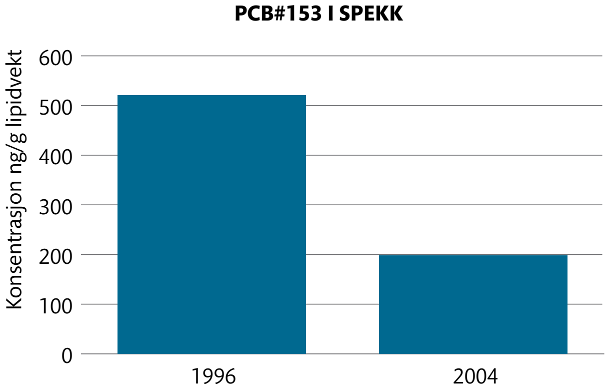
Blubber samples from white whales from the Svalbard area show higher levels of PCBs than samples that were analysed from Canada and Greenland. The levels of environmental pollutants in several whale species are rising from Canada and Greenland towards Svalbard levels. Photo: Halvard R. Pedersen.

al. 2004; Routti et al. 2008). PCBs dominate (52%), followed by DDE (23%) and chlordanes (17%).

Ringed seal have a higher capacity to convert environmental pollutants than Glaucous Gulls, but lower than polar bears (Routti et al. 2008; Routti et al. 2009a). Conversion capacity was higher in the Baltic Sea, which means that conversion increases with increased levels of environmental pollutants (Routti et al. 2008).

The Institute of Marine Research 2010b recommends including OH-PCB when monitoring environmental pollutants in ringed seal.

Ringed seals are important prey for polar bears and PCB measurements of ringed seals may therefore tell us something about the exposure of polar bears.



PICTURE 3.4.4.2.1-1 PCB#153 in blubber from ringed seal. Source MOSJ.

3.4.4.3 Whales

Samples from whales from the Svalbard region show lower levels of environmental pollutants than whale samples collected from southern sea areas. Concentrations of PCBs in fat samples from fish eating whale species (white whales and narwhal) varies between 3-9 µg/g lw. The highest levels of PCBs in whales from the Svalbard area have been measured in narwhals (Wolkers et al. 2006a). Narwhals are a toothed whale that eat higher up the food chain than minke whales. The latter is a baleen whale and eats krill. Minke whales from Western Svalbard have PCB levels of 1-5 µg/g lw (Hobbs et al. 2003).

Blubber samples from white whales from the Svalbard area show higher levels of PCBs than samples that were analysed from Canada and Greenland (Letcher et al. 2010; Wolkers et al. 2006a). The level of environmental pollutants in several whale species increase as one moves from Canada and Greenland towards Svalbard.

PROPOSED MEASURES

- Some whale species have high levels of environmental pollutants. New surveys should be conducted for white whales and minke whales from the Barents Sea area.

3.4.5 SEA FISH

3.4.5.1 Barents Sea

PCBs are one parameter the National Institute of Nutrition and Seafood Research (NIFES) uses to monitor fish in the Barents Sea.

The Institute of Marine Research has measured environmental pollutants in zooplankton and fish in the Barents Sea's pelagic ecosystem (Norwegian Polar Institute, fact sheet no. 017/N). Herring, capelin and polar cod are important plankton eaters and their diet includes Calanus finmarchicus. PCB levels in the fish are 3 to 45 times higher than in their prey. Plankton-eating fish are eaten by other fish including cod and haddock. The levels in their livers increase to 13 to 57 times above the level in Calanus finmarchicus. The Institute of Marine Research's measurements were used to roughly estimate the level of pollutants that exist in these species throughout the Barents Sea and Norwegian Sea. The quantity of PCBs were estimated at around 6 kg in all zooplankton and 14 kg in all Atlantic cod.

3.4.5.1.1 **Polar cod** *(Boreogadus saida)*

The concentrations of organic environmental pollutants in the samples of whole polar cod range from 0.097 to 0.43 ng TE/kg ww for total dioxin-like PCBs and dioxins (Institute of Marine Research, 2010b). The samples were taken annually from 2006 to 2009.

3.4.5.1.2 **Atlantic cod** *(Gadus morhua)*

Atlantic cod accumulates organic environmental pollutants such as PCBs in organs such as the liver and surveys show that the level of pollution in the Barents Sea is such that it can have an negative impact on the quality of food (Institute of Marine Research 2010b). The Institute of Marine Research 2010b documents that in 22 out of a total of 97 samples of Atlantic cod liver in 2009, the total dioxin-like PCBs and dioxins exceeded the EU's upper limit for fish liver of 25 ng TE/kg ww. The average concentration in 2009 was 20.5 ng TE/kg ww. Dioxin-like PCBs accounted for the largest proportion of the total. The variation between the sampling stations appeared to be related to the size of the fish at the various stations.

Liver from Atlantic cod from the Barents Sea has also previously be seen to contain dioxin-like PCBs and dioxins (the monitoring reports for 2008 and 2009). NIFES now has a time series of 4 years and no increasing or decreasing trend in the level of dioxin-like PCBs and dioxins in Atlantic cod liver is apparent in this. NIFES also has data (going back to 1995) for PCBs in Atlantic cod fillet. Akvaplan-niva has analysed PCBs in Atlantic cod as part of a project in Kinnvika, see chapter 3.2.2.2.1, (Evenset and Christensen 2012b). The levels of PCBs were lower than those measured in fish from Grønfjorden. Dioxin-like PCBs congeners accounted for a low proportion of the total PCBs in the fish samples.

3.4.5.1.3 **Greenland halibut** *(Reinhardtius hippoglossoides)*

NIFES has conducted a basic survey of foreign substances in Greenland halibut, NIFES, 2010a. Some of the sampling stations are located in the area around Bjørnøya west of Spitsbergen. Analyses were carried out for ∑7PCB, dioxins and dioxin-like PCBs in individuals (not composite samples). The proportion of Greenland halibut with total concentrations of dioxins and dioxin-like PCBs that exceed the EU's upper limit of 8 ng TE/kg ww from the three sampling stations off the coast of Spitsbergen was 22%, 20% and 8% respectively. ∑7PCB was approx. 30 μg/kg ww. The variation in concentrations could not be explained by the age, length, weight or fat content of the fish, and nor could it be explained by the season.

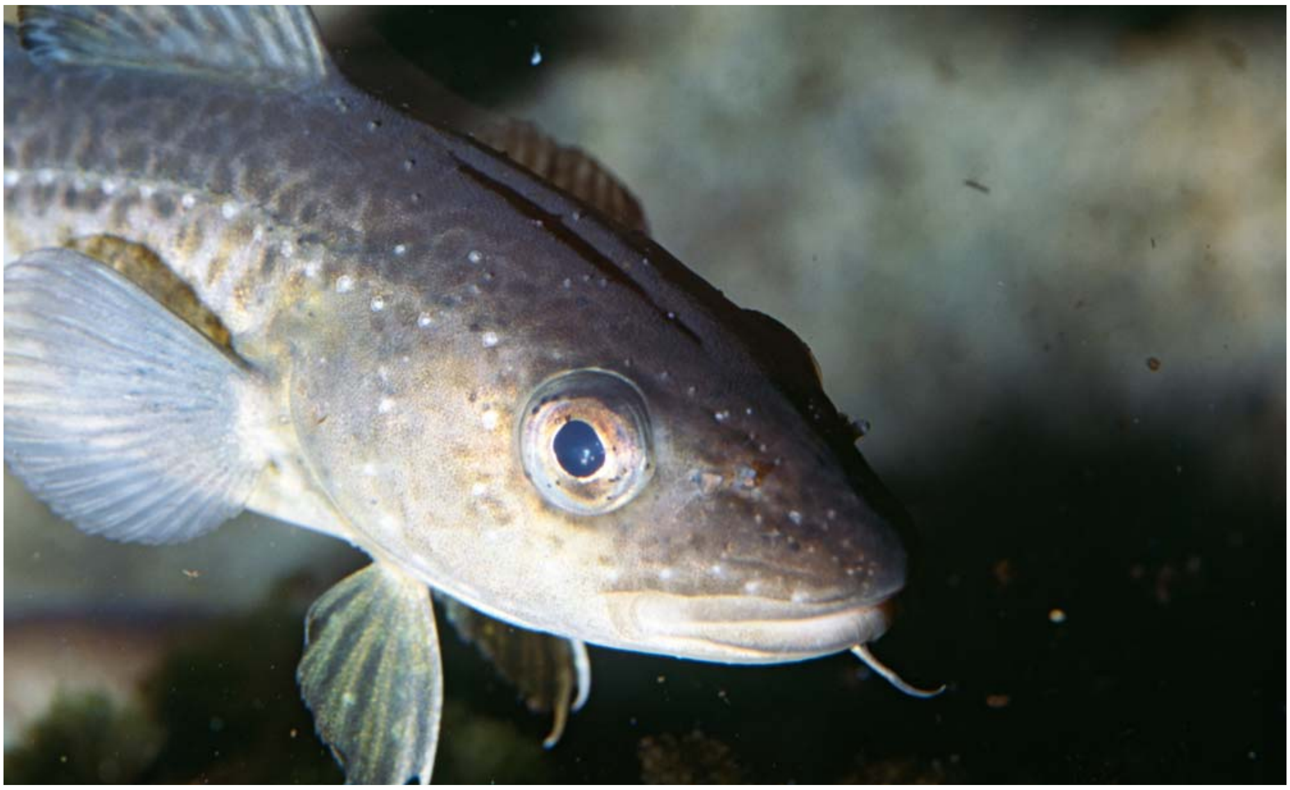
3.4.5.2 Svalbard

3.4.5.2.1 In general

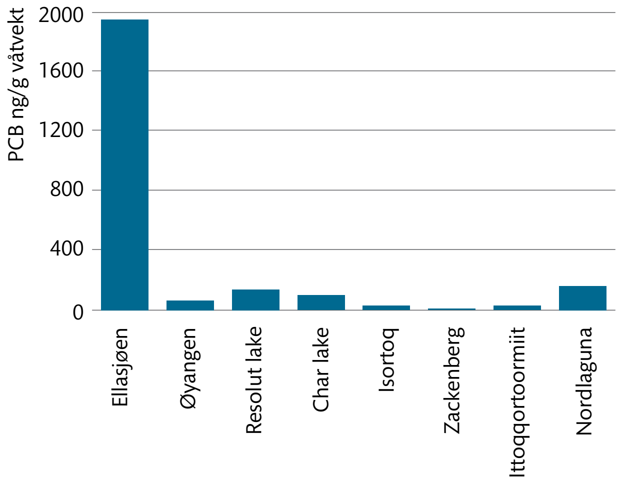
Hop et al. 2001 and Evenset et al. 2009 show that the distribution patterns of different PCB congeners in fish collected near Barentsburg indicate that local sources are contributing to contamination of the marine environment.

3.4.5.2.2 Surveys linked to the COPOL project

The COPOL project (see chap. 7.4) will generate PCB data for various species of fish from Kongsfjorden and Liefdefjorden. Some has already been published (Tessmann 2008; Gabrielsen et al. 2011; Hallanger et al. 2011; Hallanger et al. 2011b; Hallanger et al. 2011c) and more data will be published during 2012.



Cod accumulates organic environmental pollutants such as PCBs in areas of the body such as the liver. Photo: Johnér



PICTURE 3.4.6.1-1 Concentrations of PCBs in Arctic char from Bjørnøya compared with levels in Arctic char from lakes in Canada and Greenland. Source Evenset et al. 2004; 2005 and 2007a.

3.4.5.2.3 Surveys carried out by Akvaplan-niva

Akvaplan-niva has conducted surveys off Barentsburg, funded by the Svalbard Environmental Protection Fund, looking at how environmental pollutants affect marine life (Evenset et al. 2009). The highest concentrations of ∑59PCB were measured in the relatively sedentary, bottom-dwelling, scorpion fish species bull rout and Arctic staghorn sculpin (average ∑PCB of 9.3 and 14.7 µg/kg (ww)). The lives of the two species are very similar. They are sedentary, benthic fish that can lie partially buried or hidden on the seabed while they wait for their prey. Redfish (only one individual was analysed), which are also bottom-dwelling fish, had a PCB level similar to those in scorpion fish. The lowest PCB levels were measured in Atlantic cod and haddock fillets (average ∑PCB 0.84 and 0.61 µg/kg ww). The sampled Atlantic cod were probably coastal cod which live relatively sedentary lives in coastal areas, close to the bottom but not in the sediment. Young haddock in the Barents Sea are relatively sedentary, while large fish make long migrations. The highest levels were measured in the smallest fish in both Atlantic cod and haddock, which may indicate that they are more sedentary. Long rough dab and starry ray, which are also species that live in close contact with sediment, had PCB levels that lie between those in scorpion fish and Atlantic cod. Dioxin-like PCBs account for 0 – 43% of ∑PCB.

The levels of PCBs and chlorinated pesticides in fish were comparable with those that were measured in fish collected in 2001 from the same area (Hop et al. 2001). However, the levels in scorpion fish were higher than those measured in the same species from Kongsfjorden. On the other hand, the levels in Atlantic cod were comparable with those measured in Atlantic cod from Kongsfjorden (Tessmann 2008).

3.4.5.2.4 Surveys carried out by the Norwegian Polar Institute

Livers from scorpion fish (n=12) and Arctic staghorn sculpin (n=4) from various fjords in Svalbard, close to known potential sources (settlements) have been analysed for PCB (Hop et al. 2001):

- Bull rout, *(Myoxocephalus scorpius)* 7.5 µg/kg ∑6PCB ww and 18.5 µg/kg ∑33PCB ww.
- Arctic staghorn sculpin *(Gymnocanthus tricuspis)* 8.8 µg/kg ∑6PCB ww and 21.2 µg/kg ∑33PCB ww.

The concentrations were higher than those that have been observed in the area near Bjørnøya, which is known to have elevated background levels of PCBs, see chapter 3.1.5.

3.4.6 FRESHWATER FISH

3.4.6.1 Arctic char *(Salvelinus alpinus)*

AMAP's surveys on Svalbard and Bjørnøya included Arctic char. Skotvold et al. 1997 found very high PCB concentrations in Arctic char from Ellasjøen. This has subsequently been confirmed by a number of surveys (Evenset et al. 2004; 2005; 2007a and b, Christensen et al. 2008, Christensen et al. 2011), figure 3.4.6.1-1. Skotvold et al. 1997 reported generally low levels of PCBs in fish from the lakes Diesetvatn, Richardvatn and Hornsundet, while slightly elevated concentrations were measured in fish from Linnévann and Kongressvatn.

Sediments and fish from selected lakes on Svalbard were sampled by Akvaplan-niva in 2004-2005. Arctic char from Richardvatn and Åsøvatn were also analysed for PCBs, Christensen et al. 2008. Five relatively large Arctic char were analysed individually. The PCB content of Arctic char from Åsøvatn were somewhat lower than in Arctic char from Ellasjøen on Bjørnøya. Measured ∑7PCB levels varied between 14.0 - 388 ng/g ww (537 - 17 190 ng/g lw). These are higher values than those found in fish from Northern Norway. The highest levels on Spitsbergen were measured in fish from Åsøvatn, average ∑7PCB 232 ng/g ww (5 666 ng/g lw). PCB#153 was the dominant congener, followed by PCB#138, 180 and 118. The higher PCB content in fish from Åsøvatn correlates with the size of the fish. Another reason for the elevated levels in fish from Åsøvatn could be the fact that the lake is affected by bird guano, ref. findings made by Evenset et al. 2007a.

	WEIGHT	FAT CONTENT
RICHARDVATN	431-702 grams	0.41-7.24%
ÅSØVATN	705-2400 grams	1.21-10.0%

The Svalbard Environmental Protection Fund has funded a project in which levels of organic environmental pollutants in Arctic char from lakes used for angling have been mapped (Christensen et al. 2011). The analysis results show that PCBs are the dominant environmental pollutants in fish from all the lakes that were examined. The highest levels of PCBs were measured in Arctic char from Ellasjøen (134 – 2072 ng/g ww). The average level of ∑64PCB in Arctic char from Ellasjøen (1235 ng/g ww) was > 20 x higher than those measured in Arctic char from the lake with the next highest levels, Arresjøen (52,6 ng/g ww). Arctic char from Richardvatn (32.9 ng/g ww) and Annavatn (28.9 ng/g ww) had higher PCB levels than fish from the other examined lakes. The levels of environmental pollutants in anadromous Arctic char caught in the sea (Liefdefjorden) or Arctic char from anadromous Arctic char rivers (Linnévann, Straumsjøen, Dieset) were lower than in fish from lakes with only sedentary Arctic char.

The lipid normalised data draws a picture that is slightly different to that which appears when wet weight data is used. Lipid normalised PCB content was also highest in Arctic char from Ellasjøen, followed by Annavatn, Arresjøen and Richardvatn.

Christensen et al. 2008 measured ∑7PCB in Arctic char from Ellasjøen and Richardvatn. The levels in Arctic char from Ellasjøen (∑7PCB = 154 ng /g ww) were at that time lower than those that were found in 2011 (Christensen et al. 2011), while the levels in Richardvatn (∑7PCB = 17.7 ng/g ww) were comparable. The reason the levels in Arctic char from Ellasjøen were higher in the 2011 survey may be that the fish analysed in 2008 were smaller. Earlier surveys (Evenset et al. 2004; 2007) showed that large fish have higher concentrations of organic environmental pollutants than small fish.

The dominant congener was PCB#153, followed by PCB#138 and PCB#180. This is a normal picture in biological samples from Arctic lakes The dioxin-like congeners accounted for 20 – 40% of ∑PCB.

The supply of PCB environmental pollutants via guano from seabirds is the likely reason behind the elevated levels in fish from Ellasjøen, Arresjøen and Richardvatn, ref. findings made by Evenset et al. 2007a.

