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SUMMARY OF EFFECTS OF PERSISTENT ORGANIC POLLUTANTS (POPs) IN ARCTIC WILDLIFE

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Introduction

Although Arctic biota were demonstrated to contain a range of persistent organic pollutants (POPs), particularly organochlorines (OCs) in the 1970s, there was limited knowledge until recently of possible effects of these substances on Arctic species. The previous AMAP Arctic Assessment Report presented the few effect studies that were available up to 1996[1], and included identifying other species that might be at risk for specific types of effects based on their tissue concentrations of certain POPs. The second AMAP POPs assessment report has been updated with additional new data on biological effects that has emerged in the last 5 years[2]. These new results confirm suspicions raised in the first assessment.

Methods

Several approaches were used by scientists in these studies. One approach uses subtle indicators of biological responses (biomarkers) to contaminants and correlates these to tissue concentrations of specific organochlorines. In some cases, these have been complemented by field experiments and laboratory studies using Arctic species, to better build the case that specific POPs are the cause of the effects being seen. The other method compares levels of OCs in Arctic species to known detrimental levels such as no-adverse-effect-levels (NOAEL/NOEL) and lowest-adverse-effect-levels (LOAEL/LOEL), this knowledge coming from laboratory tests or from observations on affected animals in the wild. Comparisons are also made of the OC levels in the diet of selected Arctic biota to known dietary no-adverse-effect-concentrations (NOAEC) or lowest-adverse-effect-concentrations (LOAEC) in food or to environmental quality criteria/guideline values for protecting wildlife that consume aquatic biota that have been developed primarily by the U.S. and Canada. This latter approach is limited by the lack of knowledge about the diets of many Arctic organisms.

Results and Discussion

Current concentrations of some OCs in several Arctic species are correlated to various types of biological effects or are at or above the known thresholds associated with effects that have been seen in other species studied either in the laboratory or in the field. Based on biomarker studies the following conclusions could be drawn. Negative reproductive and/or developmental effects are correlated to increased levels of various POPs (primarily DDE, PCB and dioxin-like compounds) in Alaskan peregrine falcons, bald eagles from the Aleutian Islands, glaucous gulls from Bjørnøya (Norway), Norwegian shag, and Svalbard and Hudson Bay polar bears. Imposex in dogwhelks is correlated to TBT concentrations along the Norwegian coast, and imposex is also found along the coasts of the Faroe Islands, Greenland and Iceland.

Increased cytochrome P4501A (CYP1A) enzyme activities (often measured as EROD) are correlated to increased PCB levels in Arctic char from two lakes (with high or low POP levels) on Bjørnøya, in glaucous gulls at Bjørnøya, in black guillemot from Saglek Bay, Canada, in Svalbard ringed seals and in Svalbard polar bears. Increased testosterone 6-β hydroxylation (CYP3A) is correlated to increased toxaphene levels in Svalbard harp seals.

Decreased retinol levels are correlated to increased levels of PCBs in black guillemots at Saglek Bay, Canada, PCBs and/or TEQs from dioxin-like compounds in northern fur seal pups from the Aleutian Islands and PCB, HCB and HCH levels in Svalbard polar bears. In a comparison of polar bears from Svalbard (high PCB levels) and Resolute, Canada (low PCB levels), retinol levels were negatively correlated with persistent PCBs and positively correlated with OH-PCBs, suggesting that PCB affects retinol metabolism and storage in the liver. Decreased thyroid hormone levels (particularly T4) are correlated to increased levels of HCB, DDE and PCB in male glaucous gulls from Bjørnøya, increased PCB and TEQs in northern fur seal pups, and increased PCB levels in polar bear from the Svalbard/Resolute study.

In northern fur seal and Steller sea lion pups, various measures of normal immune function were negatively correlated to increasing PCB levels. Decreased antibody production after vaccination was also correlated to increased PCBs in northern fur seals. In Svalbard polar bears, a significant decrease in antibodies with increased PCB levels was found. In mothers and cubs, a similar negative correlation was found for IgG levels in cubs. In the Svalbard/Resolute study, polar bears with high PCB levels were found to exhibit immunosuppression expressed as reduced IgG production and lowered lymphocyte responses after vaccination. The intensity of nematodes was positively correlated with concentrations of DDT, mirex and PCB in glaucous gulls from Bjørnøya.

Laboratory studies with wild Arctic char show increased EROD activity correlated to PCB treatment, with stronger effects in fasted versus fed fish. Basal cortisol levels were suppressed by PCBs in starved fish after handling and disease susceptibility was highest in the fed char with no difference due to PCB exposure, while disease susceptibility increased with PCB exposure in the starved group. This indicates that PCBs compromise stress responses and reduce immunocompetence and the effect of fasting makes char more sensitive to the effects of PCBs. Glaucous gull chicks with high dietary PCB exposure show an impaired ability to produce antibodies after vaccination.

