



DETOX
C A M P A I G N

The tip of the iceberg: Chemical contamination in the Arctic

WWF International Arctic Programme



for a living planet

I. Executive summary

The Arctic is the largest un-fragmented, yet inhabited, wilderness area remaining on Earth. However, it is under increasing threat from toxic contaminants. Like the small portion of an iceberg that can be seen from above the water, chemicals that scientists now know to be contaminating the animals of the Arctic may be a warning of a larger problem that, for now, remains hidden.

Pollutants that were never produced or used in the Arctic are now showing up in this remote region of the world, sometimes in higher concentrations than in the countries where they were made and used. Air, river, and ocean currents, drifting sea ice, and migrating wildlife species carry industrial and agricultural chemicals from distant sites of production and use to the polar environment. In many cases, transport of chemicals to the Arctic from sources in Europe, Asia, or North America can occur in just a matter of days.

This report reviews and synthesizes the current status of literature and knowledge of selected toxic substances, with an emphasis on hazardous chemicals not monitored for in arctic and sub-arctic wildlife until recently. The remote and sensitive Arctic serves as an indicator of how our use of chemicals will impact life everywhere on Earth, what is happening in the Arctic is an early warning providing us with the opportunity to protect our planet from further harm.

Some of the chemicals covered in this report are in current-use while others have already been widely restricted or phased out – yet they still show up in the Arctic years later. Everywhere arctic scientists look and whichever chemicals they choose to monitor for – what they are discovering is that these chemicals have made their way to the Arctic and contaminated species covering the whole range of the food web. (See Table 1 in the Appendix.)

The chemicals covered in the report are or were previously used in a variety of commercial and industrial manufacturing processes and in agriculture. Releases of these chemicals to the environment may occur near the site of original manufacture, later on during production of common-use items such as cosmetics, plastics, and furniture cushions, from pesticide treatments to control insects or other pest species, and from waste incineration and disposal of chemicals or chemical-containing products.

This report shows widespread contamination with a range of toxic substances is evident – with a build up of these chemicals in arctic air, sediments, and many of the arctic animals that are at or near the top of the food chain. Levels of some chemicals in arctic marine mammals and bird species are exponentially increasing and are expected to continue to increase. For example, without restriction of brominated flame-retardant (BFR) use and if current trends continue, levels in the Arctic may reach the same levels as polychlorinated biphenyls (PCBs) within 10–20 years.

Although further research is needed, we already know enough about the harmful health effects of contaminants – particularly on immune, reproductive, and hormone function – to justify the need for precautionary action and protective chemical legislation. The lingering toxic legacy from chemicals widely used in the past and once thought to be safe, such as PCBs¹ and DDT,² should serve as a warning against continued use of chemicals that have not been adequately assessed for safety. PCBs, introduced in the 1920s for use in electrical equipment, and DDT, introduced in the 1930s as a successful insecticide, still persist in the environment and accumulate in our bodies many years after their phase-outs. The very quality that made these chemicals so useful in the past – their persistence – is now what enables them to remain in the environment decades after their use was discontinued in most parts of the world.

Despite the lessons of the past and our increasing awareness of the risks posed by chemical exposures, chemicals remain on the market with the status “safe until proven otherwise.” Existing chemical regulation is inadequate and out-dated, illustrated by the fact that basic safety information is not required for more than 90% of chemicals currently on the market. While some hazardous chemicals, including PCBs and DDT (with the exception of limited, controlled use to prevent malaria), were banned in 2004 under the Stockholm Convention³ due to their toxicity or persistence, there are many other un-restricted chemicals in current use for which indications of their hazardous properties are rapidly accumulating.

Chemical contamination does not only threaten the remote Arctic. We are all exposed to chemicals from our air, food, water, everyday household and workplace items, and personal products. We should have the right to know which chemicals are in the products we purchase and we need protective legislation that will reverse the current alarming situation where blood, breast milk, tears, and raindrops worldwide are full of chemicals. For these reasons, there is a growing movement, exemplified by the REACH chemical legislation⁴ currently being debated within the European Union, demanding additional and improved chemical safety data and access to this information, and control or eventual phase-outs of the most hazardous chemicals.

International agreements and safe, precautionary chemical legislation (such as REACH) have the potential to reduce further global contamination and to protect the unique arctic ecosystem and its species. While the older class of toxic chemicals has already widely contaminated humans and wildlife, we still have a chance to prevent further pollution from toxic chemicals in current use. As mixtures of many chemicals build up in our bodies and wildlife with largely unknown long-term consequences, it is more urgent today than ever before to revise and improve the current system. Only then will the many benefits chemicals can offer us outweigh the risks. REACH provides an opportunity to set a new global standard, putting chemical production and use on a safe and sustainable path.

Currently, at the individual level, for many of us our only options to minimize personal chemical exposures are to modify our habits and purchases (i.e. eat organically, wash fruits and vegetables to reduce pesticide residues, use naturally scented and colored cleaning and personal products). However, even these measures are not all universally available or practical and, at best, only allow us to reduce our exposures and not prevent them. So while we cannot escape much of the current risk posed by the numerous chemicals already present in our environment; we can regulate existing and future chemical production and use to prevent further contamination with hazardous chemicals for generations to come.