Brünnich's Guillemots in bird colonies at Prins Karls Forland. The concentrations of environmental pollutants that have been found in eggs from Brünnich's Guillemots are assessed to be below effect values. Photo: Halvard R. Pedersen

PROPOSED MEASURES:

- A number of other lakes on Svalbard are used by anglers and new follow-up in some of these water systems are recommended.
- The development of environmental pollutants in Ellasjøen should be monitored carefully in the future.

3.4.7 BIRDS

3.4.7.1 Svalbard Ptarmigan *(Lagopus mutus hyperboreus)*

Svalbard Ptarmigans are found all over Svalbard and are common in and near settlements. They are pretty much confined to their nests during nesting season. The Norwegian Polar Institute has surveyed the content of PCBs and heavy metals in ptarmigan from Longyearbyen and Ny Ålesund (Severinsen and Skaare 1997). The levels were very low.

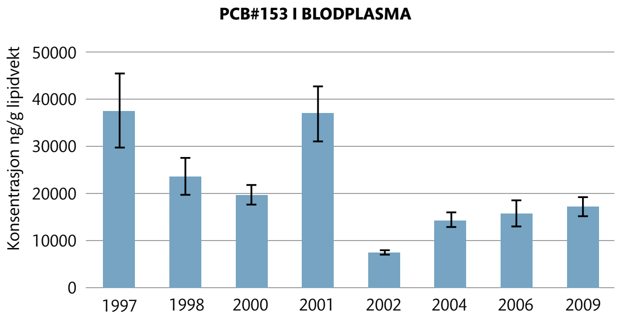
3.4.7.1 Snow Bunting *(Plectrophenax nivalis)*

Snow Buntings are the sparrows that nest the furthest north in the world and are the only common nesting sparrow on Svalbard. It is a migratory bird that winters in temperate regions. Sightings of birds ringed on Svalbard show that Snow Buntings from Svalbard can migrate in a south-easterly direction over North Western Russia and towards the Russian Steppes north of the Caspian Sea and Kazakhstan. The Snow Bunting primarily eats seeds, but they also catch insects, especially when feeding offspring. Since the Snow Bunting nests in and around settlements one could imagine them taking up local PCB contamination. Surveys of Snow Buntings in Canada show that those that nest on bird cliffs take up PCBs that are transported to land by seabirds (Choy et al. 2010).

In 2011, the Svalbard Environmental Protection Fund gave the Norwegian Polar Institute a grant to survey local pollution and any affect it has on the Snow Bunting.

3.4.7.2 Brünnich's Guillemot *(Uria lomvia)*

There is no systematic monitoring of environmental pollutants in the species, but egg samples were taken in 1993, 2002/2003 and 2007. The samples were collected in Kongsfjorden and on Bjørnøya and were analysed for PCBs. The analyses show that the levels in Kongsfjorden 2002, Bjørnøya 2003, Kongsfjorden 2007 and Bjørnøya 2007 are relatively similar. A decrease from 2002/2003 to 2007 was detected in both areas.



PICTURE 3.4.7.3-1 Concentrations of PCB#153 in blood samples from Glaucous Gulls. Source: MOSJ.

The concentrations of environmental pollutants that have been found in Brünnich's Guillemot eggs are assessed to be below effect values (Gabrielsen and Sydnes 2009; Letcher et al. 2010). It is worth noting that measurements of nitrogen isotopes, a measure of trophic level, show significantly higher levels in Kongsfjorden than on Bjørnøya and significantly higher levels in 2002/2003 compared with 2007. This will affect the interpretation of time trends in this study since levels of environmental pollutants are closely related to trophic level and the highest concentrations in 2002/2003 could be, wholly or partly, a result of these individuals having eaten food that was on a higher trophic level compared with those from 2007. The full results are presented in Bakke et al. 2008.

3.4.7.3 Glaucous Gull *(Larus hyperboreus)*

A number of chloro-organic and other compounds were detected in blood samples, tissue and eggs from Glaucous Gulls from Svalbard and Bjørnøya. Despite finding new types of environmental pollutants (brominated flame retardants and fluoro compounds), as well as metabolites, in Glaucous Gulls, PCBs still dominate and account for almost 75% if the total pollutant load (Gabrielsen and Henriksen 2001; Gabrielsen 2007), figure 3.4.7.3-1. Pesticides (DDE, chlordanes and HCB) account for less than 20%, while metabolites account for less than 1% of the Glaucous Gulls' pollutant load.

There are large differences in levels of organic environmental pollutants. Individuals that eat eggs and the young of other seabird species have twice as high environmental pollutant levels as those that eat fish. This is due to the fact that the fish are at a lower level of the food chain than fish eating seabirds like Black-legged Kittiwakes and guillemots. Other factors that affect the level of environmental pollutants in Glaucous Gulls are their ability to break down environmental pollutants and gender. Glaucous Gulls are less able to break down environmental pollutants. This is due to the fact that the level of activity of the enzymes that convert environmental pollutants are relatively low in Glaucous Gulls. Male Glaucous Gulls on Bjørnøya have twice as high levels as females. This is primarily due to the fact that females lay eggs and therefore transfer environmental pollutants from their body fat to the eggs (Gabrielsen 2007). Like other seabird species, Glaucous Gulls experience large changes in body weight throughout the year. Egg laying, incubation and the young's growth period require a lot of energy and burn body fat. Liposoluble organic environmental pollutants bound to body fat are released and end up in the blood system. This in turn results in levels increasing in sensitive to tissue like the brain. Surveys of Glaucous Gulls in recent years indicate POPs affect the birds' behaviour and immune, enzyme, hormone and vitamin systems (Verreault et al. 2010). Reproduction is also weakened in individuals with the highest levels of environmental pollutants and adult survivability in these individuals is lower. Dead Glaucous Gulls from Svalbard and Bjørnøya, that have been found in the nesting period, have 10 to 100 times higher PCB levels in the liver and brain respectively than healthy birds (Gabrielsen et al. 1994; Knudsen et al. 2006; Sagerup et al. 2009).

The results from Glaucous Gulls on Bjørnøya may indicate that current levels of environmental pollutants are affecting the population.

Impact from local pollution

Glaucous Gulls are sedentary during the nesting period from May to August. This makes the Glaucous Gull a suitable candidate for studying the take up of local PCB contamination since they can find food in and close to the settlements. Apart from bottom-dwelling species, see chapter 3.4.8.4, the Glaucous Gull is, as far as NP is aware, the only species in which an impact from local PCB pollutants can be detected. Glaucous Gulls collected from Barentsburg in August 2001 had a different PCB composition than one normally finds in Glaucous Gulls. The relative content (%) of PCB#118 was much higher and the content (%) of the higher chlorinated PCB#153 and #180 correspondingly lower than we normally find in Glaucous Gulls (Sagerup et al. 2009). Glaucous Gulls collected from Barentsburg in May (unpublished NP data) had a congener profile that was the same as that of Glaucous Gulls from other Arctic areas. This probably shows that Glaucous Gulls that were collected in August had been in the same area throughout the summer, which is the nesting season, and been impacted by PCBs from the Barentsburg area. A high content of PCB#118 and low content of PCB#153 and #180 characterise the Soviet PCB mixture Sovol, among others. The data does not provide a basis for saying whether or not the total content of PCBs was affected in these birds (Sagerup et al. 2009). As shown in the study above and for bottom-dwelling animals, it might

Glaucous Gulls feeding on a whale cadaver. Dead Glaucous Gulls from Svalbard and Bjørnøya, that have been found in the nesting period, have 10 to 100 times higher PCB levels in the liver and brain respectively compared with healthy birds. Photo: Halvard R. Pedersen be possible to detect the take up of local PCBs and differentiate these from long range transported PCBs when analyses differentiate between the different variants of PCB (congener profile).

3.4.7.4 Black-legged Kittiwakes *(Rissa tridactyla)*

In addition to benthic fauna and Glaucous Gulls, Black-legged Kittiwakes have been surveyed to determine the proportion of local PCBs. In 2008, Black-legged Kittiwake eggs from Barentsburg, Pyramiden and Kongsfjorden were surveyed. The proportion of local environmental pollutants was not determined (Miljeteig and Gabrielsen, 2009). Black-legged Kittiwakes only eat pelagic crustaceans and fish, and most often feed in front of the foot of glaciers or further out in fjord systems. Black-legged Kittiwakes that breed in Pyramiden and Barentsburg do not feed in areas affected by local PCB contamination and are therefore not affected by these pollutants.

3.4.7.5 Northern Fulmar *(Fulmarus glacialis)*

The Northern Fulmar is one of our longest living seabirds. They can live to up to 50 years old and do not start breeding before they are 10 years old. The Northern Fulmar is a pelagic seabird species that spends most of its life in the open sea, except during the breeding season - but even then it covers large sea areas hunting for food. Studies have shown that breeding Northern Fulmars on both Bjørnøya and Spitsbergen hunt for food in the central parts of the Barents Sea and as far south as the Norwegian coast when feeding offspring. Their diet is dominated by the pelagic animals that can be caught on the surface of the sea and it often eats fish offal dumped by fishing boats. The bird can be called an omnivore and is relatively sedentary in northern areas (does not migrate to southern areas with warm waters) in the winter. This makes the species relevant with respect to monitoring the impact of environmental pollutants.

Bourne and Bogan (1972) documented high levels of the environmental pollutants PCBs and DDT in Northern Fulmars from Bjørnøya as early as in 1972. NP has examined organic environmental pollutants in Northern Fulmars from Bjørnøya (n=15) in 2003, (Knudsen et al. 2007; Gabrielsen et al. 2005). ∑32PCB varied from 4,873-9,164 µg/kg wet weight. This is the same magnitude of PCB concentrations in egg, fat and liver as has been found in Northern Fulmars from Jan Mayen and Canada. The PCB concentrations did not exceed calculated threshold values for reproductive effects determined for avian eggs. The PCB congeners 153, 118 and 180 dominated (60% of ∑PCB).

Concentrations of the dioxin-like non-ortho PCBs in liver were twice as high as previously reported values from Canada and seven to ten times the levels that have been reported for Brünnich's Guillemots and Black-legged Kittiwakes from Canada (Braune and Simon, 2003). The levels of non-ortho PCBs in Northern Fulmars were 46-60% of those that have been found in Glaucous Gulls from Bjørnøya.

PROPOSED MEASURES:

- The monitoring of environmental toxins in eggs from various seabird species should continue with regular collections every 5 years.
- The monitoring/research on Glaucous Gulls should continue. The link with effect parameters is important and any population effects should be documented.

3.4.8 AQUATIC INVERTEBRATES *(marine invertebrates)*

3.4.8.1 In general

Sediment-dwelling invertebrates are exposed to the bioaccessible portion of the contaminants in the sediments. As prey for organisms higher up the food chain, they can therefore act as a link in the transfer of PCBs from sediment to animals higher in the food chain. Since invertebrates are low in the food chain and the majority have a limited ability to metabolise PCB compounds, this group of organisms can be useful in evaluating the significance of contaminated sediment and they can be used to trace local sources. Hop et al. 2001 and Evenset et al. 2009 show for example that the distribution patterns of different PCB congeners in sediments and organisms collected at Barentsburg indicate that local sources are contributing to contamination of the marine environment. Species that are sedentary and that live in close contact with the sediment have the highest relative concentrations of environmental pollutants, whereas species that swim freely in the water column and are likely to wander in and out of the polluted area, have concentrations that are comparable with the individuals sampled in areas without local sources, see also chapter 3.4.5.2.3.

3.4.8.2 Zooplankton

Zooplankton are the sea's herbivores and the large species are predators that feed on smaller zooplankton. In theory, this group covers the 2nd and 3rd trophic levels of the marine food chain. In connection with a PhD project, zooplankton that had been collected in and outside Kongsfjorden was examined for PCBs and sprayed pesticides. The concentrations of PCBs in zooplankton and krill are in the order of 10-15 ng/g lw, see table 3.4.8.2-1, (Hallanger et al. 2011). There are no indications that the PCBs in these samples originate from local sources. There is seasonal variation in the amount of PCBs in zooplankton. The concentration is highest in May (spring bloom) and decreases during the season up to August (Hallanger et al. 2011), see also chapter 3.3.1.2.1.

		n	∑8PCB ng/g lw
Predator	May	3	15.6
Predator	July	7	10.6
Predator	October	4	6.0
Krill	May	5	13.6
Krill	July	5	14.2
Krill	October	4	16.8
Herbivore	May	4	17.9
Herbivore	July	6	13.9
Herbivore	October	9	8.6

TABLE 3.4.8.2-1 ∑8PCB in zooplankton and krill (Kongsfjorden, 78896 N, 11894 E) in 2007. Predator: Themisto abyssorum, T. libellula and chaetognatha. Krill: Thysanoessa inermis. Herbivore: Calanus finmarchicus, C. glacialis and C. hyperboreum. Source Hallanger et al. 2011.

3.4.8.3 Bivalves

Four species of marine bivalves *(Mya truncata, Serripes groenlandicus, Hiatella arctica and Chlamys islandica)* were examined for PCBs and pesticides in a Master's thesis at NP (Vieweg 2010). The bivalves were collected in Kongsfjorden and north of Svalbard. The analyses show that PCBs constitute up to 80% of the total POP effect analysed in the organisms. The study also shows that PCB concentrations in bivalves vary among the species, and in the different fjord systems on the north-west coast of Svalbard. The bivalves from Kongsfjorden show considerably higher levels compared with bivalves from the northern fjords. In general, the PCB concentrations are lower in these invertebrates compared with organisms higher in the food chain (such as fish, marine mammals and seabirds). The average value for ∑16PCB was 63 ng/g lipid weight for these four species from both the areas.

3.4.8.4 Various benthic fauna

Evenset et al. 2009 have examined substances including PCBs in benthic invertebrates collected outside Barentsburg. ∑59PCB concentrations varied from 3.03 (in the bristle worm *Pectinaria*) to 18.6 µg/kg ww (in the bivalve *Ciliatocardium ciliatum*). *Pectinaria* is a bristle worm that lives in sand/mud, and feeds on detritus found in the sediment. It is found at a relatively low trophic level.

Ciliatocardium ciliatum is a bivalve that lives buried in sand and mud. This species is probably also feeding on detritus, and like *Pectinaria*, the species is found at a low trophic level. The reason for the high PCB concentrations in this species is probably not biomagnification through the food chain, but probably because the bivalve has taken in contaminated sediment. *Buccinum sp.* also had a relatively high PCB concentration. This species is a predatory snail that eats what it finds. It is thus found at a relatively high trophic level and the PCB concentrations are likely to be a result of biomagnification. The other species that were examined had PCB concentrations that were between the specified end points.

Another reason for the varying PCB concentrations may be variations in the species' lipid content. The organic environmental pollutants are lipid-soluble and therefore the highest concentrations are usually found in individuals with high lipid concentrations. However, converting to a lipid basis did not change the overall picture. Dioxin-like PCBs constituted from 11–29% of ∑PCB, and TEQ varied from 0.03 (bivalve *Arctica islandica*) to 0.19 ng/kg ww *(Buccinum sp.)*.

Hop et al. 2001 have examined environmental pollutants in 7 species of marine macrobenthos and fish near Norwegian and Russian settlements in Svalbard. Likely local supplies of PCBs were found, see also chapter 3.3.3.3. The distribution pattern (% of ∑6PCB) of various congeners was found to be different between the fjords. The largest differences were between the areas close to Norwegian settlements and the areas close to Russian settlements. The results also showed that there was a difference in PCB patterns between organisms collected outside the Russian and the Norwegian settlements (Hop et al. 2001), see also chapter 3.3.3.3.

PROPOSED MEASURES:

- Increase knowledge about how PCBs affect the organisms at lower trophic levels.

FOOTNOTES CHAPTER 3

[12] congeners PCB#18, 28, 31, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187, 195 and 209.

[13] congeners PCB#28, 31, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187.

[14] congeners PCB#28, 31, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187.

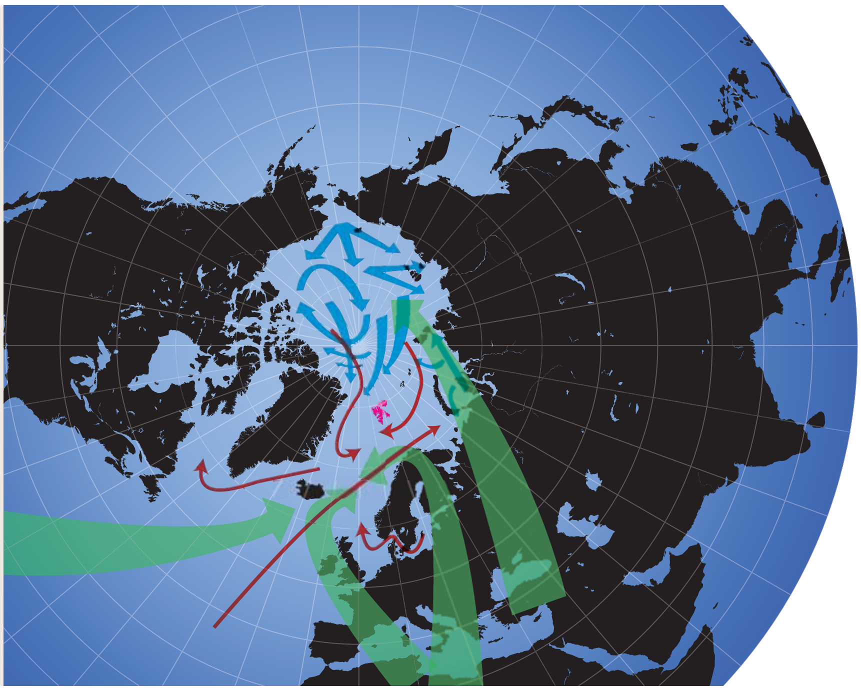
[15] PCB # 28, 31, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187

[16] measurements taken in the period from 13-28 May

[17] measurements taken in the period from 26 August-9 September

[18] PCB # 28, 31, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183 and 187


Certainly the largest supply of PCBs to Svalbard originates from other parts of the world
60% reaches Svalbard via air
30% through oceanic currents
10% through ice transport



PCBs are transported over a long range to Svalbard and Arctic areas via air (green), water (red) and ice movements (blue).

