Persistent Organic Pollutants in the Arctic

A Report for the Delegates of the 4th Conference of the Parties
Stockholm Convention on Persistent Organic Pollutants

Alaska Community Action on Toxics

"*Acknowledging that the Arctic ecosystems and indigenous communities are particularly at risk because of biomagnification of persistent organic pollutants and that contamination of their traditional foods is a public health issue.*"

From the Preamble of the Stockholm Convention on Persistent Organic Pollutants

"*Mindful of the precautionary approach as set forth in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Convention is to protect human health and the environment from persistent organic pollutants.*"

Article 1 - Objective

Why is the Arctic Vulnerable?

Introduction

The Arctic encompasses the lands and waters north of 60° latitude, including approximately 20 million km^2 of ocean; all of Greenland and Iceland; the northern reaches of Norway, Finland, Sweden, and Russia; Canada north of the southern shore of Hudson Bay; and Alaska north of the panhandle in the United States. About 8 million km^2 of the Arctic Ocean is covered with perennial ice pack.[1]

The Arctic is home to approximately half a million Indigenous Peoples, including the Aleut, Alutiiq, Athabascan, Inuit (includes Yupik and Inupiat peoples of the western Arctic as well as the coastal people of northern Labrador, Nunavik the Northwest Territories of the Canadian Arctic, and the Kalaallit of Greenland), Dene, Métis, Saami (with homelands in four countries—Russia, Sweden, Finland, and Norway); and the Dolgan, Nganasan, Nenets, Khanty, Chukchi, Evenk, Even, Enets, and Yukagir of the Russian Arctic.

The Indigenous Peoples of the Arctic face significant food security and health challenges from global contaminants and climate change. Indigenous communities of the north are reliant on a traditional diet of foods from the land and ocean for their physical, cultural, and spiritual sustenance. Some Arctic Indigenous populations have shown levels of contaminants in blood and breast milk that are higher than those found anywhere else on the Earth.[2]

Persistent Organic Pollutants

Accumulation of persistent organic pollutants (POPs) in northern latitudes is a well-documented phenomenon. This is thought to occur for a variety of reasons. In a process known as global distillation, prevailing ocean and wind currents bring contaminants to the Arctic where they are subsequently trapped by the cold climate. This process is often referred to as the grasshopper effect, as chemicals repeatedly evaporate and condense while in their journey toward the Arctic.[3] Migratory animals are thought to offload their body burdens into Arctic ecosystems through excretion of wastes and during decomposition.[4] The large rivers that empty into Arctic waters contribute as well; in a single year, these rivers contribute hundreds of kilograms of POPs such as HCH, PBDEs, and endosulfan to the Arctic.[5] The Arctic appears to have a greater capacity for storage of POPs as compared to other regions; therefore, once POPs enter the Arctic, they are readily incorporated within biological systems.[6] All of these forces contribute to a growing burden of pollutants in Arctic air, water, animals, and humans.

The lipid based food web of the Arctic is a critical element in the vulnerability of these ecosystems to POPs. Lipids are essential for insulating Arctic homeotherms and providing large energy stores for extended fasts.[7] Because many POPs bioaccumulate in lipids, Arctic organisms are capable of accruing high concentrations of these chemicals. With no efficient detoxification mechanism for persistent chemicals, POPs remain in the tissues of Arctic biota. These chemicals are then passed on to the next generation or the next organism in the food web, often ending with human consumption.

Global deposition of both legacy POPs and new POPs in the Arctic is continuing.