The European Union's REACH chemical legislation and why it is needed

Europe produces more chemicals than any other region of the world, accounting for about 35% of sales worldwide. The countries of the European Union, led by Germany, account for the majority of European chemical production. It is now known that many agricultural and industrial chemicals are accumulating in our bodies and in wildlife, even in remote regions of the world far from sources of chemical production and use. Only a fraction of all chemicals (usually those suspected of being the most hazardous) are actually monitored for in the environment. The current system of chemical regulation does not adequately assess chemicals for toxicity or protect humans and wildlife from chemical exposures. The European Union's new proposed REACH (Registration, Evaluation, and Authorization of Chemicals) legislation will, if passed in a strong form, lead to increased chemical safety.

Globally, there are an estimated 30 to 70 thousand chemicals now being produced. Current chemical regulation makes a distinction between "new" chemicals (about 3000 chemicals that came on the market after September 1981) and "existing" chemicals (the many thousands of chemicals that were on the market and registered by 1981). While all post-1981 "new" chemicals are required to undergo basic safety testing, the same is not required for the "existing" chemicals, which make up the majority of chemicals in current use. As a result thousands of chemicals, more than 90% of those on the market today, have not been evaluated for basic safety. In addition, the current system discourages industry innovation and development of new, safer alternative chemicals since the testing requirements are stricter to bring a chemical to the market today compared to continued use of a pre-1981 chemical, for which safety testing is not required.

The new REACH legislation would shift the burden of proof onto industry to show the chemicals they are producing are safe (rather than the current "safe until proven otherwise" system), make chemical safety information available to the public, and remove the arbitrary distinction between "new" and

"existing" chemicals – requiring safety information in increasing levels based on chemicals' inherent properties and production volumes. Removing the distinction between "new" and "existing" chemicals would level the playing field and promote industry innovation and development of safer alternatives.

Benefits of the REACH legislation will include public availability of chemical safety information, development of safer chemical alternatives, production and use of safer chemicals both within and outside the European Union, and numerous benefits to environmental, human, and wildlife health. Specific benefits to industry from REACH will include new markets for safer products, easier introduction of new chemicals onto the market, easier long-term planning due to a more predictable regulatory system, fewer liability lawsuits, increased trust among consumers and a more positive business environment, and improved transparency and communication through the supply chain and to downstream users.

The REACH debate has been exaggerated and distorted by inaccurate industry impact studies.

What does WWF want?

Through the DetoX campaign, WWF is working to raise greater awareness and understanding about the failures of the current chemical regulation system and the need for improved chemical legislation. WWF welcomes and supports the REACH proposal but is calling for several specific areas of the legislation to be strengthened:

- A method to identify the worst chemicals of highest concern and to substitute them whenever safer alternatives are available is essential.
- The regulatory system must be made more transparent and open, maximizing information flow to all parties.
- More detailed information is available on WWF's DetoX website at: <http://www.panda.org/detox>

II. Chemical Threat in the Arctic

Chemical contamination is a serious global threat and the Arctic is uniquely vulnerable to this threat. When air masses carrying contaminants reach the Arctic, the “cold-condensation effect” occurs – this is when air contaminants move from the gas or vapour phase into a liquid phase, and are carried to the ground in rain or snow. Once pollutants reach the Arctic, the cold temperatures and long, dark winters slow the chemical break down process. Polar ice can trap contaminants that are gradually released into the environment during melting periods, even years after their arrival in the Arctic. As a result, the Arctic acts as a final “sink” where pollutants from around the world accumulate and become trapped.

The wildlife of the Arctic is especially vulnerable to chemical pollution. Many arctic animals - such as polar bears, seals, and whales - have thick layers of body fat that help them stay warm and that also serve as energy reserves during molting, breeding, and hibernation. While these traits make the unique animals of the Arctic perfectly adapted to their cold, harsh environment, the chemical characteristics of many toxic substances cause them to preferentially accumulate in fat. While stored in the thick fat layers a large portion of these chemicals has relatively little effect on the animal. However, when the fat reserves are broken down to meet energy demands, the accumulated contaminants suddenly enter the blood stream and may reach sensitive organs such as the liver and brain, where severe damage can be done. As a result, the fat that is so essential to keeping arctic animals warm and providing them with sufficient energy throughout the year also acts as a chemical time bomb that goes off during use of this fat.

Chemical exposures, even at low levels, may lead to serious health effects, especially when exposure occurs during the critical fetal and development periods. Newborn mammals – such as polar bear cubs and seal pups – are extremely vulnerable to toxic substances because they feed on their mother’s fatty and contaminant-laden milk during the especially critical development period. In addition, many arctic animals – such as whales – have long life spans, leading to many decades of chemical exposure and the potential to build-up high and dangerous levels of toxic substances in their bodies. The Arctic is mainly a marine ecosystem, placing it at higher risk of contamination than terrestrial ecosystems because pollutants that enter seawater are easily absorbed by plankton and thereafter make their way all the way up the food chain. Thus, the combination of global chemical transport to the Arctic and the special characteristics of the ecoregion and its wildlife places arctic species at high risk of suffering harmful effects caused by pollution.

Contaminant exposure has the potential to affect wildlife growth and survival, at both the individual and population levels, and thus represents a major obstacle to preserving the Arctic as a region where wildlife can flourish – now and in the future. Exposure to chemicals was a key factor in the mass deaths of European harbor seals due to infection by morbilliviruses,⁵ is thought to play a role in the continued decline of the Alaskan Stellar sea lion populations,⁶ and may have affected age distribution and reproductive potential of the Svalbard, Norway polar bear population.^{7,8} Strong scientific indications for the association between long-term contaminant exposure and negative health and reproductive impacts in key arctic species became available with the second AMAP report⁹ and CACAR II report.¹⁰ Svalbard polar bears have immune suppression, lowered Vitamin A levels, and lowered testosterone hormone levels; beluga whales from the St. Lawrence Estuary in Canada have increased cancer occurrences; Northern fur seals exhibit lowered Vitamin A levels, depressed thyroid hormone function, and immune suppression; the egg shells of peregrine falcons are thinning; and the survival rate of some Canadian glaucous gull populations is

lowered, their eggs do not develop successfully, and their breeding behavior is altered. Although all of these health effects may not be exclusively caused by chemical exposures, scientific studies indicate that these health effects are associated with the levels of various chemicals in the bodies of the animals.