4. PCBS – SOURCES, PATHWAYS AND CLIMATE CHANGE

"PCB concentrations in the atmosphere are still considerable. Changes in the climate will intensify this."

Professor Roland Kallenborn, Norwegian University of Life Sciences

4.1 SOURCES AND PATHWAYS FOR PCBS

4.1.1 GENERAL

In addition to local PCB sources, PCBs and other environmental pollutants primarily reach Svalbard and the Arctic through long range transport via for example oceanic and air currents, and ice, figure 4.1.1-1. This is supported by findings from a number of studies and environmental monitoring programmes (Ballschmiter 1992; Iwata et al. 1993; Nürnberg et al. 1994; Pfirman et al. 1995; Oehme et al. 1996; Emery et al. 1997; Pfirman et al. 1997; Rigor and Colony 1997; Klif 1998; Berg et al. 2004; Macdonald et al. 2000; AMAP 1998 and 2004a; Pfirman et al. 2004; Pavlov et al. 2004; Pavlov 2007; Kallenborn et al. 2007; Hung et al. 2010).

When the substances reach the Svalbard area, they are distributed via local and regional air and water currents, precipitation, ice transport and by being part of the biological systems through the food web. The processes involved in transport, distribution, degradation and accumulation are highly complex and could also be affected by climate change, see chapter 4.2.

- Atmospheric transport is the quickest method (days or weeks) to transport organic environmental pollutants such as PCBs from Europe and other continents to Svalbard (Berg et al. 2003; Eckhardt et al. 2007; Hung et al. 2010). But there are significant differences in how the air transports the various congeners. Some are deposited in transit, and subsequently evaporate and

The Zeppelin station in Ny-Ålesund measures environmental toxins in the atmosphere. Photo: Tor Ivan Karlsen, Norwegian Polar Institute.

continue their journey for a series of steps, the so-called "grasshopper effect" or "global distillation" (see figure 4.1.1-1). On Zeppelin mountain at Ny-Ålesund there is a measuring station (78° 54`N, 11° 53`E) that continuously records pollutants such as PCBs in the air. The Zeppelin station is part of an AMAP network of air monitoring stations. It plays a crucial international role in the efforts to monitor persistent organic pollutants over the long term. In 1997 the original measurement programme, which covered 10 PCB congeners, was expanded to include 29 congeners. In 1998 the number of congeners rose to ∑33PCB, (Klif, TA-2033/ 2004). In addition, the total of all PCB congeners with 3 to 10 chlorine atoms was decided upon. Records show a significant supply of PCBs via the air in the Barents Sea and deposition from the air constitutes the largest source of PCBs supplied to the Barents Sea, (Green et al. 2010). This is related to increased gaseous exchange with the atmosphere and greater atmospheric deposition at low water temperatures and in the presence of sea ice, see chapter 3.1.4.

- Oceanic currents from Europe divide off the Norwegian coast. Some flow along the west coast of Spitsbergen, carrying pollutants from central parts of Europe. See picture 4.1.1-2. The supply of pollutants from oceanic currents is a significantly slower process than from atmospheric transport.

- Sea ice, polluted via atmospheric deposition, and ice that is being transported westwards from the major Russian rivers and into the Barents Sea are carrying PCBs. The substances are released when the ice and snow melts in the marginal melting zones in Framstredet and around Svalbard and Bjørnøya (Burkow et al. 1998, SWIPA 2011).

A rough estimate[19] is that about 60 per cent of long range transported particulate-bound PCBs reach Svalbard through direct and continuous transportation in the air, 30 per cent directly from oceanic currents and 10 per cent through ice transport (particles in ice floes) and the annual melting.

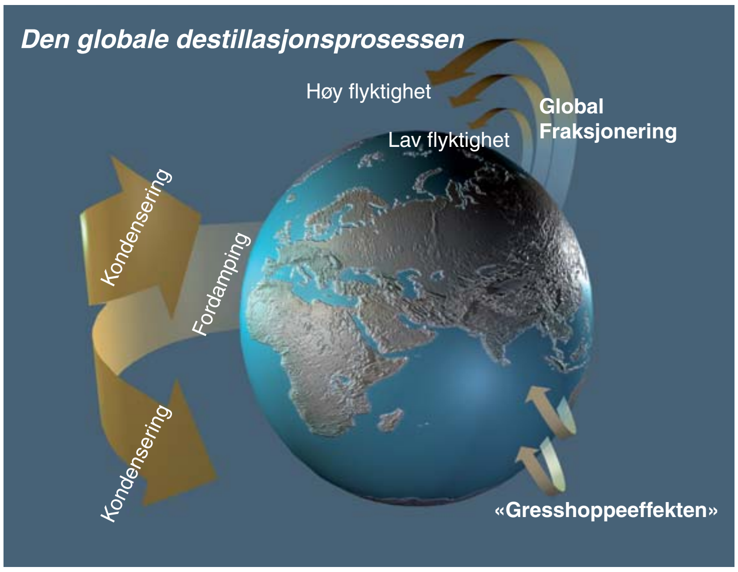
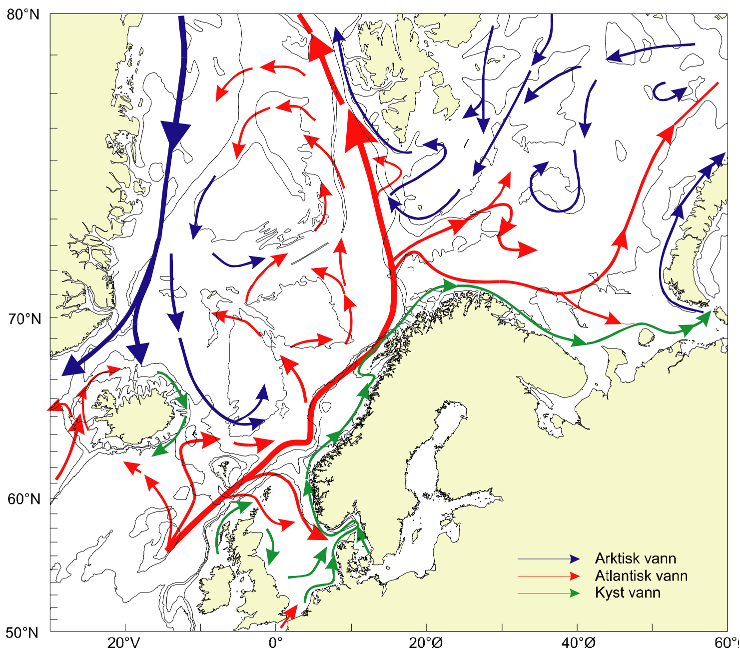
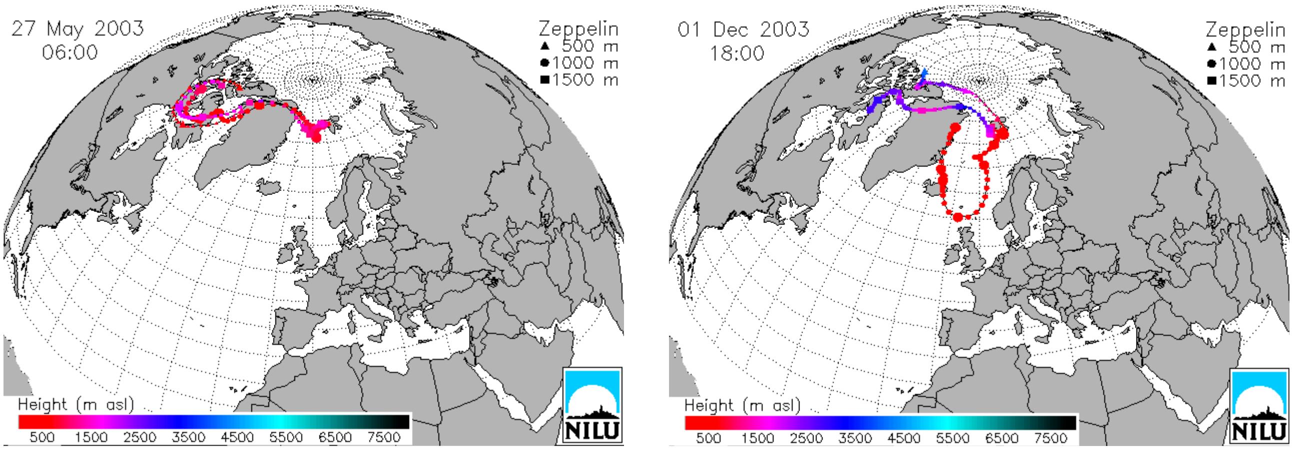


FIGURE 4.1.1-1 Through various processes PCBs and other environmental pollutants are spread to Arctic areas. Source: Norwegian Polar Institute



PICTURE 4.1.1-2 The current systems in the North Sea, Norwegian Sea, Greenland Sea and Barents Sea. The Gulf Stream leads to the whole Norwegian Sea and large areas of the Barents Sea being free of ice and open to biological production. Source: Institute of Marine Research.



PICTURE 4.1.2-1 The prevailing wind directions on Svalbard transport air masses from the south and in across the archipelago. The two highest air measurements, taken at the Zeppelin station, were recorded in air masses that had passed North America and over Russia respectively. The pictures illustrate the calculated trajectories of air masses that arrived at the Zeppelin station during sampling in 2003 of the samples for weeks 22 and 50, with the highest values for ∑PCB. Source: Aas et al. 2004

4.1.2 Atmospheric long range transported PCBs

Long range transported pollutants include a number of environmental pollutants. Transport principally takes place via the atmosphere. Once the air currents reach Arctic areas, the pollutants are deposited through cold condensation and other means (Wania et al. 1993; AMAP 2004a; Hung et al. 2010), see figure 4.1.2-1. A large proportion of the PCBs being deposited on the Norwegian mainland and in Svalbard are such long range transported pollutants that are due to emissions from other countries (AMAP 2002 and 2009, Oehme et al. 1996a and b; Hansen et al. 2009; Verreault et al. 2010). Chapter 7.1 documents, based on model calculations, several potential source regions in the northern hemisphere of long range transported PCB pollutants to Svalbard and other areas.

PCBs have low water solubility and a vapour pressure which means that the substances (particularly those with low chlorine content) can be easily transported in the gas phase via air (volatile PCB congeners) and they can combine with particles (so-called semi-volatile PCBs) in the air (Ballschmiter 1992; Beyer et al. 2000). Both forms can be washed out by precipitation such as snow or rain. PCBs can:

- be dry deposited when combined with atmospheric particles
- be deposited to the ocean/water surface when not combined, via diffusion from air to water. The opposite process could also occur in the form of evaporation, see also chapter 3.1.4.

The direction of the diffusion exchange of PCBs will be from the phase (air or water) that has the highest chemical potential (fugacity) to the phase with the lowest chemical potential, (Green et al. 2010). The process is highly dependent upon wind and temperature. The relative significance of the various forms of deposition is also highly dependent on the physical and chemical characteristics of each individual substance/congener.

The prevailing wind directions on Svalbard transport air masses from the south and in across the archipelago. The two air measurements that show the highest PCB concentrations at the Zeppelin station in 2003, were recorded in air masses that had passed over North America and Russia respectively, see figure 4.1.2-1, (Aas et al. 2004).

A comparison of PCBs in the air from six Arctic atmospheric monitoring stations shows that the concentrations in air measured at the Zeppelin station were the highest. The Canadian station Alert has reported that PCBs in the air have been following a downward trend. Such a trend can not be confirmed by the Zeppelin station (Hung et al. 2010). Instead, since 2004 an increase in certain PCB congeners has been detected (Hung et al. 2010), see chapter 3.1.3.

PCBs in the atmosphere may come from:

1) Primary man-made (anthropogenic) emissions that are a direct consequence of earlier PCB production (Breivik et al. 2002 a and b).
2) Emissions that have been unintentionally created *(de novo synthesis)* from various PCB compounds during combustion processes (e.g. Brown et al. 1995).
3) Re-emission of PCBs from secondary sources in contact with air, such as water and soil (e.g. Jeremiason et al. 1994; Agrell et al. 1999; Eckhardt et al. 2007).

4.1.3 TRANSPORT OF PCBS WITH SEA AND OCEANIC CURRENTS

The ocean areas around Svalbard contain many oceanic currents, see figure 4.1.3-1. These carry PCBs in particulate or unbound forms in the waters, redistributing PCBs across the region and locally, and sending some pollutants out of the region (Green et al. 2010).

The relatively warm Atlantic ocean waters come from the south-west. The amount and temperature of the water coming from the Norwegian Sea changes from year to year and have a major influence on how warm it is in the ocean area. The cold, less salty water comes from the north and east into the Barents Sea. Some water also comes via the coastal currents which flow along the Norwegian coast. This water originally comes from the North Sea and is supplied by freshwater and pollutants from Norwegian rivers and other sources (Slubowska-Woldengen et al. 2006).

PCBs connected to particles in the water could fall to the seabed and thereby supply further contamination to the bed sediments.

The amount of unbound PCBs in the ocean water depends on the temperature. Studies of long time series of the temperature in the water indicate that the average temperature of sea water is rising. This is viewed as a sign of a man-made rise in temperature and this trend is expected to continue (State of the Environment Norway 2010.12.28). An increase in the water temperature could lead to unbound PCBs being re-emitted and gradually released into the atmosphere again (Macdonald, Fyfe and Harner 2005; Hung et al 2010; SWIPA 2011).

PCBs are also supplied to Svalbard and the regions of sea that surround the archipelago with migratory animals and birds, etc. Exemplified by the Barnacle goose.
Photo: Halvard R. Pedersen

In its measurements and calculations, OSPAR utilises congener PCB#153 as an indicator of PCB pollutants. The latest OSPAR studies (OSPAR 2009) indicate that the ocean area around Svalbard (see figure 4.1.3-2) in 2005 was supplied with PCB#153 at a rate of approximately $1 \cdot 10^{-5}$ mg/m^2/year (OSPAR, 2008).

4.1.4 Transport of PCBs with sea ice

Sea ice in or en route to the areas around Svalbard acts as a depot for PCBs. The ice is supplied with the substances from the atmosphere, etc. In addition, run-off from the mainland, via for example rivers (including the major Russian rivers and the Norwegian coastal currents) in which PCB pollutants are frozen in the ice, can be transported to the Svalbard region. If the ice melts, this leads to local supply of PCBs to the sea water, see also chapter 3.3.1.

It is estimated that 10 per cent of long range transported PCB pollutants come to Svalbard with sea ice (Roland Kallenborn, personal statement).

The ice cover in the ocean area around Svalbard varies significantly both during the year and from year to year, see also chapter 3.1.4 and figure 3.1.4-1. Records show that the ice cover is becoming thinner and that the extent of the ice is decreasing (Gerland et al. 2010). In recent years, Spitsbergen's west coast has been ice-free year-round. The shrinking ice cover is assumed, in conjunction with the degassing of PCBs from sea water, to be the explanation for the increase in atmospheric PCBs recorded at the Zeppelin station (AMAP 2009; Hung et al. 2010), see also chapter 3.1.4.

4.1.5 TRANSPORT OF PCBS WITH ANIMALS AND BIRDS

PCBs are also supplied to Svalbard and the regions of sea that surround the archipelago through biota including migratory animals and birds.

Analysis of persistent organic pollutants in eggs from geese shows for example that the Pink-footed Goose has been subjected to greater exposure in continental Europe than the Barnacle Goose has been in Scotland (Steindal 2009). However, geese which are herbivore species, usually have low levels of POPs compared with for example seabirds or marine mammals which are found at a higher trophic level.

Supply via migrating species is assumed to be of less significance than other long range transported PCB pollutants. Supply with biota is however important in certain local areas (Blais et al. 2005 and 2007) such as in the example of PCBs being transported via bird excrement from the marine environment to Ellasjøen in Bjørnøya (Evenset et al. 2004; 2005 and 2007a). High levels of PCBs have also been measured in sediment and Arctic char from lakes influenced by seabirds to the north of Svalbard (Christensen et al. 2008, Christensen et al. 2011).

4.1.6 LOCAL AND REGIONAL SOURCES

4.1.6.1 In general

The current report compiles and documents a number of new and old local sources of PCBs in Svalbard:

- **Primary sources:** Equipment and materials containing PCBs are potential primary sources if they are not managed properly. Emissions from these sources can be prevented/avoided. A large portion of the primary sources have now been removed from the archipelago and have been sent off to be destroyed in an environmentally sound manner.

There is no available information on the quantities of equipment, products and oil containing PCBs that have been brought into Svalbard over the years. The technical properties of PCB oil meant that it was used in the mining industry, research stations and settlements, etc. Its uses included that of an insulating and cooling agent in electrical equipment (capacitors and transformers) and in hydraulic oils. PCBs have also been added and used in construction supplies, including paint. The known primary sources that still remain in Svalbard are primarily connected to painted surfaces on buildings in the Russian settlements.

- **Secondary sources:** These are PCBs that have left the primary source and are present in soil, water, air, flora and fauna and have not been broken down. The majority of PCBs that are found in Svalbard are now in the form of secondary sources.

PCB compounds have been dispersed into the environment through equipment breakdowns, when decommissioning equipment and demolishing buildings, etc. as well as through the depositing of oils and equipment containing PCBs in waste landfill sites (improper processing of waste), (Kovacs 1996). PCBs in secondary sources may be viewed as being temporarily deposited. These are substances that can be re-emitted and become bioaccessible.