Persistent Organic Pollutants:

- Are transported long distances from the source
- Resist environmental degradation
- Accumulate in biota
- Can produce toxic effects in exposed organisms

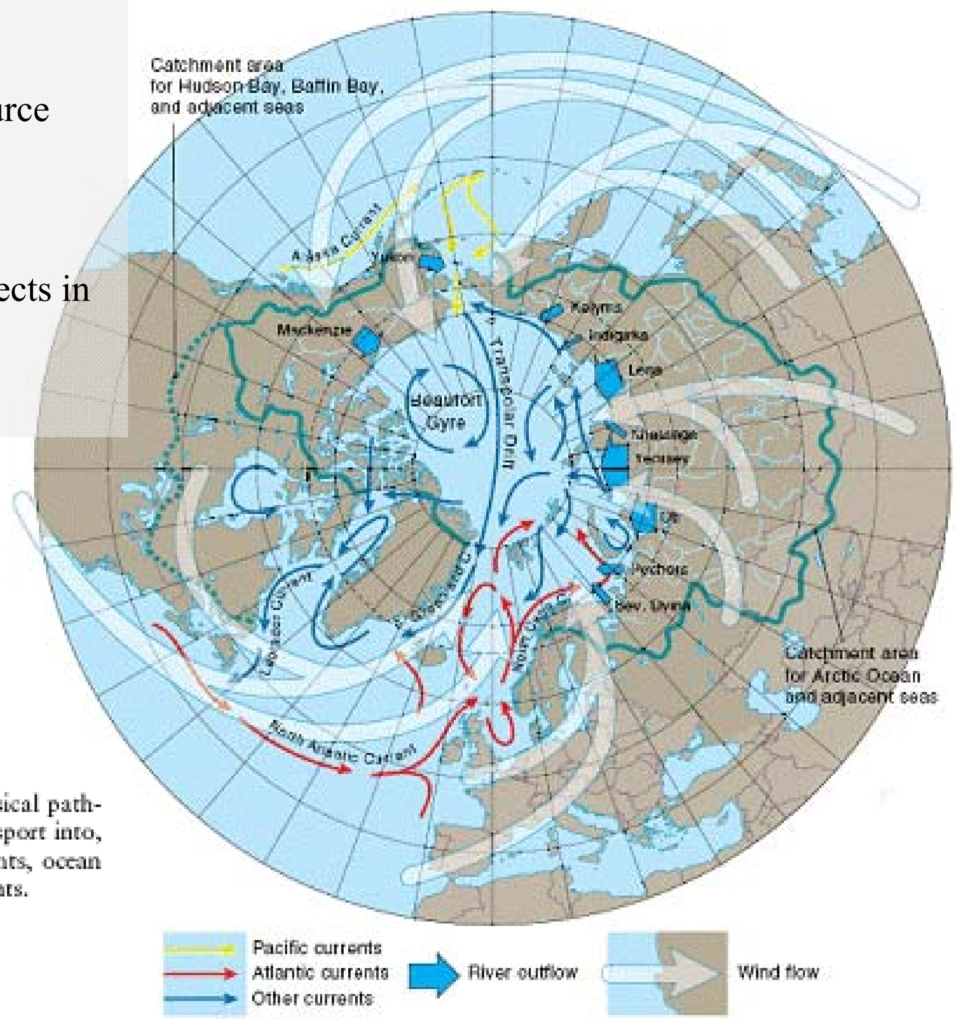
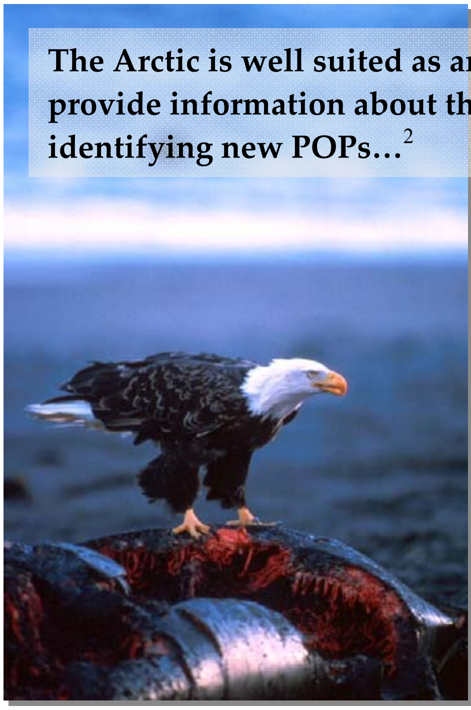


Illustration of the different physical pathways by which POPs enter the Arctic. Transport into, and within, the Arctic occurs via air currents, ocean currents, rivers, and transpolar ice movements.