Based on known thresholds for effects, several Arctic species have contaminant levels that may put them at risk for, primarily, reproductive and/or immunosuppressive effects from current levels of ΣDDT, ΣPCB, and/or dioxin-like substances. Those at greatest risk include peregrine falcons, bald eagles, white-tailed sea eagles, glaucous and great black-backed gulls, great skuas, some alcids, harbor porpoises, seals, northern fur seals, Steller sea lions, belugas, long-finned pilot whales, narwhal, minke whales, killer whales, sea otters, polar bears, and Arctic fox. If the risk for subtle neurobehavioral effects from ΣPCB in exposed offspring of mammals is included, then some reindeer and mountain hares, wolverines, walrus and gray whales are also potentially at risk. Burbot from some sites have toxaphene levels high enough to affect fry bone development and burbot, land-locked char (Bjørnøya), Greenland shark and Greenland halibut have ΣPCB levels associated with increased liver enzyme production in Arctic char. Some invertebrates are at risk for the reproductive effects of TBT, particularly those that are exposed in harbors.

An assessment of risks from dietary intake has been attempted, based on results from laboratory feeding experiments, POP levels in prey items, and information on different species' food preferences. Reproduction in piscivorous marine mammals such as minke whale, beluga, narwhal, long-finned pilot whale, harbor porpoise, and seals may be affected by dietary levels of ΣPCB in marine fish. Killer whales, walrus, polar bear, and Arctic fox that prey on seals have dietary intakes of ΣPCB that may cause reproductive effects. When environmental quality guidelines for protecting aquatic wildlife are used, dietary intakes of ΣDDT, ΣPCB, toxaphene and dioxin-like substances are problematic for many marine and freshwater piscivorous species and in some cases for molluscivores. The same is true for predatory seabirds feeding on seabird eggs and chicks and for killer whale, walrus, polar bear, and Arctic fox that consume marine mammals.

Conclusions

Effects that are biologically significant are those that affect resistance to infection, reproduction and behavior. Anything that affects these negatively reduces the margin of safety for the affected species, putting them at higher risk. Biomarkers for POP effects measure changes at the cellular or individual level and are warning signals. The results from biomarker studies in the Arctic have shown that there are associations between several biomarkers and concentrations of some POPs. Results from field experiments and laboratory studies give added weight to the possible link between some POPs and some specific effects. Therefore, based on the present evidence, it is believed that effects of biological significance are occurring in some Arctic species related to POPs exposure. These effects are:

- polar bears are at higher risk for infections due to immune effects of POPs,
- glaucous gulls with high POP levels are at higher risk of immune, behavioral and reproductive effects and effects on adult survival,
- northern fur seals are at higher risk for infections due to immune dysfunction correlated to POP exposure,
- peregrine falcons continue to exhibit egg shell thinning and reproductive effects of POPs,
- Arctic char exhibit immune effects of PCB and
- dogwhelks exhibit the reproductive effects of TBT.

There is a general lack of knowledge of the physiology of most Arctic species, particularly those with high OC exposures. This includes knowledge of baseline levels of hormones, vitamins, blood variables, immune factors etc. and what other variables affect these – time of day, time of year, reproductive state, health status, fasting etc. Because of these knowledge gaps, including the influence of confounding factors, other biomarkers studied in Arctic biota (thyroid hormones, retinol, cytochrome P450 activity) should be considered indicators of increased exposure, but it is not yet possible to conclude that changes in these imply increased risk.

A major gap in knowledge is the sensitivity of Arctic species for effects compared to other species where more knowledge is available. There are major species differences in susceptibility to the toxic effects of POPs and this in turn makes it difficult to know if the threshold values determined in other species are valid for comparison with the contaminant levels found in Arctic species. The toxicity mechanisms for many POPs are still not known and this is an urgent research need, especially for those substances found at high concentrations in Arctic biota. There is no or insufficient thresholds data for many new POPs such as PBDEs and PFOS as well as for biologically active metabolites of some POPs, such as $MeSO_2$-PCBs, $MeSO_2$-*p,p*'-DDE and OH-PCBs. Thus it is not possible to currently assess the levels of these contaminants in Arctic biota.

Studies on the effects of other stressors such as long periods of fasting on OC effects in Arctic char show modulation of OC effects. More knowledge about starvation effects is needed in birds and mammals as well.

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