4.1.6.2 Secondary sources and re-emissions

PCBs have the potential for reversible atmospheric deposition (global fractionation/the grasshopper effect), (Wania and Mackay 1995) (see also figure 4.1.1-1). The degradation and conversion processes for PCBs under Arctic conditions are slow and primarily occur in the air phase. This means that PCBs that are found in and around Svalbard could be re-emitted and further spread through provisional depositing/redistribution between different media (for example air, water, snow, soil, sediment and animal) in a process that extends over many years. Such redistribution may be viewed as a dilution process (Axelman et al. 2001). The consequences may be that a measured reduction in concentration detected in one medium (such as soil, water, air, seabed or animals) does not necessarily mean that the substances have been broken down and rendered harmless, but that they have simply been transferred to another medium, where the substances have potentially become available for subsequent bioaccumulation and biomagnification in the food chains.

Many studies have been conducted showing that PCBs and other environmental pollutants are leaking into the natural environment and that these can be ingested by organisms and introduced into the food chains in Svalbard. As the substances are persistent and combine with particles, over time they will accumulate in sediments where animals such as sediment-dwelling marine invertebrates will be exposed to the bioaccessible portion of the contaminants in the sediments. Invertebrates are low in the food chain and most have only a limited ability to convert/ break down (metabolise) PCB compounds. As prey for organisms higher in the food chain, invertebrates will therefore act as a link in the transfer of PCBs between sediment and animals higher up the food chain.

4.1.6.3 Primary sources - PCBs in buildings

In collaboration with SMS and Klif, NGU has studied the PCB content in soil, sediments and construction materials in all the settlements in Svalbard. A total of 1,019 samples have been collected from Barentsburg, Bjørnøya, Colesbukta, Fuglehuken lighthouse, Grumantbyen, Hopen, Hornsund, Isfjord Radio, Longyearbyen, Ny-Ålesund, Pyramiden and Svea. Detailed descriptions from the environmental surveys undertaken in 2007, 2008 and 2009 are presented in the NGU reports from the respective years (Jartun et al. 2007; Eggen and Ottesen 2008; Eggen et al. 2008; Jartun et al. 2009).

The results show that surface soil in Barentsburg and Pyramiden is heavily polluted compared with the other settlements. The concentrations are also high compared with similar studies on the mainland. Peeling, old paint containing PCBs and PCB oil from technical and/or electrical equipment have been the most important local sources of PCBs. PCBs were found in one or more samples of concrete and paint from all the settlements with the exception of Hopen, Hornsund and Svea.

In 2007 samples of construction materials from the three largest settlements Longyearbyen, Barentsburg and Pyramiden were collected. The study showed that flakes of paint were traceable as a source of PCBs in soil. In 2008 the project was expanded to encompass sampling from buildings in all the current and former settlements in Svalbard: Ny-Ålesund, Svea, Grumant, Colesbukta, Isfjord Radio, Fuglehuken lighthouse and the stations at Hornsund, Hopen and Bjørnøya. PCBs were found in one or more materials from all the settlements with the exception of Hopen, Hornsund, Ny-Ålesund and Svea. In summer 2009 supplementary sampling was carried out in Longyearbyen, Barentsburg and Pyramiden. PCB data now exists from one or more samples of construction materials from all the buildings in Barentsburg and Pyramiden and from the majority in Longyearbyen. The results show that about 60 per cent of the buildings in Barentsburg and Pyramiden have construction materials that contain PCBs. In Longyearbyen PCBs were detected in about 15 per cent of the buildings. As a comparison, 29 per cent of the buildings from the period 1950-1980 on the mainland have facades containing PCBs (Jartun et al. 2008).

PAINT

LOCATION	NUMBER OF SAMPLES n	ARITHM. AVERAGE ∑7PCB (mg/kg)	MEDIAN ∑7PCB (mg/kg)	MIN – MAX ∑7PCB (mg/kg)	$MEDIAN_{SETTLEM}$ / $MEDIAN_{TOTAL}$
Total	305	20.9	0.175	<0.004-3520	-
Barentsburg*	105	41.5	0.520	0.020 – 3,520	3.0
Bjørnøya	12	<0.35	<0.35	<0.35 – 0.690	1.0
Colesbukta	5	35.2	1.40	<0.35 – 160	8.0
Fuglehuken lighthouse	2	<0.35	<0.35	<0.35	1.0
Grumant	13	0.921	<0.35	<0.35 – 4.7	1.0
Hopen	5	<0.35	<0.35	<0.35	1.0
Hornsund	1	<0.35	<0.35	<0.35	1.0
Isfjord Radio	6	1.21	1.30	<0.35 – 2.20	7.4
Longyearbyen*	60	0.221	<0.35	0.005 – 1.10	1.0
Ny-Ålesund	12	<0.35	<0.35	<0.35	1.0
Pyramiden*	83	21.7	0.536	<0.004 – 1290	3.1
Svea	1	<0.35	<0.35	<0.35	1.0

*Lower detection limit in 2007 (<0.004 mg/kg)

TABLE 4.1.6.3-1 Overview of ∑7PCB (mg/kg) in paint from the settlements in Svalbard. Source: the Geological Survey of Norway (NGU)

CONCRETE

LOCATION	NUMBER OF SAMPLES n	ARITHM. AVERAGE ∑7PCB (mg/kg)	MEDIAN ∑7PCB (mg/kg)	MIN – MAX ∑7PCB (mg/kg)	$MEDIAN_{SETTLEM}$ / $MEDIAN_{TOTAL}$
Total	122	0.149	0.01	<0.004-7.09	-
Barentsburg*	50	0.303	0.025	<0.004 – 7.09	1.3
Bjørnøya	-	-	-	-	-
Colesbukta	-	-	-	-	-
Fuglehuken lighthouse	-	-	-	-	-
Grumant	-	-	-	-	-
Hopen	1	<0.02	<0.02	<0.02	1.0
Hornsund	2	<0.02	<0.02	<0.02	1.0
Isfjord Radio	1	<0.02	<0.02	<0.02	1.0
Longyearbyen*	18	0.016	0.010	<0.004 – 0.081	1.0
Ny-Ålesund	6	<0.02	<0.02	<0.02	1.0
Pyramiden*	44	0.058	0.010	<0.004 – 0.724	1.0
Svea	-	-	-	-	-

*Lower detection limit in 2007 (<0.004 mg/kg)

TABLE 4.1.6.3-2 Overview ∑7PCB (mg/kg) in concrete from the settlements in Svalbard. Source: the Geological Survey of Norway (NGU)

The tables 4.1.6.3-1 and 4.1.6.3-2 provide an overview of the results from three years' studies of PCBs in construction materials, paint and concrete in Svalbard. The tables specify the number of samples within each category, arithmetic average concentration, median value and concentration distribution (min.-max.). There is also a category showing the relationship between the median value in each settlement and for the entire data set. This gives an indication of the degree of the contamination in each settlement. Results below the detection limit are counted as half the detection limit in the statistics.

The newest buildings in Longyearbyen, Svea and Ny-Ålesund were excluded from the study since these were constructed many years after the PCB prohibition came into effect in 1980. This means that the buildings have not been examined for potential PCBs contained in modern paint, (Hu et al. 2010).

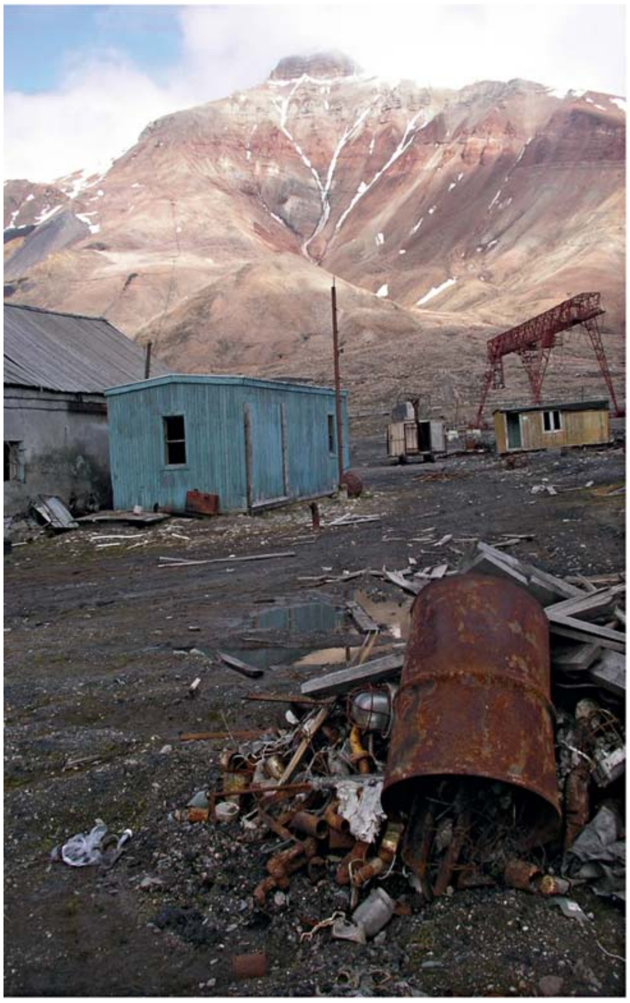
PROPOSED MEASURES:

- Ensure proper waste management when undertaking renovation work on facades containing PCBs.

4.1.6.4 Primary sources - PCBs in technical equipment

Mapping, sampling, removing and decommissioning of equipment containing PCBs in all existing and abandoned settlements has been carried out. Buildings and facilities have been inspected for equipment that potentially contains PCBs (in operation, left behind or stored). Where there has been a suspicion of PCBs, verification samples have been collected and analysed for ∑7PCB. On completion, the status of the project is:

- ☺ **Longyearbyen:** all electrical equipment known to contain PCBs has been removed. Abandoned transformers at mine 5 have been sampled and verified as free from PCBs. Double-glazed windows containing PCBs have been registered and labelled. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen.
- ☺ **Barentsburg:** all electrical equipment known to contain PCBs is assumed to have been removed. The main transformer in Barentsburg has not been sampled. Electrical equipment situated underground in the mine shafts has not been verified, however TA has stated that electrical equipment is air cooled/insulated (i.e. none of the electrical mining equipment is oil-filled).
- ☺ **Svea:** all electrical equipment known to contain PCBs has been removed. Double-glazed windows containing PCBs have been registered and labelled. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen.
- ☺ **Ny-Ålesund:** all electrical equipment known to contain PCBs has been removed. Double-glazed windows containing PCBs have been registered and labelled. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen.
- ☺ **Hopen,** meteorological station: all electrical equipment known to contain PCBs has been removed. Double-glazed windows containing PCBs have been registered and labelled. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen.
- ☺ **Hornsund**, Polish research station: No equipment containing PCBs has been identified.
- ☺ **Pyramiden:** leaking high voltage electrical equipment has been removed. All electrical equipment containing PCBs is now assumed to have been removed.
- ☺ **Grumant:** No equipment containing PCBs has been identified.
- ☺ **Bjørnøya**, meteorological station: all electrical equipment known to contain PCBs has been removed. Double-glazed windows containing PCBs have been registered and labelled. Any panes removed from the body of the building must be delivered to the Waste Facility in Longyearbyen. The wreck of the vessel "Petrozavodsk" has been examined for PCBs, among other substances, and no sources were detected, (The Norwegian Coastal Administration 2010).



Barentsburg has been surveyed for PCBs in buildings. Large amounts of electrical waste, construction leftovers and scrap metal lie in the terrain, especially in the Russian settlements. Some of this waste contained PCBs. Photo NGU.

In addition to heavy high voltage electrical equipment, a total of 4,762 capacitors from light fittings and smaller electrical/electronic equipment have been collected, see figure 4.1.6.4-1. This represents in the order of 250 kg of PCB oil. A total of 415 double-glazed windows containing PCBs have been mapped and marked for subsequent waste treatment.

PROPOSED MEASURES:

- Follow up to ensure that windows containing PCBs are treated in accordance with the regulations

4.1.6.5 Primary sources - Other local sources

Under certain conditions, PCBs may be formed during combustion processes such as burning coal, see chapter 3.1.7. It has also been established that PCBs may be formed during the production of certain types of colour pigments (Hu et al. 2010). For example, the congeners PCB#11, 206, 207, 208 and 209 have been found in modern pigments (Hu et al. 2011).

The relationship has also been found to apply to so-called colour concentrates used in paints that are available on the Norwegian market (Klif, archive no. 2010/1348). The extent to which this potential PCB source exists in the settlements in Svalbard is not known.

4.2 EFFECTS OF POSSIBLE CLIMATE CHANGE

The latest climate reports (UNEP/AMAP Expert Group 2011, IPCC 2007, ACIA 2005) identify the expected changes that could affect Svalbard and other Arctic areas.

Arctic areas appear to be affected more quickly and with greater impact than any other regions of the planet (SWIPA 2011; IPCC 2007). In addition to direct effects in Arctic areas, climate change may also have consequences which will indirectly affect PCB pollutants in Svalbard and other areas; at lower latitudes an increase in the frequency of forest fires can increase the supply of environmental pollutants to the Arctic via the air (Øyseth 2010, Noyes P. D. et al. 2009).

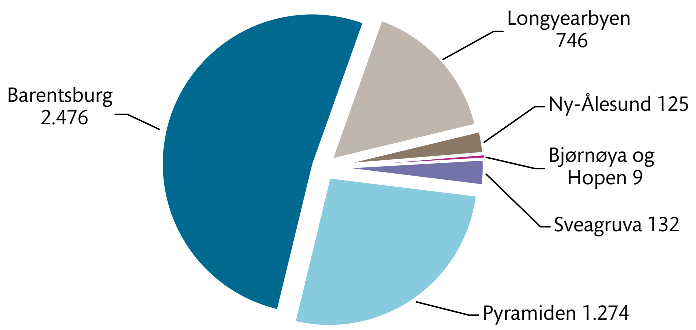
Forecast climate change may affect ice cover and air and oceanic currents flowing into the Svalbard area (Macdonald et al. 2005). In addition, for example temperature-dependent processes such as absorption and accumulation of PCBs could be affected. The result can be direct or indirect changes in sources, transport processes and pathways, and degradation patterns such as:

- supplied types of congeners and supplied amounts (Øyseth 2010)
- distribution between supply pathways. Studies have for example shown that temperature changes have altered the distribution (partitioning) of organic compounds, such as PCBs, between unbound and particulate phases in water (Smith and McLachland, 2006) and air (Macdonald et al. 2005).
- geographic distribution of the substances. Greater precipitation can lead to increased erosion and more rapid wash-out of PCBs from secondary sources, such as substances temporarily held in soil, snow and ice. Moreover, increased rates of glacial and sea ice melting may release the substances that are bound in the ice (Øyseth 2010 NorAcia). Measurements taken in food chains from Svalbard suggest a seasonal variation that may indicate an influence from local glacial sources, (Hallanger et al. 2011).
- transformation and degradation (for example photochemical and microbial).
- bioaccessibility, and thus intake and accumulation in organisms (Noyes et al. 2009; Borgå et al. 2010). Increased sea temperatures may for example indirectly affect the ecosystems through changes in turnover and effects. Changes in the structure of the food web as a result of climate change have been documented in Arctic fjords (Willis et al. 2006 and 2008; ACIA 2005). It has also been reported that the nutritional intake of polar bears from Western Hudson Bay has undergone changes which have resulted in an increase in the concentrations of persistent organic compounds in tissues (McKinney et al. 2009). Changes in the timing of the annual breakup of sea ice explained a significant part of the differences in food intake.
- Effects. In addition to effects from a growing quantity of environmental pollutants, other stress situations could interact negatively in areas such as nutritional stress. An example being seabirds which deplete their fat stores during periods of nutritional scarcity and where environmental pollutants that have already been stored may be released from body fat into the blood. The released environmental pollutants may contribute to reduced breeding success and diminished survival with the concomitant decline in population.

Since 2004 the Zeppelin station has recorded an increase in the levels of certain PCB congeners and hexachlorobenzene (HCB). This may indicate that the supply of contaminants to Svalbard and the Barents Region is affected by climate change, see chapter 3.1.4. Warm Atlantic water flowing up along Spitsbergen's west coast which has been ice-free year-round in recent years is assumed, in combination with the degassing of PCBs from sea water, to be the explanation for the recorded increase (AMAP 2009), see chapter 4.1.3. Modelling of this data material has been conducted based on IPCC scenarios (Ma et al. 2011).

INNSAMLETE PCB-KONDENSATORER 2007-2010

totalt 4.762 stk



Kilde: Sysselmannen på Svalbard, 2010

PICTURE 4.1.6.4-1 Number of PCB capacitors collected in the settlements. Electrical equipment containing PCBs are sent away for destruction.

The polar bear will continue to struggle with PCB contaminants. Based on present knowledge it is not possible to predict the effects of the climate change, however a potential outcome is that PCBs in Arctic areas will increase. This will then take place in spite of the efforts of the Stockholm Convention to phase out and safely destroy the substances. Over the years, this should have suggested a reduction in levels of the substances. Photo: Magnus Andersen, Norwegian Polar Institute

NorACIA has pointed out the following (NorACIA 2010):

- Little research has been undertaken that can contribute to predicting how the impact of the environmental pollutants will change in response to climate change. There is a need to map how changes in air and oceanic currents will affect the supply of contaminants and how the composition of contaminants which affects Arctic ecosystems will change as a consequence of this.
- Furthermore, it is important to gain knowledge about how changed contamination effects, temperature changes and other stress factors in aggregate are affecting species and ecosystems. This type of new knowledge is crucial if we are to predict the effect of the changes and implement measures to counter the most pernicious influences where applicable.

Research work has been initiated which will remedy some of this deficiency in knowledge, including COPOL (Contaminants in Polar Regions) and "Combined Effects of Climate Change and Contaminants" (an AMAP initiative), the final report is expected at the beginning of 2012.

Based on current knowledge it is not possible to predict the effect of all the changes with a high degree of certainty. A potential outcome of the notified climate changes is that PCBs in Arctic areas will increase. This will then take place in spite of the intentions and efforts of the Stockholm Convention to phase out and safely destroy the substances and which was intended to reduce levels of the substances/contaminants over time.

Model experiments (Lamon et al. 2009) indicate that a reasonable international phasing out of primary sources in line with the Stockholm Convention is most important in achieving the reductions.