AMAP. 2002



The Arctic is well suited as an indicator region for long-range transport. Monitoring data that provide information about the fate of chemicals in the Arctic will therefore be critical in identifying new POPs…[2]

New chemicals are appearing in the Arctic. Previous determination of POP status relied heavily on K_{ow}, a measure of lipid-water partitioning and the potential of a substance to bioaccumulate. New potential POPs such as endosulfan, HCH and PFOS are accumulating in Arctic biota despite low relatively K_{ow} values.[8,9] These chemicals have high K_{oa} values, meaning they will tend to bioaccumulate in air breathing animals rather than in fish.[8] They pose a risk to air-breathing animals including birds, terrestrial and marine mammals, and humans because of their slow rate of elimination from the lungs. "These low K_{ow}—high K_{oa} chemicals, representing a third of organic chemicals in commercial use, constitute an unidentified class of potentially bioaccumulative substances that require regulatory assessment to prevent possible ecosystem and human health consequences."[8]

POPs are only one of many difficulties facing the Arctic. Climate change, accumulation of toxic trace metals, radioactive contamination, and development all threaten these ecosystems.[2] Climate change alone threatens ecosystem stability for numerous Arctic species, but research suggests that the endocrine disrupting actions of POPs may make Arctic animals less able to cope with these changes.[10] Additionally, toxic metals such as mercury are still accumulating in Arctic species at levels that can pose a threat to health.[11] Development of Arctic habitat physically disturbs ecosystems and increases toxic burden as well.[2] POPs not only inflict individual harm, but may also affect the ability of Arctic biota to cope with a rapidly changing landscape.[12]

It is clear from past experience that POPs can take a devastating toll on the environment and human health. We have learned from past experience that PCBs and other known POPs continue to cause harm to wildlife and humans throughout the Arctic and the world. The Parties to the Convention have an unprecedented opportunity to take precautionary action on chemicals that are also of concern because of their persistence, bioaccumulation, long-range environmental transport, and toxicity.

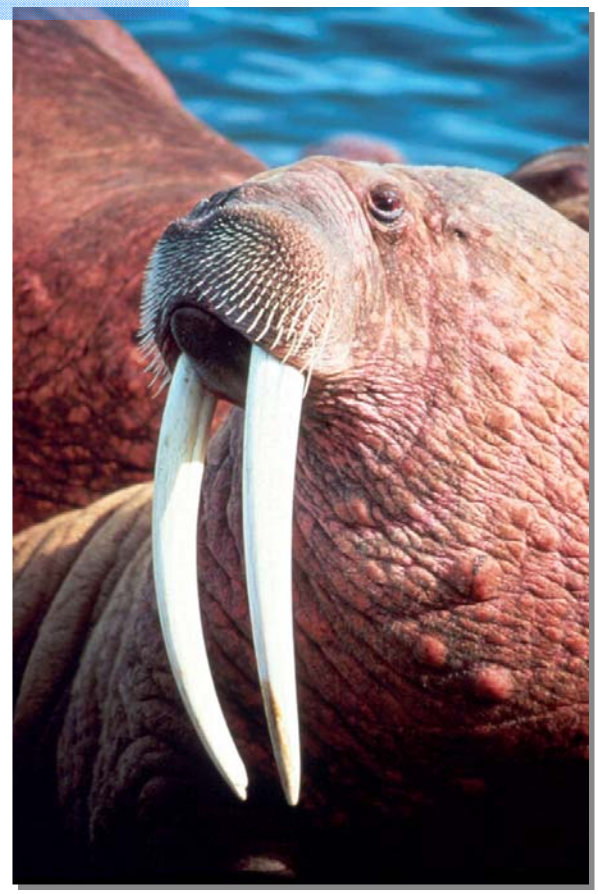
A Public and Environmental Health Crisis