Similar properties and health effects are likely shared between the older generation of persistent contaminants and many of those in current use today. More importantly, the concurrent presence in wildlife of current-use as well as older legacy contaminants could result in even more harmful cumulative effects due to chemical mixtures and interactions.¹¹ The addition of new contaminants to the existing contamination from older chemicals may intensify eminent immune suppression, reproductive decline, and behavioral alterations already present in important arctic species such as polar bears, seals, whales, birds of prey, and seabirds.

Chemicals that are toxic,¹² persistent,¹³ able to bioaccumulate¹⁴ or build up in the bodies of animals, and capable of being transported long distances are especially hazardous and pose a high risk to the diverse and sensitive arctic ecosystem. How harmful a chemical exposure will be depends on the specific chemical and wildlife species it is found in, the level or dose of the chemical exposure, which other chemicals are also present and in what dose, and the animal's age, gender, physical condition including amount of body fat, nutritional status, and metabolizing ability to break down and excrete toxic substances.¹⁵

Unlike humans, who can be assessed for neurologic function or studied to determine if chemical exposures are associated with diseases that occur many years later (i.e. cancers and reproductive problems), studying wild animal populations poses a special challenge. Measurable and easy to assess markers are needed to quickly determine how chemicals are impacting the health of wildlife. Different "biological markers"¹⁶ or indicators have been developed and are used to document more immediate changes to the animal's nervous system, immune system, and hormones that control stress responses, sexual behavior, and reproductive function. These indicators are then compared to the levels of chemicals in the animal's body to determine if the chemical exposure is associated with measurable changes. In the past few years, several studies have added to the accumulating indications that changes in the immune and hormone systems of arctic species, most notably polar bears, are associated with their exposure to hazardous chemicals. (See boxed text on pages 10-11.)

Many contaminants of concern have harmful impacts on immune, reproductive, hormone, and neurologic function; and on behavior and development. Notable reproductive effects associated with contaminant exposures include diminished fertility and reduced sperm production, altered hormone levels, decline in offspring numbers and their survival, an increase in deformities and offspring deaths,^{17,18,19} and possibly pseudo-hermaphroditism.²⁰ Behavioral modifications affecting movement, feeding, predator avoidance, learning and memory, and social interactions have been linked to alterations in thyroid hormone²¹ levels and neurotransmitter release and function.^{22,23,24,25,26,27} Lowered resistance to common bacterial and viral diseases is a prominent sign of immune suppression associated with delayed or absent immune responses and altered Vitamin A equilibrium.^{28,29,30,31,32,33,34,35,36,37,38} Finally, increases in the occurrences of cancers in exposed populations may reflect exposure to certain toxic substances.^{39,40}