4.2.1 MODELLED CLIMATE CHANGE IN EAST SVALBARD

Climate change scenarios show that the changes will be greatest and emerge first in East Svalbard. A warmer climate will lead to major changes in the natural environment and in ecosystems in the oceans and on land. The major changes over the next century, as shown in the models are:

- warmer climate (especially in autumn and winter)
- more precipitation (10-40 per cent increase compared with the current rainfall)
- more days with heavy precipitation
- greater relative increase from south to north
- more snow in the north, less snow in the south
- reduced snow depth, but not in the outer regions
- possible increase in maximum wind strength and wind speeds in all seasons

According to the Norwegian Polar Institute, East Svalbard can expect major temperature increases during this century. This applies especially to the sea east of Svalbard, and on the islands where 8 °C increases are expected during the winter as early as in the middle of the century. There is also a change in precipitation amounts, especially in northern regions, although in absolute numbers these changes may seem small as the archipelago currently has little precipitation. There may be changes in snow depth over the archipelago, and there may be more than 60 per cent less snow depth in some places.

PROPOSED MEASURES

- Continue long-term studies to clarify the relationship between climate changes and the level of environmental pollutants

FOOTNOTE CHAPTER 4

[19]Personal statement, Roland Kallenborn.

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6 SUMMARY OF REPORTS FROM LOCALISED ENVIRONMENTAL POLLUTANT SURVEYS

This table provides an overview of surveys of PCBs and environmental pollutants conducted in geographically limited areas on land and in sediments in Svalbard, with results and possible follow-up.

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
LONGYEARBYEN/ADVENTFJORDEN				
2009	Geological Survey of Norway (NGU) / Jartun et al. 2009	Follow-up surveys and PCB analyses of surface soil, paint and concrete. Low level of PCB contamination in soil. PCBs detected in low concentrations in individual samples.	PCBs in surface soil and paint.	Special measures have not been recommended in Longyearbyen beyond correct treatment of waste when demolishing/renovating buildings containing PCBs in paint/ windows and cleaning measures in the power plant to curtail emissions of newly-formed PCBs.
2009	Evenset et al. 2009 Akvaplan-niva report 4707-1.	Environmental toxins in marine sediments in Isfjorden, Svalbard 2009. Research outside Longyearbyen, Barentsburg, Pyramiden and Coles Bay.		
2007	NGU/ Jartun et al. 2007	PCB analyses of surface soil, paint, concrete, oils and capacitors. Low level of PCB contamination in soil (condition class I and II), detected in paint and in soil around huts in Nybyen and in paint from Mine 3.	PCBs in oil, paint, concrete, soil and capacitors	Local supply of pollutants to Adventtfjorden was found, but generally low values (condition class I-II). Possible sources in contaminated soil have been evaluated by NGI and recommended measures have been followed up earlier and been reviewed by Klif/SMS in 2008. The source situation in the drainage system is expected to be better than it was before the 1990s due to stricter regulations on use of the various compounds. New cleaning measures will be evaluated after new measurements taken by 2009. Will be necessary to conduct follow-up surveys to monitor status. Overview of decommissioned light fittings containing PCBs at SMS. The Power station has been required to construct a new waste disposal site that over time will reduce wash-outs along the fjord where ash is currently deposited, even though the supply of environmental pollutants and heavy metals from soil water has been found to be minimal.
2006	SMS 2006	Inspection of all buildings with the building owners covering decommissioning of light fixtures containing PCBs, marking of PCB double-glazing and treatment of hazardous waste. All capacitors are to be phased out during 2007, all windows must be marked.	PCBs in light fixtures and double-glazed glass.	
2005	Akvaplan-niva/ Velvin et al. 2006	Marine recipient survey at Longyearbyen, Svalbard 2005. Soft-bed survey in Adventfjorden for Svalbard Samfunns-drift.		
2005	Akvaplan-niva/ Evenset 2006	Environmental survey of marine sediments outside the settlements in Isfjorden. PCBs found in the sediment in Adventfjorden are within condition class I.		
2002	Akvaplan-niva/ Evenset 2002	Environmental pollutants in Adventfjorden: Related to emissions from Longyear Power station? On behalf of Longyear Energi.		
2001	Akvaplan-niva/ Evenset 2002	Follow-up of DDT and toxaphene findings in two stations from Cochrane et al. 2001. Considerably lower DDT values (class I), and with relatively higher proportions of DDE and DDD than in 1998. Local emissions of DDT at the end of the 1990s can not be excluded. Toxaphene was not rediscovered. Possible errors in the toxaphene analysis from 1998 must be considered.	PCB/HCB: drain system, old landfills PAH: Coal fired power plant, shipping, oil contamination, coal particles (natural and from coal power operation). DDT: Unknown.	
1999	Akvaplan-niva/ Savinova et al. 1999.	Biological effects of POPs on Glaucous Gulls.		
1999	NP/ Hop et al. 2001	POPs in marine macrobenthos. An insignificantly higher level of contamination was found in the material (class I).		
1998	Akvaplan-niva/ Cochrane et al. 2001	All stations in PAH, class II. PCB class I in the majority of stations, one station class II. For HCB the stations were in class I-II. DDT: one station class IV, others class I-II. High proportion of DDT in relation to DDD/DDE indicated "fresh" supply. Low values of metals (class I).		
1992	Akvaplan-niva/ Holte et al. 1994	All stations: PAH in class III. PCBs under detection limit (< 0.2 µg/kg). HCB in class III-IV. Low DDT values. Low values of metals (class I).		

GRØNFJORDEN/BARENTSBURG

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2009	Geological Survey of Norway (NGU) / Jartun et al. 2009	Follow-up surveys and PCB analyses of surface soil, paint and concrete. Supplementing previous work. Samples from all buildings. The results confirm earlier findings.	PCBs in surface soil, paint and concrete.	See "Diverse areas" below, and the reports from Akvaplan-niva and NGU 2010.
2009	Evenset et al. 2009 Akvaplan-niva report 4707-1.	Environmental toxins in marine sediments in Isfjorden, Svalbard 2009. Research outside Longyearbyen, Barentsburg, Pyramiden and Coles Bay.		
2007	NGU/ Jartun et al. 2007	PCB analyses of surface soil, paint, concrete, oils and capacitors. Over 11% PCBs in Russian capacitors. Soil from the Russian settlements was markedly contaminated with PCBs (condition class II-V for both), higher PCB content than previously found in mainland Norway. This is likely due to extremely high concentrations of PCBs in paint from Barentsburg and Pyramiden; PCBs also found in concrete in Barentsburg.	PCBs in oil, paint, concrete, soil and capacitors	Local supply of environmental pollutants has been detected, and Grønfjorden outside Barentsburg stands out as the most affected of the areas surveyed (condition class I-III). Possible sources in contaminated soil have been evaluated by NGI. Recommended measures are being followed up. The source situation in the drainage system is expected to be better than it was before the 1990s due to stricter regulations on use of the various compounds. The effect of this in the Russian settlements is uncertain. Follow-up surveys necessary to monitor status and execution of inspections. Norwegian authorities have notified equal treatment of Trust Arktikugol with regard to environmental requirements for the company.
2005	Akvaplan-niva/ Evenset 2006	Environmental survey of marine sediments outside the settlements in Isfjorden. Concentrations in Grønfjorden outside Barentsburg were in condition class II.		
1999	Norwegian Polar Institute/ Hop et al. 2001	POPs in marine macrobenthos. An insignificantly higher level of contamination was found in the material. i.e. mainly class I with the exception of PAH class II.	PAH: Coal fired power plant, shipping, oil contamination, coal particles (natural and from coal power operation). PCB/HCB: drain system, old landfills	
1998	Akvaplan-niva/ Cochrane et al. 2001	PAH in class II and PCBs in class I for all stations. HCB in class I-II. DDT: one station class III, others class I-II. Low values of metals (class I).		
2001	Akvaplan-niva/ Savinov et al. 2001.	Contaminant levels in Glaucous Gulls from Barentsburg, 2001		
1992	Akvaplan-niva/ Holte et al. 1994	All stations: PAH in class III. PCBs: one station class III, three stations class II, two stations class I. For HCB the stations were in class III-IV. Low DDT values. Low values of metals (class I).		

BILLEFJORDEN/PYRAMIDEN

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2011	Evenset et al. 2011 in progress	Studies of the spread of PCB contamination beyond the fjord, including toxicity testing.		Also contributing to the assessment of the relative contribution from local PCB sources compared with long range transported PCBs.
2009	Evenset et al. 2009 Akvaplan-niva report 4707-1.	Environmental toxins in marine sediments in Isfjorden, Svalbard 2009. Research outside Longyearbyen, Barentsburg, Pyramiden and Coles Bay.		
2009	NVE/ Benjaminsen 2009	Particulate transport from land to sea in Pyramiden and Barentsburg has been calculated. Surface run-off means that more or less the entire ground surface is washed, and finer particles are led out into the drainage system. Data are used as a basis for calculating transport of environmental toxins. In Pyramiden a single stream may transport about 100 tonnes of material out to the sea each year, mostly when it is in flood. Wind transport is assumed to be an active process, especially in Barentsburg with the large open terrain.	Particulate transport in rivers and streams at Barentsburg and Pyramiden	In Pyramiden the quantity of transported masses and the levels of particulate-bound PCBs in the river material generate annual emissions of about 7 g $\sum$7PCB. This is equivalent to a mid-sized to large Norwegian industrial emission. Sources on land are thus active and supply pollutants to the fjord.
2009	Geological Survey of Norway (NGU) / Jartun et al. 2009	Follow-up surveys and PCB analyses of surface soil, paint and concrete. Supplementing previous work. Samples from all buildings. The results confirm earlier findings.	PCBs in surface soil, paint and concrete.	

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2007	NGU/ Jartun et al. 2007	PCB analyses of surface soil, paint, concrete, oils and capacitors. Over 11% PCBs in Russian capacitors. Soil from the Russian settlements was markedly contaminated with PCBs (condition class II-V for both), higher PCB content than previously found in mainland Norway.	PCBs in oil, paint, concrete, soil and capacitors.	Local supply of environmental pollutants has been detected in the sediments (class II-III). Higher levels of PCBs in 2005 than in 1998 indicate an active source. High PCB levels in paint/concrete, disused equipment containing PCBs. Possible sources in contaminated soil have been evaluated by NGI. Big storage room for oil cleaned up in 2006. May have leaked oil. Operations were closed down in 1998, discharge ceased. Wash-out of contaminated soil may increase over time as the river erodes the town. Clearing up waste containing PCBs and measures to counter PCBs in paint and surface soil must be considered. Follow-up surveys should be conducted.
2005	Akvaplan-niva/ Evenset 2006	Environmental survey of marine sediments outside the settlements in Isfjorden. The highest concentrations of PCBs were found outside Pyramiden (condition class III).	PCBs from possible active source on land.	
1999	Norwegian Polar Institute/ Hop et al. 2001	POPs in marine macrobenthos. An insignificantly higher level of contamination was found in the material (class I)	PAH: Coal fired power plant, oils, coal particles (natural and from coal power operation). PCB/HCB/DDT: drain system, old landfills	
1998	Akvaplan-niva/ Cochrane et al. 2001	The majority of stations had PAH in class II, PCBs in class I, HCB in class I, DDT in class I-II. Low values of metals (class I-II, natural).		

KONGSFJORDEN/NY-ÅLESUND

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
1999	Norwegian Polar Institute/ Hop et al. 2001	POPs in marine macrobenthos. An insignificantly higher level of contamination was found in the material (class I).	PAH: Oil contamination, coal particles (natural and from coal power operation). PCBs: old landfill	Measures enacted on potential sources (waste disposal and tank site) have been conducted in 2003. When the sites are shut down it is necessary to determine monitoring requirements. Execution of inspection.
1997	Akvaplan-niva/ Olsson et al. 1998	PAH class II in Kongsfjorden. Concentrations on the same level as other stations in the survey in areas without local sources.		
1991/92	NIVA/ Skei 1993	Sediment survey. Increased values of PCBs - class I - at the waste disposal site in Kullhamna. PAH class V at the waste disposal site in Kullhamna and class III just outside Ny-Å. The waste disposal site and oil contamination from the tank site (leakage in 1985) may be possible sources. PAH has not otherwise been detected in the fjord in concentrations necessitating follow-up. Pesticides and PCBs mainly at background level or below the detection limit in Kongsfjorden. Metals generally at background level.		
1988	NGU	Metals in soil	Naturally increased content	Gold, arsenic detected

ISFJORDEN

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2009	Evenset et al. 2009 Akvaplan-niva report 4707-1.	Environmental toxins in marine sediments in Isfjorden, Svalbard 2009. Research outside Longyearbyen, Barentsburg, Pyramiden and Coles Bay.		
1999	Norwegian Polar Institute/ Hop et al. 2001	POPs in marine macrobenthos (west of outlet from Linnévatnet). An insignificantly higher level of contamination was found in the material. i.e. mainly class I with the exception of PAH class II.	Natural leakage of oil from the seabed, coal (natural and from mining operations) and combustion remains from coal power plant and shipping.	May be necessary to include measurement points from these surveys in follow-up surveys of sediments outside the settlements in Isfjorden planned in 2015 to follow developments in the large fjord system and monitor status.
1998	Akvaplan-niva/ Cochrane et al. 2001	PAH class II in Svensksunddjupet at the furthest point in Isfjorden. POPs and metals do not show significantly higher values (class I-II).		
1992	Akvaplan-niva/ Killie et al. 1997	PAH class III in Svensksunddjupet at the furthest point in Isfjorden. Other POPs and metals do not show significantly higher values (class I-II).		

COLESBUKTA

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2009	Evenset et al. 2009 Akvaplan-niva report 4707-1.	Environmental toxins in marine sediments in Isfjorden, Svalbard 2009. Research outside Longyearbyen, Barentsburg, Pyramiden and Coles Bay.		

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
2008	NGU/Eggen et al., 2008	Surveys of surface soil beside buildings, paint from buildings. Detection of PCBs in paint and surface soil.		
2005	Akvaplan-niva/ Evenset et al. 2006	Environmental survey of marine sediments outside the settlements in Isfjorden. Low concentrations of PCBs (condition class I).	PCB pattern indicates long range transporta-tion as source.	
2001	NGI 2002		Diesel in free phase by barges.	Obligatory clean-up requirement by SMS, execution by Trust Arktikugol.
FORLANDSUNDET				
1998	Akvaplan-niva/ Cochrane et al. 2001	PAH class II south of Poolepynten in Forlandsundet. Other POPs and metals do not show significantly higher values (class I-II), lower values than in Isfjorden, and in accordance with "background values" around Svalbard.		Follow-up not necessary.
SVEAGRUVA				
2009	Akvaplan-niva/ Evenset & Christensen 2009	Studies of environmental pollutants in sediment outside Kapp Amsterdam, Svea. Akvaplan-niva report 4709-1		On behalf of Store Norske Spitsbergen kullkompani
2008	Akvaplan-niva/ Velvin et al. 2007	Recipient monitoring in Van Mijenfjorden Akvaplan-niva report 3809 - 01		On behalf of Store Norske Spitsbergen kullkompani
GRUMANT				
2009	Geological Survey of Norway (NGU) / Jartun et al. 2010	Some sediment samples analysed, difficult sampling.		
2008	NGU/Eggen et al., 2008	Surveys of surface soil beside buildings, paint from buildings. Detection of PCBs in paint and surface soil.		
FRESHWATER				
2009 -2010	Akvaplan-niva/ Christensen et al.	Studies of environmental pollutants in Arctic char from 8 lakes at Spitsbergen and 2 at Bjørnøya.	POPs and Hg in muscle tissue from Arctic char	Arctic char from Ellasjøen, Laksvatn (Bjørnøya), Richardvatn, Arresjøen, Annavatn, Ratjørna, Diesetvatn, Linnévatn, Straumsjøen and Liefde-fjorden were analysed for POPs and Hg. The analysis results show that PCBs are the dominant environmental pollutants in fish from all the lakes that were examined. Lakes affected by seabirds had generally the highest concentrations of environmental pollutants.
2008	Akvaplan-niva/ Christensen et al. 2008	Coordinated, national sediment surveys. Part III: Status of metals and organic pollutants in sediments and fish from selected lakes within the Norwegian AMAP area	POPs and metals measured in sediment.	Sediment from Ellasjøen, Kongressvatn, Arresjøen, Richardvatn and analysed for POPs and metals. Fish from Ellasjøen, Richardvatn, Åsøvatn and Arresjøen are analysed for POPs and Hg.
1997	Akvaplan-niva/ Skotvold et al. 1997.	Heavy metals and persistent organic pollutants in sediment and fish from lakes in Northern Norway and in Svalbard.	PCBs measured in sediment.	PCBs measured in sediment from Ellasjøen and Barentsvann. High levels in Ellasjøen. Relatively low levels in Barentsvann. Fish from Ellasjøen, Diesetvannet, Richard-vatn, Hornsundet and Kongress-vatn analysed for environmental pollutants.