Numerous studies have found that both the legacy POPs and the proposed additions to the Stockholm Convention are present at biologically relevant levels in the Arctic.[13,14] These chemicals can affect the health and fitness of animals and humans alike.[15,16] POPs present a significant hazard to the health and cultures of Indigenous Peoples of the Arctic. Indigenous Peoples should not be forced to choose between maintaining their traditional diet and protecting themselves from the harmful effects of POPs in their food.[1] Levels of certain POPs can be significantly higher in traditional foods such as fish and marine mammals than in market foods.[17] In many cases, there is no alternative to the subsistence way of life of Arctic Indigenous Peoples due to lack of a cash based economy.[18]

For the peoples of the Arctic,
POPs represent not only
an affront to the local environments, but a direct threat to the human health and prosperity of Native culture.

Despite the actions of the Stockholm Convention on the initial twelve POPs, these chemicals are still present at toxic levels in the Arctic and will require vigilant action in the continuing implementation of the Convention.[12,19] It is imperative that additional POPs be removed from global use. Action must be taken to prevent further contamination of these rich and productive ecosystems and to protect the health of Indigenous Peoples who are so closely tied to them.

Individual Chemicals and Toxic Effects



The Stockholm Convention on Persistent Organic Pollutants is a living treaty created to remove known and potential persistent organic pollutants from global use. The treaty functions on the basis of precautionary science. A lack of scientific certainty should not delay the listing of a persistent organic pollutant in light of the potential consequences. Each of the following chemicals has been determined to be a likely POP by the scientific review committee of the Stockholm Convention. The committee determined that these chemicals are likely to cause significant adverse effects on humans or the environment. Upon review of the available evidence it is recommended that all proposed chemicals be listed in Annex A of the Stockholm Convention.

Chlordecone

There is a lack of research on the effects of chlordecone in Arctic environments since production appears to have ended some decades ago. However, chlordecone is a POP that is highly toxic to aquatic organisms, and closely related to mirex[20]. Due to its POPs properties, chlordecone should be listed in Annex A of the Stockholm Convention to regulate remaining stocks and prevent future reintroduction of production and use.

Endosulfan

Endosulfan is still a widely used pesticide, and concentrations are still increasing in Arctic air.[21] Research indicates that deposition from air to Arctic waters is a significant source of endosulfan for the Arctic.[22] Arctic biota is also clearly contaminated by endosulfan. Predators including polar bears from Svalbard[14] and Arctic fulmars[23] show elevated concentrations of endosulfan. Minke whales have also been found to contain elevated endosulfan concentration in their blubber.[24] Even low environmental concentrations of endosulfan can have potentially harmful effects on exposed animals.[25] Endosulfan is toxic to aquatic organisms and has been shown to damage the gills, liver and kidneys of fish.[26] In mice, endosulfan reduces overall sperm count and increases the prevalence of malformed sperm.[27] In humans, endosulfan exposure has been associated with congenital defects, developmental delays, and death.[28]

Hexabromobiphenyl

Although worldwide production and use of hexabromobiphenyl has declined since the 1970s, hexabromobiphenyl appears to be present in many Arctic animals, including important food sources such as ringed seals, minke whales, pilot whales and polar bears.[13] “In Arctic and North Atlantic regions, where the traditional diet includes top predators…exposure has not ceased. Especially the level of PBBs in pilot whale blubber of up to 17 µg/kg lipid indicates the presence of hexabromobiphenyl in food."[29] Concentrations of hexabromobiphenyl in ringed seals from Svalbard were found to be between 0.29 and 4 µg/kg lipid in two studies,[30,31] and concentrations in guillemot (an Arctic seabird) muscle were as high as 50 µg/kg lipid.[31] In animal studies, PBBs have been shown to disrupt immune [32] and reproductive function,[33] cause birth defects,[34] hepatic damage[35] and cancer. [36,37]