Harmful Effects Linked to Contaminant Exposures in Polar Bears

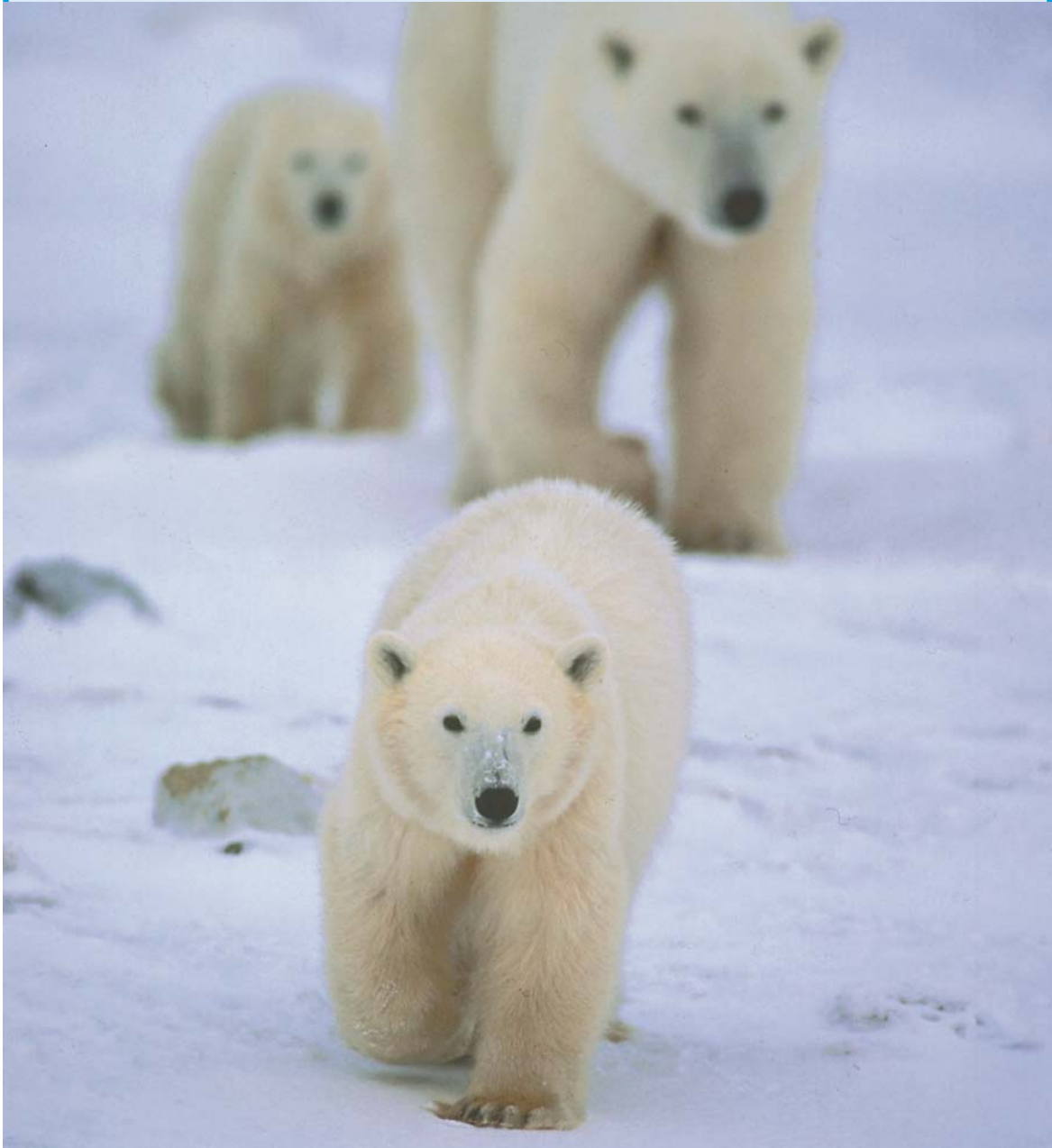


Photo: WWF-Peter Prokosh

As the top predator within the Arctic, the polar bear is of special importance to the ecoregion, is at high risk from chemical contamination, and is a research priority.

Since 2000, several scientific studies of polar bears in the Norwegian or Canadian Arctic have been

published indicating that exposure to several “older” contaminants is associated with changes in reproductive and thyroid hormones and immune status. Reduced immunity and altered hormone levels have the potential to pose a serious threat to polar bears since impaired development, lowered reproductive ability, and changes in behavior may result.

Taken together, these recent studies provide the first indications that contaminant levels in polar bears are already at levels where biological changes are occurring and likely contributing to harmful reproductive and immune function outcomes.

In polar bears from Svalbard, Norway¹ protective IgG antibodies² were found to decrease with increasing levels of PCBs,³ indicating a possible immunotoxic effect. Decreased immune function in polar bears from Norway and Canada was associated with exposure to organochlorine chemicals and PCBs – indicating that high organochlorine exposure may reduce the bears' ability to produce antibodies and may leave them more susceptible to infections.

Studies are also beginning to show indications of contaminant-associated changes in both male and female reproductive hormones. In female polar bears from Svalbard,⁴ PCB exposure was associated with increases in the hormone progesterone.⁵ In male polar bears from Svalbard,⁶ testosterone⁷ hormonal changes were associated with pesticide and PCB exposure. These hormone changes may result in reproductive toxicity including reduced fertility.

In addition, a study⁸ of male and female Svalbard polar bears found associations between altered levels of the hormone cortisol⁹ and pesticide and PCB exposure. This finding indicates the potential for a wide range of negative health effects since cortisol regulates energy metabolism, growth and development, stress response, and reproductive and immune function. Thyroid hormone and retinol levels were associated with PCB and HCB¹⁰ exposure in Norwegian polar bears.^{11,12} Thyroid hormone imbalance may lead to negative impacts on learning ability, behavior, and reproductive function.

These recently published studies relied on blood and tissue samples taken from polar bears between the years 1991–1999. Since 1999, many new chemicals such as some of those discussed in this report have been added to the mixture of toxics that are now reaching the Arctic. It is highly likely that these new chemicals – on their own and as part of chemical mixtures – are also associated with similar biological effects.

The continued use of inadequately tested chemicals will allow further environmental contamination to occur at a time when we are just beginning to understand how many chemicals build up in our bodies and the ways they affect us. There is therefore an urgent need for safer chemical legislation, such as REACH, to protect our global environment, and key ecosystem

species such as the polar bear, from further contamination and a range of potentially harmful effects.

