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Report from the AMAP Conference and Workshop

Impacts of POPs and Mercury on Arctic Environments and Humans

Norsk Polarinstitutt
INTERNRAPPORT
Nr. 12 - Tromsø 2003

Internrapport nr. 12

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Tromsø, 20-24 January 2003

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Norsk Polarinstitutt 2003

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Grafisk design: Jan Roald
Trykket: April 2003
ISBN: 82-7666-197-1

Preface

In January 2002, the Ecotoxicology group at the Polar Environmental Centre, Tromsø, Norway, organized the Conference and Workshop "Impacts of POPs and Mercury on Arctic Environments and Humans" on behalf of the Arctic Monitoring and Assessment Programme (AMAP). A total of 171 participants, representing researchers, management and political authorities from all Arctic countries, took part in the Conference and the subsequent Workshop.

The present report summarizes scientific information and identifies knowledge gaps presented at the Conference and Workshop including needs for future monitoring and research. The report is based upon the summaries presented from the following topics:

1) POPs distribution: Levels and trends
2) Mercury distribution: Levels and trends
3) Effects of POPs on Arctic wildlife
4) Effects of POPs on humans in the Arctic
5) Effects of mercury on Arctic wildlife and humans
6) Future monitoring and risk assessment
7) Impact of climate change on POPs in the Arctic

The Organizing Committee would like to thank the invited key-note speakers Derek C.G. Muir, Cynthia de Wit, Joseph Wos, Ingvar Brandt, Eric Dewailly, Evert Nieboer, Pàl Weihe and Bo Wahlström for their help and scientific expertise. Their help contributed significantly to this report.

The Organizing Committee would like to thank the Scientific Committee for planning the scientific content of the Conference and Workshop. Members of the Scientific Committee were; Derek C.G. Muir, Cynthia de Wit, Sergey V. Kotelevtsev, Madelein Nyman, Bjørn M. Jenssen, Geir W. Gabrielsen, Lars-Otto Reiersen, Janneche U. Skåre, Evert Nieboer, Pàl Weihe, Jon Ø. Odland and Even Jørgensen.

The Organizing Committee would also like to thank the Ministry of Foreign Affairs, the Ministry of the Environment, the Ministry of Fisheries, the Ministry of Health, the Ministry of Education and Research, the Barents Secretariat, the Norwegian Research Council, the Transport and Effect Programme (Norwegian Polar Institute/Ministry of the Environment), the Norwegian Polar Institute, the Norwegian Institute of Nature Research, Akvaplan-niva and the Norwegian Institute of Air Research for financial support of the Conference.

The Organizing Committee gives special thanks to Linda Kvammen, Merete Stefanussen, Eldbjørg Heimstad and Ingrid Storhaug. Their help was vital to the success of the Conference.

1. BACKGROUND

On 21–24 January 2002, the AMAP (Arctic Monitoring and Assessment Programme) Conference and Workshop on "Impacts of POPs and Mercury on Arctic Environments and Humans" were held at the Polar Environmental Centre, Tromsø. The conference gathered a total of 171 participants from all Arctic countries. Most of these were active researchers but also representatives from political authorities and management. During the conference 46 oral and 40 poster presentations provided information on ongoing highly relevant research in the Arctic, within the fields of levels and trends of POPs and mercury, and effects of POPs and mercury on Arctic wildlife and humans. The conference ended with a one day workshop in which the participants were divided into five discussion groups which attempted to summarize the information provided during the conference, and to discuss knowledge gaps, future research needs and priorities, and future monitoring and risk assessment.

Eight internationally renowned researchers were invited as keynote speakers to the conference in order to present the "state of the science" within their respective research fields. They also participated in the workshop and were asked to write a short summary report after the meeting. In these reports they summarized the information presented at the conference and the workshop. They also identified knowledge gaps and future research needs for monitoring and research. These reports, written by Derek C.G. Muir (levels and trends), Cynthia de Wit, Joseph Wos and Ingvar Brandt (effects of POPs on wildlife), Eric Dewailly and Evert Nieboer (effects of POPs on humans), Pàl Weihe (effects of mercury), and Bo Wahlström (future perspectives, monitoring), form the basis for this report.

This report aims to summarize the current status on the knowledge of levels, trends and effects of POPs and mercury in the Arctic, and, based on the discussions during the workshop and the reports written by the keynote speakers, to provide guidelines for research priorities and risk assessment/monitoring in the future. We hope the report will be valuable as background for the research priorities that are to be made in the future strategies of the "PROFO" research programme, "Environment and development", Norwegian Research Council.

It is also our hope that the report will be valuable as background for the future risk assessment/monitoring projects envisaged by the international "decision making" institutions. We will also ensure that the report will be implemented in the report from the "Transport and Effect Programme" (Norwegian Polar Institute/ Ministry of the Environment).

Finally, we hope the report will be valuable as background for the future planning and execution of research programmes within AMAP and other environmental monitoring and assessment initiatives.

2. LEVELS AND TRENDS, POPs

Research on transport and fate of persistent organic pollutants and mercury (Hg) is still an important scientific issue after continuous research throughout the past 40 years. The results of the conference on "Impacts of POPs and mercury on Arctic environments and humans" confirmed the importance of continuous POP monitoring in the Arctic environment.