HexaChlorocyclohexane (HCH) Isomers

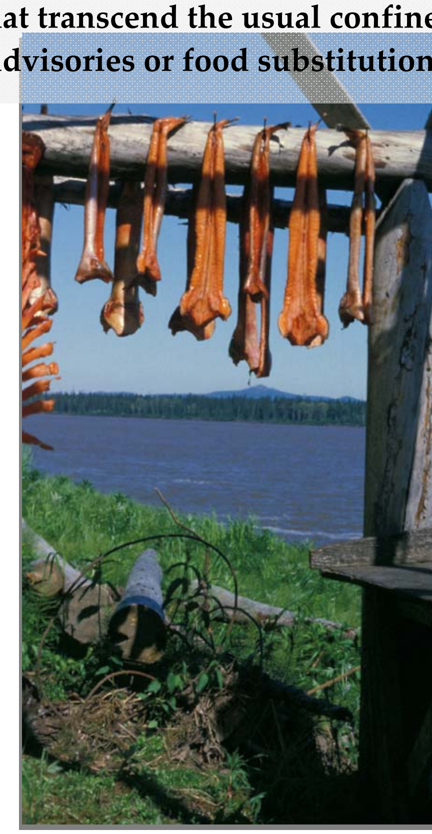
The production of every ton of lindane (gamma-HCH) results in 6-10 tons of alpha and beta-HCH waste isomers that continue to be a source of HCH isomers to the Arctic.[38]

Alpha Hexachlorocyclohexane

In many areas of the Arctic, Alpha-HCH is the most prevalent organochlorine pollutant in the environment.[39] Over several decades, alpha-HCH concentrations from Canadian ringed seals showed no significant decline.[38] A similar trend was found between 1991 and 2002 for Hudson Bay polar bears,[40] and concentrations increased from 18-25% for polar bears from eastern Greenland. Elevated concentrations have also been detected in beluga whales[41] and bowhead whales.[42] "Estimated daily intakes of alpha-HCH of Arctic indigenous people…exceeds safe intake reference values""[43] Indigenous communities in Alaska were found to have levels above the level of concern for dietary intake of alpha-HCH with regard to both chronic toxicity and cancer risk.[44]

As with other HCH isomers, the potential health effects of alpha-HCH are numerous. The acute toxicity of alpha-HCH to aquatic organisms and mammals alike has been well documented. Effects in laboratory animals range from convulsions and neurological effects to endocrine disruption, organ damage and carcinogenesis.[45]

"The contamination of these food sources raises problems that transcend the usual confines of public health and that cannot be resolved simply by health advisories or food substitutions"[1]



Beta Hexachlorocyclohexane

Beta-HCH is one of the most common POPs in the Arctic.[46] When polar bears from the Beaufort Sea were analyzed, HCH concentrations were approximately 770 ng/g wet weight in fat, and beta-HCH constituted 93% of total HCH levels. According to data collected between 1992 and 1997, beta-HCH concentrations increased in several Arctic species including seals and polar bears.[41] According to the US EPA, multiple traditional foods for Arctic Indigenous Peoples are contaminated with beta-HCH.[44] Elevated concentrations were found in marine mammals such as seals and whales, with levels of 215 ng/g and 391 ng/g respectively, but even local berries were contaminated with an average of 10 ppb HCH. Elevated levels of HCH have also been found in beluga whales of the St. Lawrence River estuary.[24] It is estimated that beta-HCH would have a half-life of 10 years in human adipose tissue. In addition to other toxic effects such as liver damage and endocrine disruption,[47] beta-HCH has been shown to have carcinogenic properties.[48] Indigenous communities in Alaska were found to be exposed above the level of concern for dietary intake of beta-HCH with regard to both chronic toxicity and cancer risk.[44]

Lindane

Lindane is still an actively used organochlorine pesticide in come countries, despite the fact that "HCH isomers, including lindane, are the most abundant and persistent organochlorine insecticide contaminants in the Arctic."[49] Lindane differentially accumulates in the cold regions of the world,[47] and it is estimated that in the conditions of the Arctic Ocean, lindane could have a half-life of 110 years.[44] Lindane has been found to bioaccumulate in a multitude of marine mammals at levels comparable to PCBs and DDT.[45] Lindane is also passed on to children through breast milk.[41] Lindane has been shown to cause damage to the liver,[50] nervous system,[51] heart,[52] and testes.[53] Additionally, lindane is classified as a probable human carcinogen based on development of cancer in exposed laboratory animals.[45]