References

- ¹ Lie E, Larsen HJ, Larsen S, Johansen GM, Derocher AE, Lunn NJ, Norstrom RJ, Wiig O, Skaare JU. *Does high organochlorine (OC) exposure impair the resistance to infection in polar bears (Ursus maritimus)? Part I: Effect of OCs on the humoral immunity.* J Toxicol Environ Health A. 2004 Apr 9;67(7):555–82.
- ² Antibodies are proteins produced to protect the body against foreign invaders such as bacteria or viruses. IgG antibodies are one of 5 classes of antibody found in vertebrate species.
- ³ Polychlorinated biphenyls, or PCBs, are a group of chemicals developed in the 1930s and finally banned in the early 1980s due to recognition of their hazardous properties. PCBs were used primarily as coolants and lubricants in electrical equipment and can now still be found in the environment and in the bodies of humans and wildlife.
- ⁴ Haave M, Ropstad E, Derocher AE, Lie E, Dahl E, Wiig O, Skaare JU, Jenssen BM. *Polychlorinated biphenyls and reproductive hormones in female polar bears at Svalbard.* Environ Health Perspect. 2003 Apr; 111(4):431–6.
- ⁵ Progesterone is a female steroid hormone that results in the uterus being suitable for implantation of a fertilized egg and maintains the uterus throughout pregnancy.
- ⁶ Oskam IC, Ropstad E, Dahl E, Lie E, Derocher AE, Wiig O, Larsen S, Wiger R, Skaare JU. *Organochlorines affect the major androgenic hormone, testosterone, in male polar bears (Ursus maritimus) at Svalbard.* J Toxicol Environ Health A. 2003 Nov 28;66(22):2119–39.
- ⁷ Testosterone is a male steroid hormone required for development of the reproductive organs, sperm, and secondary sexual characteristics.
- ⁸ Oskam I, Ropstad E, Lie E, Derocher A, Wiig O, Dahl E, Larsen S, Skaare JU. *Organochlorines affect the steroid hormone cortisol in free-ranging polar bears (Ursus maritimus) at Svalbard, Norway.* J Toxicol Environ Health A. 2004 Jun 25;67(12):959–77.
- ⁹ Cortisol is a steroid hormone that regulates many important bodily functions including blood pressure, metabolism, the immune system, and responses to stressors such as physical injury, temperature changes, and psychological reactions.
- ¹⁰ Hexachlorobenzene, or HCB, was mainly used as a pesticide up until 1965 in order to protect crops from fungus. HCB breaks down very slowly in the environment and levels can build up in the bodies of humans and wildlife.
- ¹¹ Braathen M, Derocher AE, Wiig O, Sormo EG, Lie E, Skaare JU, Jenssen BM. *Relationships between PCBs and thyroid hormones and retinol in female and male polar bears.* Environ Health Perspect. 2004 Jun; 112(8):826–33.
- ¹² Skaare JU, Bernhoft A, Wiig O, Norum KR, Haug E, Eide DM, Derocher AE. *Relationships between plasma levels of organochlorines, retinol and thyroid hormones from polar bears (Ursus maritimus) at Svalbard.* J Toxicol Environ Health A. 2001 Feb 23;62(4):227–41.

III. Some Toxic Substances of Concern in the Arctic

The following section provides a brief overview on the production and use of selected groups of chemicals that often have been monitored for and studied in the Arctic for only a short time, as well as general regional background on environmental levels (i.e. in air, snow, sediments, wildlife, humans) and trends in North America and Europe. More detailed information is available in the Appendix.

I. Polychlorinated naphthalenes (PCNs)

PCNs are a group of 75 compounds that are structurally similar to PCBs⁴¹ and that were widely used from the 1930s up until the late 1980s. Industrial applications included use as flame-retardants, in transformer and capacitor fluids, fungicides, sealants, and as a plastic and rubber additive. Production and use ended in the United States in 1977 and in most of Europe a few years later. However, unintentional formation through former PCB⁴² use, waste incineration, and re-emission from old reservoirs such as landfills has added to the environmental burden even after the 1980s.^{43,44}

Polychlorinated naphthalenes are capable of long-range transport, slow to break down in the environment and their levels are known to build up in animals.^{45,46} PCNs have a tendency to deposit on ocean sediments, potentially placing bottom-feeding species at risk. PCN exposure interferes with communication between cells,^{47,48} causes developmental injury to the embryo, and acts as a general hormone disruptor.⁴⁹

So far, contamination with PCNs has been detected in arctic and sub-arctic animals including polar bears from Alaska, ringed seals from the Baltic Sea, Baffin Island, and Svalbard, grey seals from the Baltic Sea, Canadian harp seals, Baffin Island beluga whales, harbor porpoise from the Baltic Sea and Sweden, and 3 bird species in Canada. PCNs have also been found in highly endangered Vancouver Island marmots that live only in the mountains of sub-arctic Vancouver Island, Canada.⁵⁰ There are about 100 of these rare marmots left in the world and such chemical contamination may represent an additional threat to their survival. (See Table 8 in the Appendix.)

2. Brominated flame-retardants (BFRs)

Brominated flame-retardants are a diverse group of chemicals – including 5 major forms: tetrabromobisphenol A (TBBPA), hexabromocyclododecane (HBCD), polybrominated diphenyl ethers (PBDEs), and 3 commercial PBDE mixtures called “penta”, “octa” and “deca”. BFRs are added to many common consumer products (e.g. furniture cushions, children’s clothes, computers) to reduce flammability. Asia is the top BFR user, followed by the Americas, and Europe.⁵¹ Although the European Union recently banned “octa” and “penta” BFRs, there are currently no restrictions on another flame retardant of concern, the “deca” commercial mixture, which can break down in the environment into the “octa” and “penta” forms.

The PBDE flame-retardants are slow to break down, attracted to fat, and able to evaporate into and be transported through air.⁵² PBDE brominated flame retardants are likely to cause cancer and function as hormone disruptors, adversely affecting reproduction and thyroid hormone function.^{53,54,55,56,57} Distinct neurobehavioral effects in rats (e.g. decline in memory function and learning ability) were noted after developmental exposure.^{58,59,60} Doubling levels of PBDE have been noted in North America every 4-6 years.⁶¹ Although BFR levels in Europeans are lower than in North Americans,⁶² increasing levels detected in European women’s breast milk raise serious concerns about infant exposure.⁶³

In the Arctic, brominated flame-retardants have already been detected in polar bears from Svalbard, arctic foxes, Swedish grey seals, ringed seals from Sweden, Norway and Canada, beluga whales from Canada and Norway, Faroe Island pilot whales, and bird species from Greenland, Norway, Canada, and Sweden. Sub-arctic contamination has been documented in the Baltic Sea and the San Francisco Bay as well as in waters off the United Kingdom, Denmark, the Netherlands, Belgium, and southern Sweden. Contaminated species include white-beaked dolphins, minke and sperm whales, and mackerel off the coast of the Netherlands, harbor porpoise in the North Sea and off the coasts of the United Kingdom and Belgium, harbor seals from the North Sea, San Francisco Bay, and off the coast of the Netherlands, blue mussels from Denmark, Swedish salmon, Baltic Sea pike, bird species from the United Kingdom, Norway, Sweden and the Baltic Sea, and endangered Vancouver Island marmots. The “deca” flame retardant has been detected in some polar bears and glaucous gulls from Svalbard, Norway. (See Table 6 in the Appendix.)