YEAR	INST./ REFERENCE	RESULTS/CONDITION	SUBSTANCES/ SOURCES	SUMMARY AND FOLLOW-UP
DIVERSE AREAS				
2010	Akvaplan-niva/ Evenset 2010	The report provides an overview of environmental studies undertaken at settlements in Svalbard and has a stage 1 risk assessment for contaminated sediment. The concentrations of most compounds are lower than the threshold value for ecological risk (cf. Klif's guidelines), with the exception of several PAH compounds (all areas) and PCBs in sediment at Pyramiden. If the supply from local sources were to stop, sedimentation would lead to a natural improvement in the environmental conditions in the seabed.		• Monitoring of the seabed should continue and the intake and effects of environmental pollutants in the most contaminated areas should be investigated further. • It is recommended to refrain from implementing measures to counter a contaminated seabed now, instead focus on the sources on land and measures there to prevent leakages of environmental pollutants into the sea. • Necessary to study how far out in the fjord PCBs are spreading and effects on the marine ecosystem.
2007-2009	Geological Survey of Norway (NGU) / Jartun et al. 2010	PCBs from local sources in Svalbard, surface soil and products from 2007-2009, combined report for 1,019 samples collected from all the settlements in Svalbard. 60% of the existing buildings in Barentsburg and Pyramiden contain PCBs in one or more types of materials. In Longyearbyen traces of PCBs have been found in 15% of the buildings examined, either in outdoor paint or concrete. There are also rough estimates of the PCB content in the surface soil in the three largest settlements and for background levels. Barentsburg and Pyramiden are substantially contaminated with PCBs, whereas there is little in Longyearbyen.	PCBs in soil, sediments, construction materials (paint, concrete, etc.)	• The authorities, in conjunction with Trust Arktikugol, must ensure that due and proper care is taken in connection with moving surface masses, particularly in the Russian settlements, as well as ensure that contaminated soil and building waste are safely disposed of. • Background levels of long range transported pollutants should be more thoroughly calculated based on further samples and broader analyses.
2008	NGU/Eggen et al. 2008	With the exception of Svea, PCBs have been found in one or more samples of surface soil or paint from all the settlements. Paint is the primary local source in Barentsburg, Colesbukta, Grumant, Isfjord Radio and Longyearbyen. Secondary sources of PCBs (soil and sediments) in Barentsburg, Colesbukta and Ny-Ålesund.	PCBs in oil, paint, concrete and soil	More samples were collected in 2009
1994 1992	Akvaplan-niva/ Olsson et al. 1998 Killie et al., 1997	Measurement of the level of long range transported pollutants in Hinlopen, Storfjorden, Erik Eriksenstretet et al.		Follow-up not necessary.
1987	NGU, Ottesen et al.	Geochemical mapping of 50 elements		Sample material has been archived in NGU's sample bank.
BJØRNØYA, HOPEN AND HORNSUND				
2008	NGU/Eggen and Ottesen, 2008	Mapping potential local sources of PCBs at Bjørnøya, Hopen and Hornsund	PCBs in paint and surface soil	Bjørnøya, Hopen and Hornsund are largely free from local sources of PCBs, but there are still some PCBs in paint and surface soil in Bjørnøya
THE GOVERNOR OF SVALBARD				
2010	SMS 2010	The PCB project 2010 Annual Report and final report: 1. all equipment containing PCBs has been destroyed (4,762 capacitors and two tonnes of heavy industrial equipment) 2. PCBs in soil and buildings have been mapped and documented (including the labelling of 415 windows containing PCBs), meaning future waste can be handled responsibly 3. documentation of PCB levels on land and in the fjords 4. many interim reports containing new knowledge about PCBs, all translated into English and Russian 5. good cooperation with the Russian mining company Trust Arktikugol on joint Norwegian–Russian environmental monitoring and interdisciplinary collaboration 6. best practices and lessons learned publicised in several international forums	PCB	The project has encouraged the Ministry of the Environment to implement the following measures to increase knowledge and information: - if possible, estimate how large the local PCB sources are in relation to the long-range contamination, and - make the results of the work available to international forums, such as The Stockholm Convention - share experience and contribute to more international cooperation to prevent the local dispersion of PCBs.

2009	Norwegian School of Veterinary Science	Analyses of PCBs in polar bear (fat, liver and muscle) and reindeer show that sporadic ingestion of meat from the sampled polar bear would not constitute a health risk to an adult human. No PCBs were found in the reindeer meat.	PCBs in polar bears and reindeer	
2009	SMS 2009	The PCB project 2009 Annual Report	PCB	See above (SMS 2010).
2008	SMS 2008	The PCB project 2008 Annual Report	PCB	See above (SMS 2010).

BIRDS/NORWEGIAN POLAR INSTITUTE

2010	NP brief report no. 16, 2010	Environmental pollutants in Brünnich's Guillemot eggs from Kongsfjorden and Bjørnøya during the period from 1993 to 2007. For the majority of the organic environmental pollutants studied, including PCBs, a significant reduction in concentrations was found from 1993 to 2002/2003 and from 2002/2003 to 2007.	PCBs/ Long range transport	The concentrations of all analysed substances were generally comparable with previously reported concentrations in seabird eggs in the Arctic and the Barents Sea (AMAP 2004, Helgason et al. 2008). The concentrations of environmental pollutants that have been detected in Brünnich's Guillemot eggs are below the limit for negative effects on eggs and embryonic development.
2009	NP Brief Report no. 14, 2009 and Final report to Svalbard's Environmental Protection Fund 2010	Environmental pollution in eggs from Black-legged Kittiwake (Rissa tridactyla) from Barentsburg, Pyramiden and Kongsfjorden – a study of contributions from local pollutants to Black-legged Kittiwake seabirds in the settlements in Svalbard. The study of Black-legged Kittiwake eggs did not find any differences in the concentrations or composition of environmental pollutants in Kongsfjorden, Barentsburg and Pyramiden. The sources of the environmental toxins in nesting Black-legged Kittiwakes are therefore long range transported pollutants. An explanation for this may be that Black-legged Kittiwakes only spend part of the year (April to September) in nesting areas. In addition, Black-legged Kittiwake principally collect food from out in the fjord system or beside glacier fronts where swimming sources of nutrients such as fish and crustaceans are unaffected by local sources of contamination.	PCBs/ Long range transport	There is not a need for follow-up studies of seabirds that exclusively collect food from the sea/surface of the sea (i.e. pelagic crustaceans and fish, not benthic fauna– benthic food) regarding contamination contributions from local sources in Svalbard.
2007	NP brief report no. 7, 2007	Organic halogenated environmental toxins and mercury in Ivory Gull eggs. High concentrations of environmental pollutants in Ivory Gull eggs have been found compared with levels in eggs from a number of seabird species (such as Ivory Gulls, Glaucous Gulls and Black-legged Kittiwake) from across the Arctic. In addition, negative associations have been found between egg shell thickness and a number of environmental toxins, indicating that egg shell thickness is affected by environmental pollutants.	PCBs/ Long range transport	The high concentrations of environmental toxins, particularly organochlorines, found in Ivory Gull eggs from Svalbard and the Russian Arctic are probably so high that they are affecting Ivory Gulls and can have an impact on the Ivory Gull population. The high concentrations mean that Ivory Gulls must continue to be monitored for environmental pollutants.

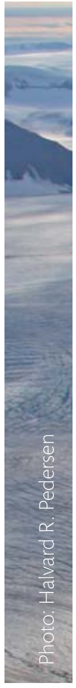
Photo: Halvard R. Pedersen

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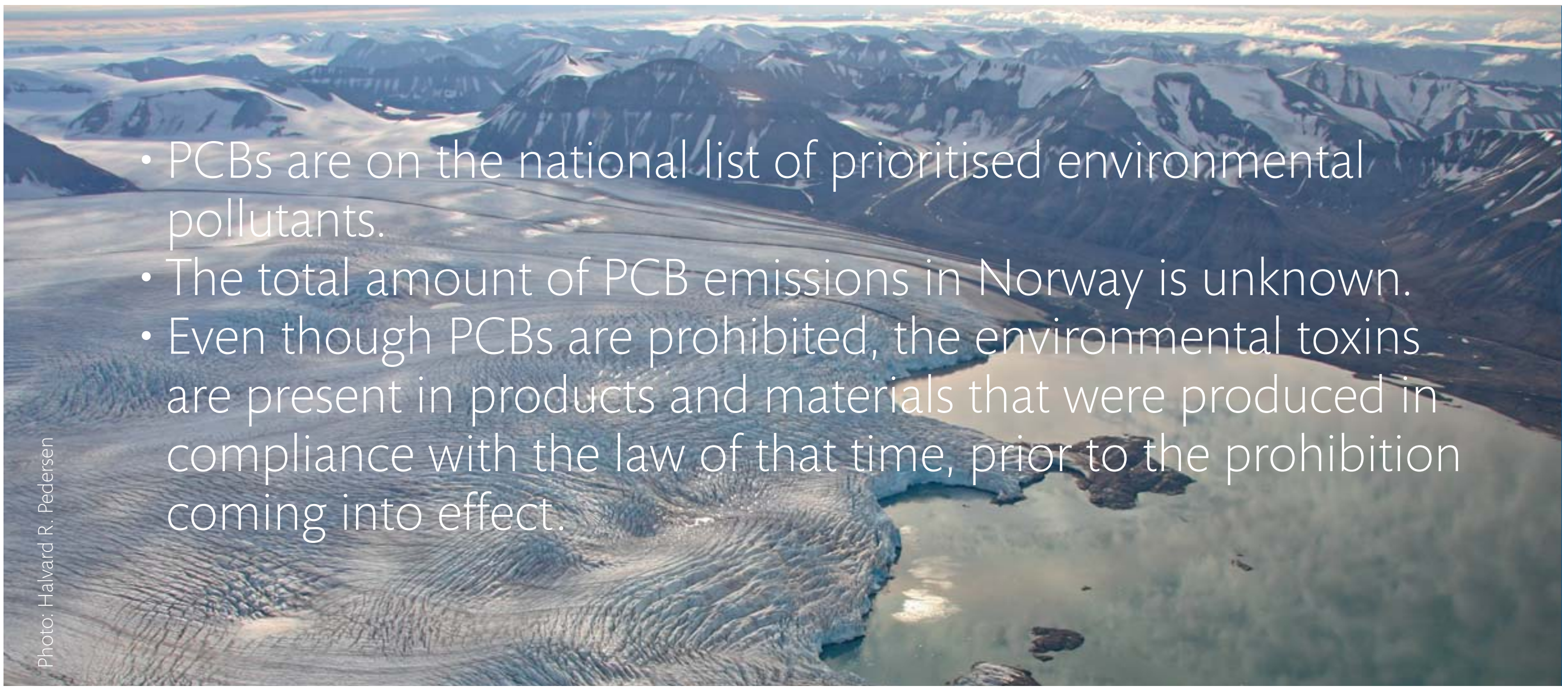


Photo: Halvard R. Pedersen

7 APPENDIX

Supplement to previous chapters.

7.1 LONG RANGE TRANSPORTED POLLUTANTS: SOURCES IN THE NORTHERN HEMISPHERE

GENERAL

Model calculations can provide an overview of potential source regions of contaminants that are affecting the Svalbard region. The calculation shown below for PCB#28 was performed by the Pollution Monitoring Project (Tilførselsprosjektet) and has been documented by Green et al. 2010:

The simulations have been conducted with the atmospheric dispersion model FLEXPART (Stohl et al. 1998; Stohl and Thomson 1999; Stohl et al. 2005 http://transport.nilu.no/flexpart). The model is based on so-called "Lagrangian particle dispersion" and has been validated through several different studies, for example continental dispersion experiments (Stohl et al. 1998); transport of biomass burning emissions from Eastern Europe to the Arctic (Stohl et al. 2006); long range transported air pollutant episodes between continents (Stohl et al. 2003) and in the Arctic (Eckhardt et al. 2003), as well as long range transport of PCB#28 to Birkenes station in Southern Norway (Eckhardt et al. 2009). Meteorological data for running the model comes from European Centre for Medium-Range Weather Forecasts (ECMWF 2002).

The results from the model have been obtained using data from 2007 and give a three dimensional distribution of potential emission sensitivity - PES - (unit s/kg), for the locations.

STATION NO.	SITE	COORDINATES
1	Zeppelin	78.9°N 11.9°E
3	Barents Sea	78.9°N 25°E
4	Barents Sea	75.0°N 20°E
5	Barents Sea	75.0°N 28°E

FLEXPART Simulation results

An annual average transport pattern for 2007 for the sites is shown in figure 7.1-1. The most important source region for the air found at these sites is the Arctic area, Northern Scandinavia, Greenland and Northern Russia, but also Northern Europe can be expected to contribute to these locations. Figure 7.1-2 shows the same information, but displayed seasonally. The influence from continents shows large differences between the summer and winter, while spring and autumn are showing average results. In the summer, air lingers in the vicinity of the sites for a longer period of time and there is less transport of air towards the Arctic, whereas in the winter there is increased potential for transport from the continent. This is also clearly shown in the expected concentration estimates figure 7.1-2.

Zeppelin station is located at the summit of a mountain, 478 metres above the sea. Emission sensitivity (ES) is reduced from the station in all directions, but the decline is slowest in the direction of Europe and Siberia, particularly in the winter. This indicates that emissions from these areas will most likely be able to reach Zeppelin over the course of this time of year. Figure 7.1-3 shows the same analysis, but displayed separately for each site. There is a clear difference between the two northernmost places and the others. The two display a clear maximum persistence time for the air to the north of Svalbard. The Zeppelin station (no. 1) shows an influence from Russia that is very different compared with Andøya (no. 2), which is more affected by source regions in Western Europe and further down in the North Atlantic.

For each season and every site, the expected average concentration of PCB#28 has been estimated and is shown as an emission contribution map (figure 7.1-4). It is clear to see that Great Britain, Europe and Western Russia are the dominant emission regions for all the sites.

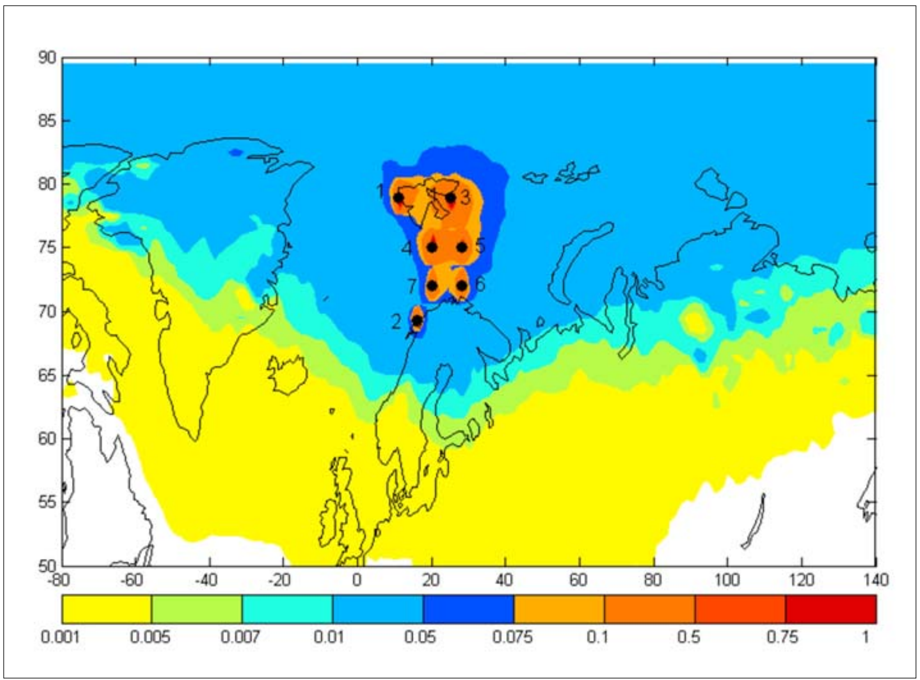


FIGURE 7-1 Footprint map showing the average emission sensitivity (ES) (0-100 m.) for air [ns/m3] represented by PCB#28 and the average for the sites throughout 2007. Source Green et al. 2010.

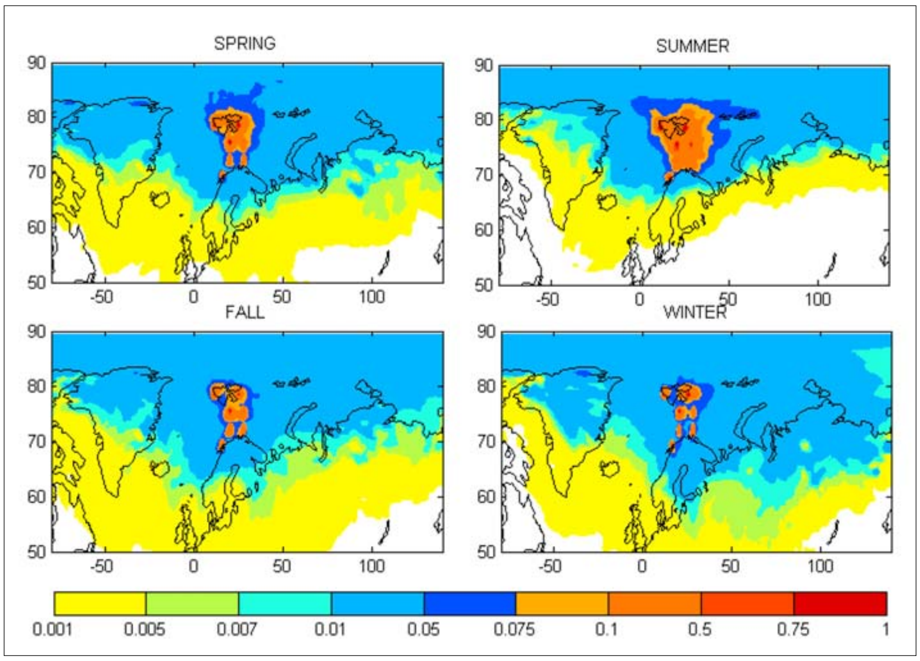


FIGURE 7-2 Footprint map showing the average emission sensitivity (ES) (0-100 m.) for air [ns/m^3] represented by PCB#28 and the average for the sites in spring, summer, autumn, and winter 2007. Source Green et al. 2010.