"To discover that the food which for generations has nourished them and kept them whole physically and spiritually is now poisoning them is profoundly disturbing and threatens Indigenous Peoples' cultural survival."[2]

Octabromodiphenyl Ether

Commercial octa-BDE is a mixture of multiple poly-BDEs, most notably hexa-BDE, hepta-BDE, octa-BDE and nona-BDE. In addition, Octa-BDE and other highly brominated diphenyl ethers such as Deca-BDE are known to degrade into BDE congeners with fewer bromines. Hexa- and hepta–BDE have been detected in species of Arctic predatory birds.[54] Increasing concentrations of PBDE congeners were also detected in the eggs of Arctic birds between 1983 and 2003.[55] Octa-BDE congeners were detected in the serum of Norwegians at gradually increasing levels between 1977 and 1999, and have stabilized since 1999.[56] Studies of organisms at multiple trophic levels in the Baltic and northern Atlantic seas revealed detectable concentrations of octa-BDE specific congeners in zooplankton, sprat, herring and salmon.[57]

Increasing evidence suggests similar toxicological profiles and therefore, equivalent hazards and concerns, between PBDEs such as octa-BDE, and PCBs.[58] Octabromodiphenyl ether has been shown to disrupt thyroid hormone levels and increase liver weights in weanling rats.[59] In addition, octa-BDE exposure has been associated with abnormal behavior and hyperactivity in mice.[60] In human breast cancer cells, octa-BDE increased micronucleus formation and growth kinetics, characteristics of developing cancer cells.[61]

"The central and most distinguishing feature of the modern Arctic indigenous economy continues to be its dependence on wildlife and the habitat that supports it."[2]

Pentabromodiphenyl Ether

Penta-BDE is one of several brominated flame retardants that have bioaccumulative and toxic properties. Penta-BDE has been discovered in many of the Arctic's predatory species at levels that suggest it is ubiquitous in the environment.[23,62,63] Species such as beluga whales, peregrine falcons, and polar bears, all have detectable concentrations of penta-BDE.[14,64,65,66] Penta-BDE is also present in animals in the traditional diet of Indigenous Peoples such as seals, walruses and whales.[67,68] These data suggest that the Arctic food webs are being significantly affected by penta-BDE.

Penta-BDE has been shown to permanently impair memory, motor function and behavior in mice.[69] Research has shown that penta-BDE exhibits estrogen-like actions in human cells.[70] Furthermore, penta-BDE has been shown to disrupt thyroid hormone function.[71] Penta-BDE binds to the aryl hydrocarbon receptor, as do PCBs and dioxin, and has been shown to reduce the AHR-mediated immune response in mice.[72]

Pentachlorobenzene

Pentachlorobenzene (PeCB) has been used as a multipurpose chemical intermediate, flame retardant, pesticide, and with PCBs in dielectric fluids for electrical equipment. PeCB is also unintentionally produced and released to the environment by many of the sources that produce dioxins and furans. When samples of ringed seal collected by Inuit hunters were analyzed, they revealed PeCb levels as high as 8.4 ppb.[73] Another study of Arctic Russian seals revealed concentrations in harp seals up to 12 ppb.[74] PeCb was found to be ubiquitous in polar bears from the Svalbard Islands, with an average of 7.9 ppb wet weight.[14] Mean PeCb levels for beluga whales from St. Lawrence Bay were 24.5 ppb for females and 144.5 for males, with concentrations of over 1500 ppb in some individuals.[24] Additionally, total polychlorobenzene concentrations in polar bears from multiple locations in the Arctic were found to have increased from 1997 to 2002.[75]