3. Perfluorooctanesulfonate (PFOS) and Perfluorooctanoate (PFOA)

Fluorinated compounds, such as PFOS and PFOA, have been produced for over 40 years for use as surface and stain protectors for products such as coated cookware, carpets, upholstery, leather, and paper packing – including fast food wrappers. PFOS was previously used in Scotchguard™ products and was voluntarily phased out by a major producer, 3M Corporation, in 2001 in response to evidence of toxicity. Despite safety concerns, there are few regulations regarding PFOA and it is in widespread use, although some companies are monitoring for environmental contamination and health effects.

Due to their chemical properties, fluorinated compounds were long considered unlikely to spread to sites far from their original source. However, this assumption has been proven wrong and these compounds are now widely found in our bodies and wildlife.⁶⁴ Alarming, recent studies have shown some fish can break down other fluorinated chemicals – transforming them into more harmful forms including PFOS and PFOA.⁶⁵ Studies from the United States and Europe show levels of PFOS are increasing in wildlife and humans. Once in the environment, these chemicals are unusually persistent and do not degrade under normal conditions. PFOS and PFOA have been shown to have harmful effects on cell membranes and communication between cells.⁶⁶ Effects including memory decline; impaired learning; decreased reflex time response, and neonatal deaths have been demonstrated in laboratory rats.^{67,68,69,70} Harmful liver effects were observed in wood mice living near a fluoro-chemical plant.⁷¹

The first peer-reviewed scientific reports of PFOA in arctic wildlife were published in 2004. Most studies focused on the Canadian Arctic where PFOA was detected in polar bears, fox, mink, ringed seals, and several bird species. Harbor porpoise from Iceland, Norway, Denmark, Germany, and the Baltic Sea also tested positive for PFOA. PFOS has been detected in polar bears from Alaska, Greenland and Canada, fox from the Canadian Arctic, ringed seals from Norway and Canada, Alaskan Stellar sea lions and Northern fur seals, Canadian grey seals, and several bird species from Canada. Sub-arctic PFOS contamination includes harbor porpoise from northern European and North Sea waters, ringed seals from the Baltic Sea, grey seals from the Baltic and North seas, and eagles from Poland and Germany. Fin and sperm whales, hooded seals, striped, white-beaked, and white-sided dolphins, shrimp, crabs, and starfish from the North Sea are also contaminated. (See Tables 4 and 5 in the Appendix.)

4. Hexachlorobenzene (HCB)

Hexachlorobenzene was formerly used as a fungicide but now has no commercial use. Released during waste incineration, as well as during military activities and firefighting training exercises, it is also formed as a by-product of the production of several other chemicals and metals, and in combustion processes. Global use has been

declining and use as a fungicide was banned in the United States in 1984 and in the European Union in 1988, but the re-emission of old HCB from soil continues to add to environmental levels.^{72,73}

This pesticide is extremely resistant to degradation and builds up primarily in fatty body tissues. Its presence in amniotic fluid of both humans and farm animals raises concern for exposure of infants.^{74,75} In North Americans, levels measured in fat tissue have declined since 1973, but a ubiquitous presence in breast milk of North American women indicates infants may be exposed after birth as well as during fetal development.⁷⁶ HCB exposure leads to a wide range of toxic effects, including immune suppression,^{77,78} hormone disruption,⁷⁹ and cancer.⁸⁰ In bird species, environmental exposure to multiple chemicals, including HCB, has been linked to reduced body condition in white-tailed eagles,⁸¹ terns, and herring gulls.^{82,83,84}

HCB is a global pollutant with established long-range atmospheric transport, and it is present in arctic snow, air and seawaters.⁸⁵ HCB has been detected in arctic wildlife from Alaska, Canada, Russia, Greenland, Norway, and the Barents, North and White seas. Contaminated species include polar bears, wolves, 6 seal species, 6 whale species, 2 porpoise species, walrus, sturgeon, 8 bird species, squid, and endangered Vancouver Island marmots. Environmental exposure to multiple chemicals, including HCB, has been linked to hormone disruption and immune suppression in polar bears⁸⁶ and Baltic Sea seals.⁸⁷ Exposure to multiple chemicals, including HCB, was associated with thyroid hormone alteration in Arctic-breeding glaucous gulls.⁸⁸ (See Table 7 in the Appendix.)

5. Short-chained chlorinated paraffins (SCCPs)

Short-chained chlorinated paraffins are used in the metal processing and building industries, and in rubber and leather treatment. In Europe, use has declined by 9000 tons since 1994, while use has increased in the United States by 5500 tons.⁸⁹ As use of other better-studied types of flame-retardants is restricted due to their known hazardous properties, use of SCCPs as flame-retardants may increase.