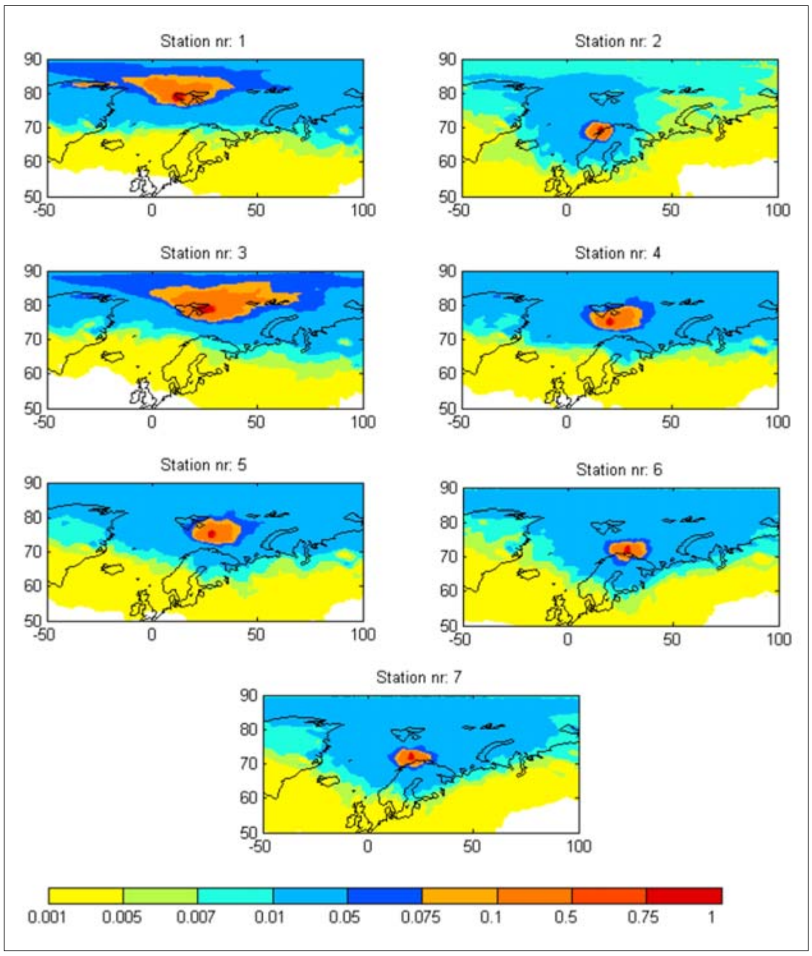


FIGURE 7-3 Footprint map showing the average emission sensitivity (ES) (0-100 m.) for air [ns/m^3] represented by PCB#28 and the average for the sites throughout 2007. Source Green et al. 2010.

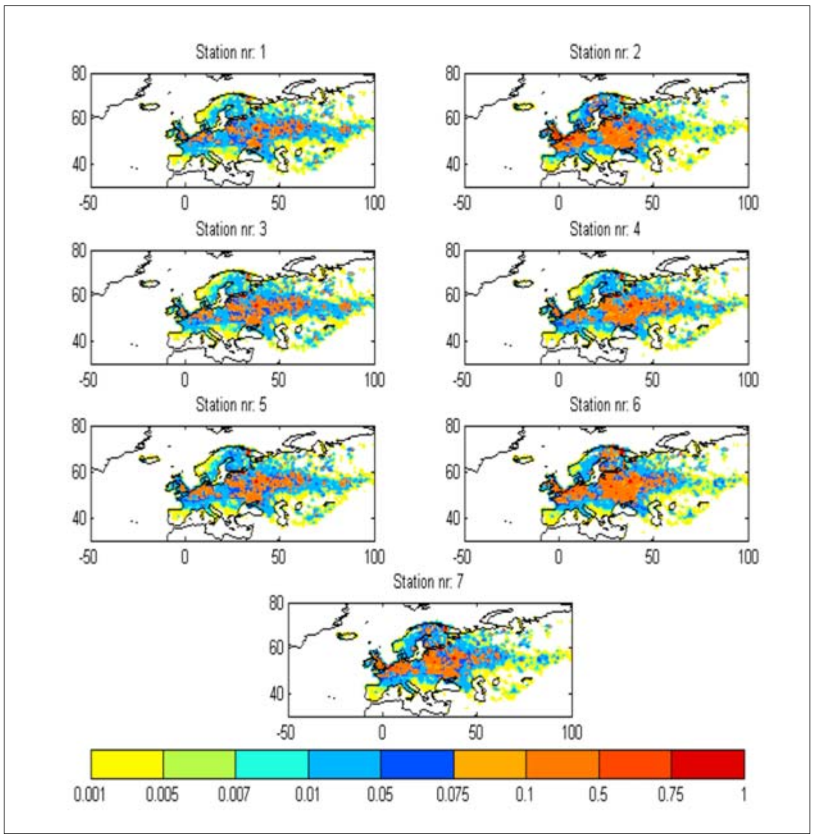


FIGURE 7-4 Average emission contribution (EC) for 2007, represented by PCB#28 tracer [1E12 pg/m^8]. Source Green et al. 2010.

There is a very clear seasonal variation in PCB#28 concentration. Modelled values are low in the winter and high in the summer. In the summer, air persists in the area for much longer periods and there is reduced transport into the region. This means that it would be reasonable to expect that deposition of atmospheric supply to the sea varies significantly during the year. Other studies (for example Eckhardt et al. 2003) have found that in this region North Atlantic Oscillation (NAO) plays a vital role in long range transport episodes from the continent to the northern areas. Since the NAO index has been fairly stable in recent years, the annual variation is expected to be much lower than the seasonal variation.

EMEP Simulation results

For comparison purposes, the results from the EMEP model may be considered. This model shows which of the OSPAR countries are contributing the most, so-called source matrix calculations.

The EMEP model has been developed to support relevant activities during the long range transport conversion (e.g. Malanichev et al. 2004) and is probably the most utilised model for management purposes in Europe both with regard to organic and metallic environmental toxins. This model is developed and run by MSC/East (Meteorological Synthesizing Centre – East) which is one of the centres under UN/ECE EMEP (http://www.emep.int).

Gusev et al. 2009 present EMEP calculations of how various countries affect the concentrations and deposition of organic environmental pollutants, including calculations pertaining to how individual countries contribute to deposition of PCB#183 in the year 2006. In the region described as "Arctic Water" certain similarities in the supply pattern can be expected. But it can not be assumed per se that the supply pattern for other organic environmental pollutants corresponds to the pattern for PCB#183, since the potential for long range transport varies (Beyer et al. 2000; Beyer et al. 2003) and due to differences in source areas for the various substances (Breivik et al. 2004).

7.2 REGULATIONS AND CONVENTIONS

Even though PCBs are prohibited, the environmental toxins are present in products and materials that were produced in compliance with the law of that time, prior to the prohibition coming into effect. These are so-called primary sources, from which it is still possible to prevent emissions, for example via proper waste management and destruction. In addition, there already exists a large quantity of PCBs in the natural environment, resulting from spills, emissions and accidents, which has meant that the substances are detectable in contaminated soil, water, snow, air and other areas.

7.2.1 NATIONAL

The national use and management of products and materials containing PCBs is currently principally regulated through:

- regulations relating to restrictions on the use of chemicals and other products hazardous to health and the environment (Product regulations), § 2-2 and § 3-1
- regulations relating to the recycling and treatment of waste (Waste regulations), including chapters 9, 11 and 14
- Svalbard Environmental Protection Act

PCBs are on the national list of prioritised environmental pollutants. The total amount of PCB emissions in Norway is unknown.

7.2.2 INTERNATIONAL

PCBs are internationally regulated by inter alia the Stockholm convention and the long range transboundary air pollution convention for the ECE area (LRTAP convention) and the underlying POP protocol. Norway is included in these conventions.

7.2.2.1 The Stockholm Convention

The Stockholm Convention has been established to protect human health and the environment from persistent organic pollutants (POPs). Over 160 countries have ratified the convention since it was signed in 2001. The convention involves an obligation to phase out the most hazardous POPs, including PCBs, DDT and dioxins.

Implementation of the global Stockholm convention (www.chm.pops.int) will promote PCB emission-reducing measures globally through the requirement of ceasing production and use, requirements for phasing out certain products within defined deadlines, requirements for the treatment of waste and requirements relating to reducing/minimising emissions from specified industrial sources. These regulations are vital in reducing global emissions and looking ahead the main focus needs to be on the parties' implementation and adding new environmental toxins to those listed in the agreement. At the present time, there are no plans to revise the requirements that have been set out in the agreement.

In 2009 nine new environmental toxins were covered by the agreement, including PFOS, pentaBDE, octaBDE, and lindane. Including these, the agreement now covers 21 substances. In the future several more POPs could be included under the convention.

7.2.2.2 Convention on long range transboundary air pollution for the ECE area (LRTAP)

Norway is a party to the convention on long range transboundary air pollution, LRTAP convention, (www.unece.org/env/lrtap/) and the underlying POP protocol. The LRTAP convention means that 51 countries have committed to protecting human health and the environment against air pollution and wherever possible to reduce and prevent emissions of long range transboundary air pollution. The convention contains eight protocols, including addressing persistent organic pollutants (POPs) and heavy metals.

The protocol requires the parties to cease production and use of PCBs, phase out certain products containing PCBs within defined deadlines and dispose of waste containing PCBs in an environmentally sound manner. A proposal has been forwarded to establish requirements to reduce annual PCB emissions from industrial sources as compared against a selected reference year, however an agreement on this has not yet been reached. Norway has not yet gained support for its proposal of tightening the deadlines relating to the phasing out of products in use and establishing stricter requirements for the treatment of waste. The parties' obligations also include applying the best available technologies and remaining within the limits for certain emission sources pursuant to the provisions of the protocol (the protocol presently has no PCB emission limits, only for dioxins and PAH). These regulations are vital in reducing aggregate European emissions and long range transported European and transatlantic air pollutants and are therefore very important in reducing the long range transported supplies to Norway and the Arctic.

7.2.2.3 Other international organs and conventions

Other international organs and conventions for protecting the environment and which regulate PCBs are:

- Oslo–Paris conventions (www.ospar.org) OSPAR Decision 92/3, regulating PCBs and requiring them to be phased out. The objective of the convention is to protect the marine environment against contamination, whether the emissions are to air or water. The convention has been ratified by 15 countries in addition to the EU commission, as the representative for the European Union. The parties are obliged to work to stop emissions of prioritised environmental toxins by 2020. Over the long term, the aim is for the concentrations of naturally occurring hazardous substances to return to the background level and the concentration of man-made substances to be as close to zero as possible.
- The Basel convention, was established to prevent the transfer of hazardous waste to less developed countries. The objective is to minimise wastes generated and ensure that hazardous waste is destroyed in an environmentally sound manner. The parties shall reduce to a minimum the transport of hazardous waste across country borders, minimise the amount and toxi-

city of hazardous waste generated and ensure that management of the waste is environmentally sound and occurs as close to the source as possible. The convention establishes strict requirements relating to notification, authorisation and traceability of the movements of hazardous waste over national borders and contains a general prohibition against exporting or importing hazardous waste between member countries and non-members.
- The Rotterdam convention, shall prevent the unwanted import of chemicals and dumping of hazardous chemicals in countries that have weak control regimes and chemical legislation. The countries shall send notification to the Secretariat of the convention about substances they have prohibited or have strictly regulated. If a substance is reported by countries from two of the total of seven regions, the substance will be evaluated for inclusion in a list of chemicals, which currently has 41 substances. These substances may not be exported without the prior consent of the importing country. The convention also establishes a requirement that the parties, when exporting chemicals that they have prohibited themselves, shall notify the importing country about this prohibition.
- The Helsingfors convention
- OECD

PCBs and products that contain PCBs are also regulated by several EU directives.
- Council directive 96/59/EC on the disposal of PCBs/PCTs
- Council directive 89/677/EEC on restrictions on the marketing and use of certain dangerous substances and preparations
- Council directive 75/439/EEC on the disposal of waste oils
- Council directive 94/67/EC on the incineration of hazardous waste
- Council regulation 92/2455/EEC concerning the export and import of certain dangerous chemicals, ”PIC”
- Council directive 91/689/EEC on hazardous waste
- Council regulation (EEC) no. 259/93 on the supervision and control of shipments of waste within, into and out of the EU

EU's strategy in relation to PCBs is documented and available at www.europalov.no, among other places.

7.2.3 NATIONAL OBJECTIVES AND PLANS

7.2.3.1 Generation target

PCBs are a prioritised environmental pollutant, and a national target has been established to stop or substantially curtail the emissions. The so-called generation target.

For the local management of Svalbard this could mean that the primary focus in coming years will be to contribute to ensuring that products and materials containing PCBs are handled in such a way that they do not generate emissions (information on amounts and use of PCBs prior to 1980 in Svalbard and figures for what has been responsibly phased out have been impossible to come by).

The generation target of halting emissions by 2020 will be a major challenge. The reason for this is that it will not be realistic to stop the continued dispersion of PCBs that have already been released into the environment. Therefore the work in this area must be concentrated on maintaining an overview of the contamination and to curtail the emissions and dispersion from known sources of PCBs to the greatest extent possible.

7.2.3.2 Action plan for reduced emissions of PCBs

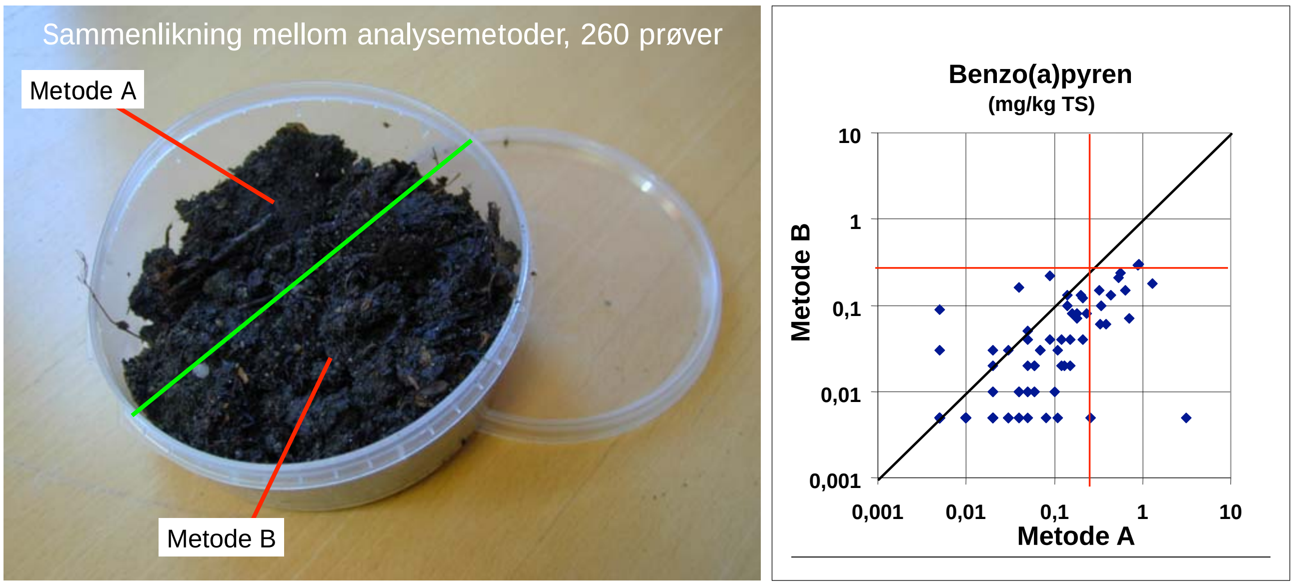
In order to meet the national environmental targets, the authorities have set out an action plan that provides a basis for the efforts to counter the PCBs.

The plan involves a continuation of the work that was systematised at the time when the action plan for reduced emissions of PCBs was drawn up in 2003, also including the clean-up work in sediments and contaminated soil. Climate and Pollution Agency is responsible for following up the plan.

7.3 METHOD REQUIREMENTS, SAMPLING, ANALYSES, ETC.

A number of factors may play a role in determining the outcome of the measurements and how they are interpreted, examples include:

1. Sample type and sampling variability in the field
2. Differing methods for processing the samples
3. Problems related to different analysis batches
4. Problems in connection with detection limits and how to manage values below the detection limit
5. Contamination from sample containers
6. Problems associated with laboratory samples of heterogeneous sample material



PICTURE 7.3.2-1 The picture shows the results after the same samples have been analysed using two different dissolving methods. Source: the Geological Survey of Norway (NGU)

7.3.1 SAMPLE TYPE AND SAMPLING VARIABILITY

Duplicate sampling in the field is a crucial tool for establishing the variation in the field. Natural variation will often be larger than the variation that arises during chemical analysis in the form of uncertainty related to the analysis. Duplicate sampling is routinely undertaken in certain projects, however most of the studies in Svalbard are encumbered by a lack of good control of the variability in the field.

7.3.2 DIFFERING METHODS FOR PROCESSING THE SAMPLES

The dissolution methods vary from laboratory to laboratory. Even though standardised methods are used, each laboratory will often have its own variant of the method. This particularly applies to commercial laboratories. Picture 7.3.2-1 shows the results after the same samples have been analysed using two different dissolution methods. A total of 260 samples were analysed using both methods. In Method B the samples were heated up during the dissolution, which led to certain compounds evaporating readily. Consequently, the results indicated lower concentrations of the compounds that evaporated readily in method B compared with method A.

7.3.3 PROBLEMS RELATED TO DIFFERENT ANALYSIS BATCHES

That no two days are the same may equally be applied to a laboratory. Both the members of staff and the instruments have their day-to-day differences and no-one works in exactly the same way all the time. Ideally, all the samples pertaining to a project should be sampled by just one person, dissolved by the same person and analysed using the same instrument, by the same operator. Preferably on the same day. However this is rarely the case, and researchers therefore use standard samples containing a known quantity of substances that are analysed to provide a useful starting point. Picture 7.3.3-1 shows the results of dioxin determination in the same sample in two different batches. The samples have been analysed at the same lab, but with two different laboratory samples. The figure shows a systematic difference between the analyses; the first analysis gave higher concentrations than the second. For long environmental monitoring programmes, problems relating to batches will arise.