There are clear health effects associated with PeCb exposure. Pentachlorobenzene exposure is correlated with increased liver and kidney damage as well as disrupted thyroid hormone levels in lab animals.[76] Similar to other chlorinated benzenes, pentachlorobenzene has been associated with cancer in rats.[77,78] Additionally, accumulated maternal burdens of PeCb are transferred to offspring, possibly amplifying the harmful effects during development.[79]

Perfluorooctane Sulfonate

Perfluorooctane sulfonate (PFOS) is a ubiquitous organic pollutant. It was largely overlooked for many years due to the fact that it accumulates in proteinaceous tissue rather than in lipids as with most POPs.[80] Despite this, PFOS is still accumulating in the Arctic. A study on the presence of PFOS in the livers of Arctic animals revealed elevated PFOS levels in almost all species studied. Polar bears had significantly elevated concentrations of PFOS, due to bioaccumulation through the food web.[81] In a recent study of foods consumed by a Canadian Inuit population, traditional foods were more widely contaminated and contained higher concentrations of PFCs than non-traditional foods. Caribou had the highest concentrations of perfluorinated compounds (PFCs), including PFOS. [17] This is likely due to accumulation of PFOS through terrestrial ecosystems, a characteristic of POPs with high K_{oa}.[9] Numerous studies have documented the toxic effects of PFOS on the immune,[82] reproductive,[83,84]and nervous[85] systems as well as its carcinogenicity.[86] Maternal PFOS is transferred to fetuses through the placenta,[87] and maternal PFOS exposure has been correlated to low birth weight in humans[88] and mice.[89]

Short Chain Chlorinated Paraffins

Research has shown that short chain chlorinated paraffins (SCCPs) are ubiquitous in the Arctic. SCCPs have been detected in Arctic air,[90] lakes[91] and biota.[92] SCCPs have been found in numerous Arctic animals including walrus, ringed seals, and beluga whales. Ringed seals from Ellesmere Island, Canada were found to have levels as high as 770 ppb, representing significant contamination well within the Arctic Circle. In addition, the same study found enrichment of shorter chain chlorinated paraffins in animals from the Arctic.[93] Short chain chlorinated paraffins are also present in the breast milk of Inuit women in Northern Canada; a mean of 13 ppb was measured with concentrations up to 17 ppb.[94] Mice exposed to SCCPs over two years developed liver and thyroid cancer, in addition to other health effects such as decreased activity and abnormal breathing.[95]

Closing

The effects of POPs on Arctic Indigenous communities are primarily threefold. When the traditional diet is replaced by imported foods, numerous negative health effects have been observed including increases in obesity, diabetes, anemia, and dental problems, as well as decreases in physical activity and resistance to disease.[1] Traditional foods provide beneficial nutritional qualities such as omega-3 fatty acids. It has also been hypothesized that removing traditional food sources would reduce the available mineral intake to the point of deficiencies in most Arctic populations.[18]

In addition to the biological effects, removing traditional foods also has numerous negative effects on the community and culture of Arctic Indigenous Peoples. Communal harvesting and sharing practices are central to the spiritual and cultural vitality of a village. These practices reinforce interdependence of community members and overall community self-reliance.[2,18]

Finally, subsistence hunting of traditional food animals is not a choice in most rural Arctic communities. Villages rely on harvesting available foods to ensure all community members in need are cared for. Cash economies are often tenuous or nonexistent, and opportunities for local employment are scarce.[18] Even when available, imported foods are often not an economically feasible option.[1]

It is important to note that, while research typically focuses on single chemicals or chemical groups, Arctic wildlife and people are exposed to multiple environmental pollutants. These toxins, which include but are not limited to POPs, can have significant cumulative and synergistic effects. All available action must be taken to eliminate sources of POPs in order to provide long-term protection to the ecosystems and people of the Arctic.

> "*How could the Arctic, seemingly untouched by contemporary ills, so innocent, so primitive, so natural, be home to the most contaminated people on the planet? I had stumbled upon what is perhaps the greatest environmental injustice on Earth.*"
> —Marla Cone, **Silent Snow: The Slow Poisoning of the Arctic** (Grove Press, New York, 2005)

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