Chlorinated paraffins are persistent and do not easily break down, they accumulate in the bodies of humans and wildlife, and transformation to other potentially harmful compounds occurs in fish, birds and mammals. Evidence suggests that these chemicals may be transported over long ranges by air and ocean currents. SCCPs inhibit cell-to-cell communication,⁹⁰ have the potential to cause cancer, and affect thyroid hormone function.^{91,92}

SCCPs are prevalent in Norwegian and United Kingdom environmental samples,^{93, 94, 95} and have been reported in air and 50-year-old sediment samples from the Canadian Arctic.^{96,97} Thus far in the Arctic or sub-Arctic, SCCPs have been detected in grey and ringed seals from Norway, beluga whales, walrus, and in fish, birds, and ocean sediments from the United Kingdom. (See Table 9 in the Appendix.)

6. Octachlorostyrene (OCS)

This chemical is an inadvertent by-product of production of magnesium, high-temperature processes involving carbon and chlorine, and possibly from some types of incineration and combustion. OCS has no known commercial use and was never produced intentionally.

Octachlorostyrene is persistent and is known to bioaccumulate in the bodies of animals. OCS has a tendency to bind to sediments, is highly toxic to fish, and has been detected in fish from Elb River, Germany⁹⁸ and the Midwest, United States.^{99,100} Little information is available on health effects associated with OCS exposure. However, secondary sex characteristics were altered in snapping turtles from Canada exposed to a mixture of contaminants including octachlorostyrene.¹⁰¹

OCS has been reported in air samples from the Canadian Arctic,¹⁰² soil samples in Ontario,¹⁰³ and sediment samples from the Great Lakes basin.¹⁰⁴ An accumulation of this chemical has been detected in coastal fish from Norway¹⁰⁵ and Baltic Sea eels.¹⁰⁶ OCS has been detected in the blood of Swedes,¹⁰⁷ Elb River residents in Germany,¹⁰⁸ and newborn babies from Inuit and local fishermen populations in Quebec,¹⁰⁹ indicating potential OCS contamination of marine food diets from the Atlantic Ocean. OCS found in albatross suggests similar contamination of the marine food web in the Pacific Ocean.¹¹⁰ In addition, octachlorostyrene has been detected in the waters of several harbors in northern Norway and in Canadian ringed seals, European harbor porpoise, and 2 sub-arctic bird species. A possible metabolite of OCS, hydroxyheptachlorostyrene, has been detected in Canadian polar bears. Hydroxyheptachlorostyrene was shown to bind to proteins in the blood of the polar bears, indicating the potential to disrupt hormone function.¹¹¹ (See Table 13 in the Appendix.)

7. Methoxychlor and Endosulfan pesticides

These pesticides are currently registered for use in Canada and the United States to protect crops against insects. Agricultural and urban areas in Eurasia and North America are thought to be the most likely source of environmental contamination for both pesticides. There are no global regulations covering endosulfan and methoxychlor, although they are restricted or banned in some countries.

Endosulfan and methoxychlor are persistent, have a high potential for biomagnification and accumulation, and are known to be toxic to aquatic species, birds, and mammals. Methoxychlor and endosulfan are hormone disruptors known to adversely affect reproduction,^{112,113,114,115,116} thyroid gland function^{117,118,119} and immune response.^{120,121} There is also evidence for neurotoxicity¹²² and altered reflex response time.¹²³

Methoxychlor and endosulfan have been detected in arctic air, water from the arctic ocean, snow from the Canadian Arctic, and snow over Northwest Alaskan sea ice – providing strong evidence for transport by air and ocean currents.^{124,125,126} Increasing levels of endosulfan in Canadian arctic air (Nunavut) have been noted since the first Arctic Monitoring and Assessment Program (AMAP) report.¹²⁷ Thus far, methoxychlor has been detected in wildlife from arctic Canada, Norway, Russia, Greenland, and in the Barents and North seas. Harbor and harp seals, as well as blue, humpback and minke whales are known to be contaminated. Endosulfan has been detected in wildlife from Russia, Canada, Greenland, Norway, and the White, North and Barents seas as well as in ocean sediments from the Caspian Sea. Contaminated species include minke whales and harbor, harp, and bearded seals. (See Tables 10 and 11 in the Appendix.)

8. Pentachlorophenol (PCP)

Pentachlorophenol is formed during production of several other chemicals and is also formed from metabolism of hexachlorobenzene (HCB) in mammals. PCP was widely used as a pesticide in the past and is currently used as a plant-protecting chemical¹²⁸ and as a commercial wood preservative for telephone poles, utility fencing, etc. The United States is the major exporter for PCP use in Europe, where PCP production ended in 1992.

PCP accumulates mainly in organs such as the liver, kidney, and brain. Treated wood is an important environmental source for PCP found in ospreys¹²⁹ and commercially raised beef cattle in the United States.^{130,131} Toxic effects are not yet well defined although PCP causes cancer in rats¹³² and has the potential to disrupt hormones.¹³³ PCP exposure has had harmful effects on developing salmon embryos¹³⁴ and caused deaths in bats exposed to PCP-treated roost boxes.¹³⁵ The presence of PCP in amniotic fluid raises concerns for infant exposure.¹³⁶

Infants from Inuit and local fishermen populations in Quebec are contaminated with PCP,¹³⁷ indicating polluted marine food diets and/or ongoing HCB exposure and metabolism. Levels of PCP have been linked to fish consumption in Latvian and Swedish men.¹³⁸ The first peer-reviewed scientific studies of PCP in sub-arctic wildlife came out in 2004 and showed contamination of the eggs of 4 Norwegian bird-of-prey species – golden eagles, ospreys, peregrine falcons, and white-tailed sea eagles. A breakdown product of PCP has been found in Canadian arctic snow¹³⁹ and lake sediments,¹⁴⁰ indicating likely long-range transport of this chemical to remote regions. (See Table 12 in the Appendix.)