7.3.4 DETECTION LIMITS AND HOW TO MANAGE VALUES BELOW THE DETECTION LIMIT

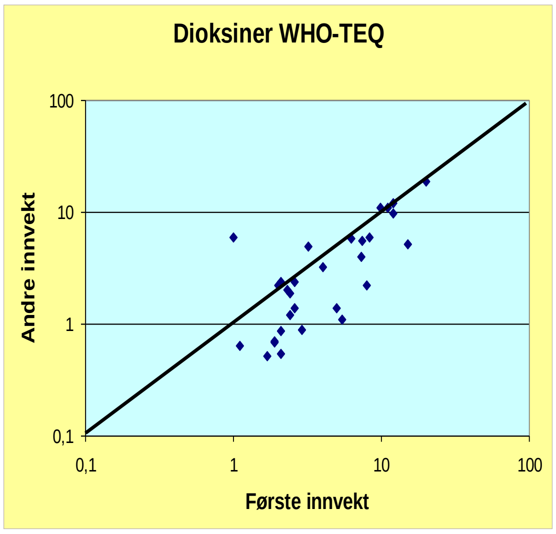
In environmental monitoring, researchers operate with low concentrations, often investigating whether a substance has been detected or not. Data material therefore consists of many results below the detection limit/sensitivity limit. The processing of such "less than" values is crucial in determining how the data material is portrayed and presented. Environmental monitoring which extends over several years or decades has to contend with challenges in relation to both developments in analysis instruments and problems in connection with batches. During the course of the last 30 years instruments have undergone a revolution. It is presently possible to determine PCBs in ultra-low concentrations and researchers are able to better differentiate the individual congeners from one another. There is therefore every reason to be cautious when directly comparing old measurement results with new data in temporal trend analyses.

7.3.5 CONTAMINATION FROM SAMPLE CONTAINERS

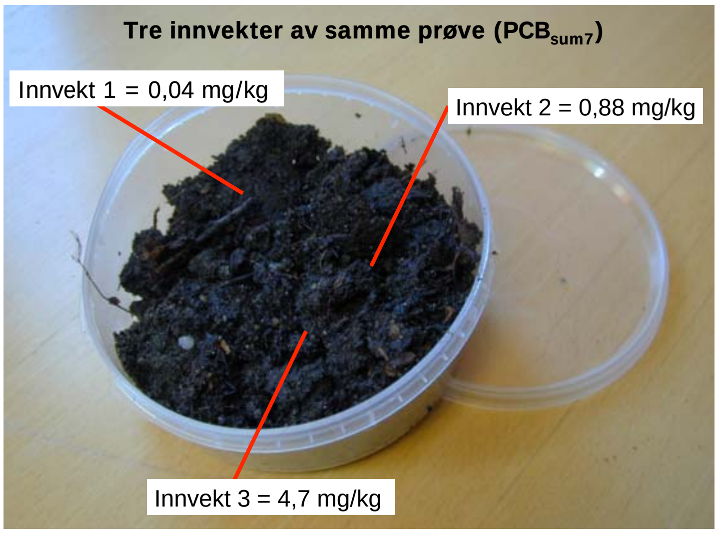
NGU has examined PCBs in various types of containers (table 7.3.5-1) and PCBs have been detected in several of them, even in new products (Andersson et al. 2012). Rilsan bags and aluminium foil are safe as regards PCBs. Glass is also considered to be safe, but plastic lids should be avoided (or at least examined prior to use).

7.3.6 PROBLEMS ASSOCIATED WITH LABORATORY SAMPLES OF HETEROGENEOUS SAMPLE MATERIAL

It is normal to have heterogeneous samples. This makes "laboratory sampling" onerous. Tests that are conducted on soil samples show large differences in PCB content between different laboratory samples. Picture 7.3.6-1 shows how three different laboratory samples of the same sample can vary when the sample is heterogeneous.



PICTURE 7.3.3-1 The picture shows the results of dioxin determination of the same sample in two different batches. The samples have been analysed at the same lab, but with two different laboratory samples. Source: the Geological Survey of Norway (NGU)



PICTURE 7.3.6-1 Selection of materials for chemical analysis is difficult due to inhomogeneous samples. Source: the Geological Survey of Norway (NGU)

	PAPER 1	PAPER 2	ZIPLOCK BAG	PLASTIC BAG	HDPE POT	HDPE SCREW CAP
2,4,4´-TriCB, #28	71000	1900	2400	1300	510	290
2,2´,5,5´-TeCB, #52	10000	790	900	460	230	110
2,2´,4,5,5´-PeCB, #101	1900	150	480	320	130	<100
2,3´,4,4´,5-PeCB, #118	4300	380	140	110	<100	<100
2,2´,3,4,4´,5´-HxCB, #138	1900	400	140	110	<100	<100
2,2´,4,4´,5,5´-HxCB, #153	1400	180	200	160	<100	<100
2,2´,3,4,4´,5,5´-HpCB, #180	410	130	<100	<100	<100	<100
∑7PCB	91000	3900	4300	2500	870	400

Table 7.3.5-1 PCB content in plastic and paper packaging (ng/kg). Source NGU/Andersson et al. 2012.

7.4 ENVIRONMENTAL MONITORING PROGRAMMES AND OTHER INFORMATION SOURCES

7.4.1 ENVIRONMENTAL MONITORING PROGRAMMES

Monitoring environmental pollutants in Svalbard and in the Arctic is of crucial strategic importance because:

- The areas are situated far from the major sources of emissions and the detection of environmental pollutants is thus a strong indication of long range transported supply
- Svalbard is situated in an area where air and oceanic currents produce a particularly large long range transported supply
- The cold climate means that substances are broken down very slowly in the environment

While the atmospheric and ocean-based transport are prioritised in the regional monitoring programmes, the local contribution is far from being sufficiently well mapped.

Data from environmental monitoring is currently only accessible to a limited extent to other parties than the institution which has undertaken the measurements. The measurement results of environmental pollutants, inc. PCBs should be made electronically accessible to everyone in order to avoid duplication of work and raise the effectiveness of research and environmental monitoring.

Monitoring programmes which currently cover or can disseminate information about PCBs in and around Svalbard include:

- MOSJ (Environmental monitoring of Svalbard and Jan Mayen). MOSJ is built up around a series of indicators. In aggregate, the indicators shall provide a picture of the environmental conditions and form the basis for evaluating whether the government's environmental targets for the area have been met. The level of PCBs is included as a parameter in the seabed contamination outside the settlements in Isfjorden, air in Ny-Ålesund (Zeppelin mountain, ∑33PCB), polar bears (PCB#153), arctic foxes (∑7PCB), ringed seals (PCB #153), Glaucous Gulls (PCB#153) and Brünnich's Guillemots (PCB#153). MOSJ does not conduct the monitoring studies itself, but compiles data from other studies that have been funded by various sources.
- COPOL is a project that began during the International Polar Year (IPY). The project is a collaboration between the Norwegian Polar Institute, NIVA, Akvaplan-niva, NILU, NTNU and NINA. The research project is dependent upon financial support from The Research Council of Norway and The Fram Centre. The aim of the project is to enable better prediction of how possible climate-related changes in the marine food web are reflected in the levels and effects at higher trophic levels. Five sampling trips have been conducted (in May, July and October 2007, as well as in July 2008 and 2009). The samples include benthic and pelagic food chains from fjords in Svalbard with varying influences of Atlantic and Arctic waters (Kongsfjorden with Atlantic and polar waters and Liefdefjorden with cold polar waters). The indications are that secondary sources may have an influence on the fjord areas and the ecosystems.
- The Pollution Monitoring Programme was started in 2009 by Klif to directly follow-up on the management plan for the Barents Sea. The programme calculates and models pathways to the Barents Sea and measures levels of environmentally hazardous substances in selected indicators, and collects other data. The Pollution Monitoring Programme covers sites for monitoring air, sediments, seawater and biota. The programme utilises and supplements ongoing monitoring programmes organised by Klif, HI, NIFES, NIVA, NILU, Akvaplan-niva and Norwegian Radiation Protection Authority among others, and the data are reported nationally and internationally. A rolling monitoring scheme has been established to cover the areas addressed by the management plan. In 2009 attention was focused on the Barents Sea in order to obtain further data to update the management plan in 2010. Passive sampling devices have been placed in the air and sea in Bjørnøya. The stations and measurements made by passive sampling devices will yield new data for monitoring the air and sea in the Barents Sea.

During case processing of inter alia emissions permits, requirements are, and may be, made for a recipient survey and/or emission measurements that can provide information on PCB contamination:

- Klif's permit for coal operations in Sveagruva contains requirements for a recipient survey with a focus on Braganzavågen and Kapp Amsterdam every five years, first survey in 2007.
- Klif's permit to Longyearbyen Power station contained requirements for verification measurements of any PCB emissions (see chapter 3.1.7).
- Longyearbyen local authority received a new permit in 2009 to operate the waste management system and waste disposal site in Adventdalen and this contained several conditions including the requirement to monitor the contamination situation.
- According to the plan, surveys of marine sediments outside the settlements in Isfjorden from 1992, 1998, 2005 and 2009 shall be followed up by monitoring every 5 years, i.e. in 2015, 2020 etc.

7.4.2 INFORMATION SOURCES VIA THE INTERNET

Other central information sources are:

- AMAP (Arctic Monitoring and Assessment Programme). In connection with AMAP, much research has been conducted into PCBs and the effects of the group of substances, which is relevant to Svalbard.
- NIFES activities include the monitoring of environmental toxins in seafood. Samples are collected by Institute of Marine Research.
- Institute of Marine Research (IMR) conducts surveys of environmental pollutants in sediment, crustaceans and fish.

7.5 ABBREVIATIONS, SYMBOLS AND UNITS OF WEIGHT

7.5.1 ABBREVIATIONS

lw	Lipid weight or fat weight
POP	Persistent Organic Pollutants
∑7PCB	PCB#28+#52+#101+#118+#138+#153+#180
TEQ	Toxic equivalency quotient
TEF	Toxic equivalency factor
dw	Dry weight
ww	Wet weight

Institutions

Klif	Climate and Pollution Agency
NGU	Geological Survey of Norway
NILU	Norwegian Institute for Air Research
NP	Norwegian Polar Institute
NIVA	Norwegian Institute for Water Research
NVE	Norwegian Water Resources and Energy Directorate
NVH	Norwegian School of Veterinary Science
SMS	The Governor of Svalbard
TA	Trust Arktikugol
UiB	University of Bergen
UNIS	The University Centre in Svalbard
UMB	Norwegian University of Life Sciences

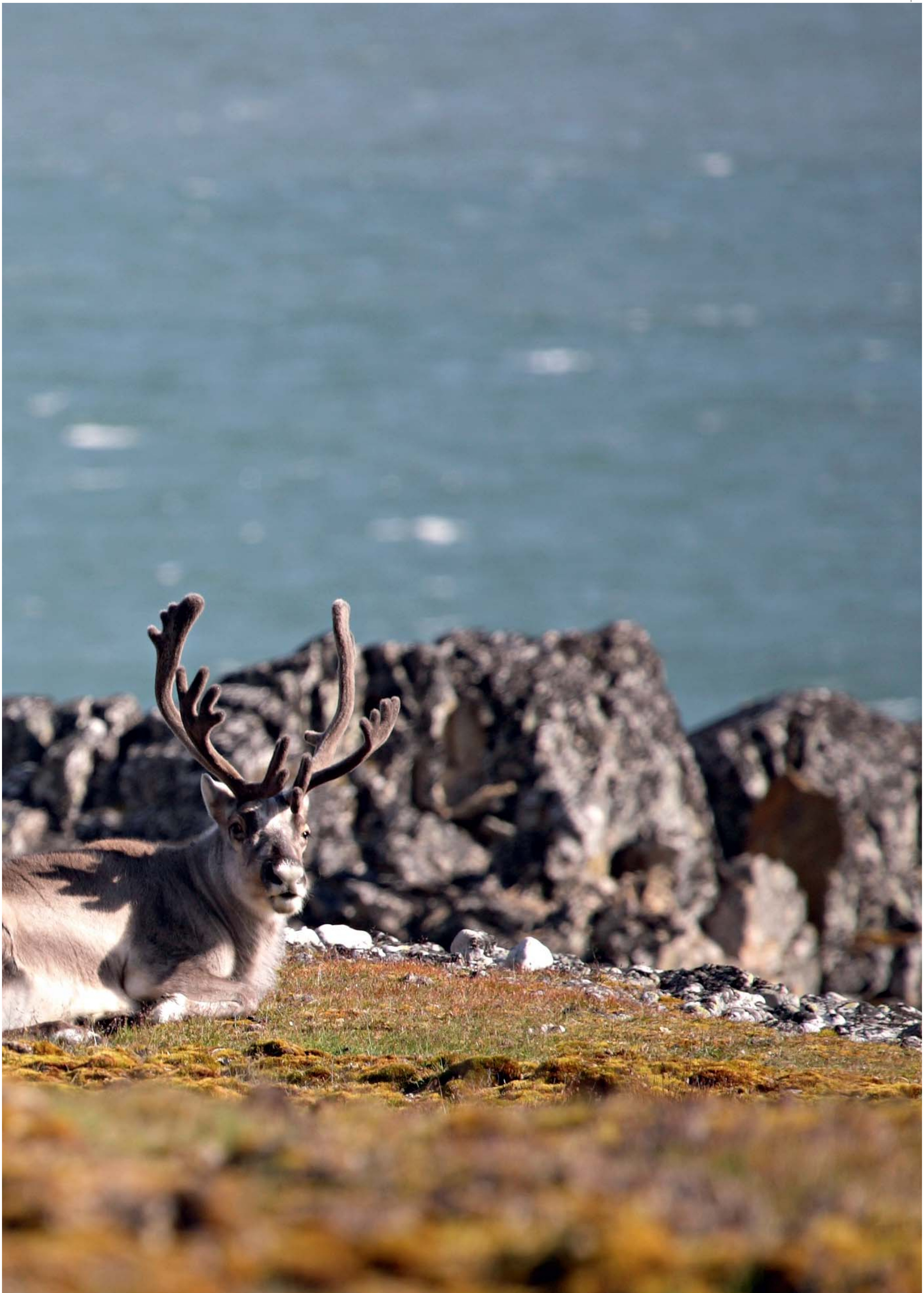
7.5.2 WEIGHT UNITS

1 kg (kilogram)	1000 g	10^3 g
1 g (gram)	1 g	10^0 g
1 mg (milligram)	0.001 g	10^{-3} g
1 µg (microgram)	0.000001 g	10^{-6} g
1 ng (nanogram)	0.000000001 g	10^{-9} g
1 pg (picogram)	0.000000000001 g	10^{-12} g
1 fg (femtogram)	0.000000000000001 g	10^{-15} g

FURTHER INFORMATION ON PCBS AND THE CHALLENGES RELATED TO ENVIRONMENTAL POLLUTANTS IS AVAILABLE AT:

ORGANISATION, INFORMATION, ETC.	WEBSITE
Arctic Climate Impact Assessment (ACIA)	http://amap.no/acia/
The Arctic system	http://www.arcticsystem.no/no/thearcticsystem/
Dioxins and dioxin-like PCBs	http://www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft_6039&MainArea_5661=6039:0:15,4520:1:0:0:::0:0&MainLeft_6039=6041:69501::1:6043:6:::0:0#eHandbook695012
Dioxins and dl-PCBs - factsheet	http://www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft_5648&MainArea_5661=5648:0:15,2917:1:0:0:::0:0&MainLeft_5648=5544:67050::1:5590:2:::0:0
Environmental Protection Agency, USA	http://www.epa.gov/waste/hazard/tsd/pcbs/index.htm
EU's strategy in connection with PCBs	http://europalov.no/politikkdokument/om-gjennomforingen-av-eus-strategi-om-dioksiner-furaner-og-polyklorerte-bifenyler/id-4126 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52007DC0396:EN:NOT
UN, independent report on PCBs and health effects	http://www.inchem.org/documents/cicads/cicads/cicad55.htm#6.1
EU commission, Food safety: Theme pages on dioxins and dl-PCBs	http://ec.europa.eu/food/food/chemicalsafety/contaminants/dioxins_en.htm
Norwegian Institute of Public Health	http://www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft_5648&MainArea_5661=5648:0:15,2917:1:0:0:::0:0&MainLeft_5648=5544:67050::1:5590:2:::0:0
Climate and Pollution Agency	http://www.klif.no/Tema/Kjemikalier/PCB/Handlingsplan-mot-PCB/
MAREANO	www.mareano.no
State of the Environment Norway	http://www.miljostatus.no/Tema/Kjemikalier/Noen-farlige-kjemikalier/PCB/
OSPAR (Oslo & Paris Commissions)	www.ospar.org
PCB compounds that are not dioxin-like	http://www.fhi.no/eway/default.aspx?pid=233&trg=Area_5775&MainArea_5661=5648:0:15,2917:1:0:0:::0:0&MainLeft_5648=5775:0:15,2917:1:0:0:::0:0&Area_5775=5544:72341::1:5780:5:::0:0
PCBs in Svalbard (The Governor of Svalbard) Report in Norwegian, English and Russian	http://www.sysselmannen.no/hoved.aspx?m=51645
WHO: Facts about dioxins and their effects on health	http://www.who.int/mediacentre/factsheets/fs225/en/

Ringed seal by a breathing hole, Tempelfjorden Svalbard, Photo: Halvard R. Pedersen



PCBS ON SVALBARD: STATUS OF KNOWLEDGE AND MANAGEMENT 2011

PARTICIPATING INSTITUTIONS

Akvaplan-niva
Directorate for Nature Management (DN)
Climate and Pollution Agency (Klif)
Geological Survey of Norway (NGU)
Norwegian Institute for Air Research (NILU)
Norwegian Polar Institute (NP)
Norwegian Institute for Water Research (NIVA)
Norwegian Water Resources and Energy Directorate (NVE)
Norwegian School of Veterinary Science (NVH)
The Governor of Svalbard
Trust Arktikugol (TA)
University of Bergen (UiB)
University Centre in Svalbard (UNIS)
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