IV. Other contaminants of concern, for which arctic data are not yet available

I. Dicofol

The pesticide dicofol has a global usage of 2750 tons/year. Asia leads in total consumption, followed by the United States, and Western Europe.¹⁴¹ Dicofol is a known hormone disruptor.¹⁴² Multiple contaminant exposure including dicofol has been linked to delayed maturation in female carp and inhibited sperm production in male carp from the Ebro River, Spain;¹⁴³ egg shell thinning and altered reproductive behavior in captive American kestrels;^{144,145,146} developmental abnormalities of reproductive organs and altered sex hormone status in Florida alligators;¹⁴⁷ and immune suppression in marine toads and frogs from Bermuda.¹⁴⁸ An increased risk among Italian farmers of prostate cancer has been associated with DDT and dicofol pesticide exposure.¹⁴⁹ Although dicofol has not yet been monitored for in remote arctic areas, it is thought to be capable of long-range transport.

2. Bisphenol A

Bisphenol A is globally used in the manufacture of many plastics and has also been used as a fungicide, antioxidant, flame retardant, rubber chemical, and stabilizer. Polycarbonate baby bottles leach Bisphenol A after dishwashing, boiling and brushing, and releases also occur from food cans and other plastic products.¹⁵⁰ In addition, transfer of Bisphenol A to the fetus during pregnancy is of concern.^{151,152} Bisphenol A is a hormone disruptor and is toxic to male reproductive organs in rats.^{153,154} It affects brain cell survival and development,¹⁵⁵ and has the potential to cause cancer.¹⁵⁶ In salmon, exposure causes behavioral changes and damage to the egg yolk sac.¹⁵⁷ Bisphenol A is already known to be present in the Norwegian and United Kingdom environments.¹⁵⁸

V. Conclusion

Like the small portion of an iceberg that can actually be seen from above the water, the chemicals discussed in this report are only warnings of the larger problem that, for now, remains beneath the surface. The same can also be said of the Arctic, it represents the visible tip of the iceberg that must serve as an alert: contamination of the Arctic is an early warning. The ability to monitor what chemicals have made their way into our bodies, wildlife, and our environment depends on the development of methods used to detect contaminants, the level of scientific and global interest in the issue, and funding for research. Therefore, the evidence of chemicals that have been found in particular arctic species and at certain locations (presented in detail in the Appendix) does not represent the complete picture of arctic wildlife contamination. Many species and specific chemicals have not yet been assessed at all in the Arctic, however, wherever we look in the Arctic we are now detecting contamination from chemicals produced and used in distant regions of the world.

The Arctic was long thought to be pristine and isolated from the actions of the rest of the world, we now know this is not the case. The detected levels of chemicals in the bodies of arctic wildlife are a testament to the widespread presence of these contaminants within the arctic marine food web. The continued poorly regulated use of chemicals will result in increasing levels of contamination in the bodies of arctic marine mammals and bird species in the near future.

Current global threats to arctic marine ecosystems are complex and highly interactive. Pollution, climate change, over-fishing, habitat destruction due to human development and resource utilization, eutrophication,¹⁵⁹ ultra-violet radiation,¹⁶⁰ and introduction of non-native species are all important key factors that alter ecosystems.¹⁶¹ These many concurrent threats are expected to impair arctic species' resilience and ability to successfully adapt to their changing environment, thus jeopardizing the viability and sustainability of the arctic marine and terrestrial systems as a whole. Pollution-associated and climate-related changes to arctic ecosystems will have dramatic global consequences. The remote arctic region, far from many of the main sources of pollution, is considered a sentinel or indicator that can provide us with an early alert to the threat posed by our use of toxic chemicals. However, it is up to us to act on this early warning while we still have time to protect this unique region and its wildlife, as well as the rest of our planet.

Similar to the older generation of pollutants, current-use toxic substances reaching the Arctic are apparently originating mainly from distant source regions. To date, few studies have assessed the potential harmful health effects to arctic wildlife from newer generation contaminants. However, long-term exposure to the older generation of chemicals has been linked to immunological, behavioral, reproductive, and neurological harmful effects in key species, such as polar bears. Many of the current-use and older generation chemicals share structural similarities and chemical properties, and most likely contribute to common health consequences.

Compelling scientific studies of harmful health effects associated with contaminant exposures are just now becoming available. However, it is essential to heed the lessons from our experience with the last generation of legacy chemicals and to immediately act on the side of precaution to prevent the build up of additional harmful chemicals in our global environment. Vast numbers of both indigenous and non-indigenous peoples and animals are dependent on the Arctic for their very survival. The arctic environment and the great variety of species it supports are extremely sensitive to threats from pollution. The Arctic serves as a global environmental indicator, an early warning system where we can gauge the health of our planet. Learning to protect and

conserve the Arctic will not only ensure this magnificent region and its unique wildlife are around for generations to come, but will also serve as an example and a model of how we can live in harmony with nature.

Passing a strong and protective version of the REACH legislation will be a great step towards reducing, and eventually ending, environmental contamination with hazardous chemicals. The Titanic, one of the most modern and advanced ships at its time, was thought to be “practically unsinkable” prior to its fatal collision and the deaths of hundreds of people in 1912. Likewise, we cannot afford to continue with the unsupported and dangerous assumption that chemicals are “safe until proven otherwise.” What we already know about the hazards of chemicals, while it may only be the “tip of the iceberg,” foreshadows what lies beneath. The time to act and move towards safer, sustainable chemical use is now.