Temporal trends for POPs in the atmosphere have been investigated at several stations around the Arctic Ocean (Svalbard, Canada, Iceland, Finland, Russia). Also key species in the Arctic environment, such as polar bears, ringed seals, glaucous gulls and guillemots, are continuously monitored as indicator species for POP and Hg contamination. Temporal trend data on POPs now exist over periods of 25-30 years for a selection of species, such as ringed seals and Arctic char. Recently performed trend studies have taken advantage of the availability of archived sample tissue materials (polar bears, beluga whales, guillemots, birds of prey and glaucous gulls). Today, significant temporal trend data for POPs are available for chlorinated dioxins and furans (PCDD/F), polychlorinated biphenyls (PCB), chlorinated pesticides, chlorobornanes, dichlorodiphenyltrichloroethane derivatives (DDT) and other industrial by-products (e.g., Hexachlorobenzene (HCB)).

2.1 Current knowledge status

Temporal trends: Current knowledge from trend data obtained during the last 20-30 years in various species and areas points to a slow decline in concentrations of total PCB and DDT in some Arctic sampling locations (e.g., atmospheric samples from Alert, Canada). However, species and region-specific trend-patterns seem obvious. Total hexachlorocyclohexane (HCH) has remained stable during a period of 10-20 years. Nevertheless, due to official restrictions in the use of the technical HCH mixture as insecticide in agricultural applications, the proportion of the a- HCH isomer is continuously decreasing whereas the g-HCH shows no decreasing tendencies neither in the abiotic or the biotic environment over the past decade. The levels of b-HCH, however, have continuously increased in ringed seal from the Canadian Arctic during the past 10 years. Polybrominated biphenylethers (PBDE) concentrations increased in the Canadian Arctic until the late 1990s. Short chain chlorinated paraffins (SCCP) and chlorinated diphenyl ethers (PCDE), declined in the Canadian Arctic in the same period. Considerable levels of SCCP and PCDE are also reported from the European Arctic, but no continuous long-term monitoring data are yet available to verify temporal trend analysis.

Spatial trends: In general, most POPs of concern are found in higher levels in the European (i.e. Svalbard, White Sea) than in the Canadian Arctic environment. Studies of ringed and harp seals in the White Sea have shown that levels of PCB and DDT-derivatives are higher compared to North American animals. Very high PCB concentrations were found in Arctic char tissues from Ellasjøen (Bjørnøya) and in glaucous gull from Bjørnøya compared to general levels reported from other Arctic sites. These findings demonstrate that there is evidence for unique "hot spot" locations in the Arctic with strongly elevated POP contamination. Seabird guano and/or elevated precipitation are under investigation as possible contamination sources. Circum-polar trend studies for PCB and chloropesticides were recently published for polar bear (blood), ringed seal, beluga and glaucous gull, confirming the general tendency that higher POP levels occur in the European compared to the North American Arctic. However, PCB levels found in polar bear blood from Svalbard were significantly lower than in polar bear blood samples from Franz Josef Land and the southern Kara Sea.

2.2 Knowledge gaps and needs

Several knowledge gaps were identified for spatial and temporal trends of POPs in marine Arctic biota.

- Especially data from the Russian Arctic (the Kara, Laptev and East Siberian seas) are needed in order to complete the circumpolar picture of POP distribution.
- For temporal trend studies and retrospective evaluation of "new" contaminants, specimen banking of biota and abiotic - samples seems one of the cornerstones for a reliable investigation. Proper maintenance of existing sample archives-

is, thus, important for future trend monitoring. The establishment of a new specimen bank for the European Arctic- is recommended.
- Integrated studies on dietary sources implementing stable isotope measurements are needed also in Arctic ecotoxicological research.
- The selection of contaminants for monitoring is usually confined to methods and techniques available and does not necessarily reflect the ecotoxicological importance of the compounds analysed. Thus, a new broad analytical approach should be envisaged which also includes non-target analysis for the identification of hitherto unknown contaminants, which should be implemented and acknowledged in national research programmes.
- The accessibility of data available for temporal and spatial trend studies is still not satisfactory. A renewed effort by AMAP to archive the data in the respective data centres is recommended.

3. LEVELS AND TRENDS, MERCURY

The major focus for mercury research has been on the marine environment.

3.1 Current knowledge status

Temporal trends: A significant increase is found for ringed seals in the Canadian and west Greenlandic Arctic. Increasing Hg levels are also reported from the Russian Arctic; increased Hg concentrations in sediments are determined in the Pechora River region in northwest Russia.

Hg levels in lake sediments from the border between Russia and Norway have increased strongly probably due to continuous pollution from smelters in the Murmansk region. Wild salmon from Alaska contain moderate Hg concentrations (70 – 90% present as methyl-mercury). Sockeye salmon, returning in large numbers to their Canadian and Alaskan spawning grounds, are transporting significant amounts of nutrients and contaminants (including methyl-mercury) into the local food webs.

Arctic springtime depletion must be considered as an important additional seasonal Hg source for the Arctic ecosystems. Investigations on cord blood, maternal blood as well as maternal hair samples from northern Quebec mothers show similar levels as determined for women from the Faeroe Islands in the 1990s.

Spatial trends: No comprehensive information is available yet to make firm conclusion about the spatial distribution of Hg species in the abiotic and biotic Arctic environment.

4. EFFECTS OF POPs ON ARCTIC WILDLIFE

4.1 Current knowledge status

A number of field studies on polar bears, seals and glaucous gull have been performed. Many of these have been correlative, i.e. look for possible correlations between effect parameters and individual concentrations of POPs. These studies have shown correlations between high PCB levels and reduced vitamin A and/or thyroid hormones in Alaskan northern fur seals and Svalbard polar bears, and reduced testosterone levels in Svalbard polar bears. Similar correlations have also been seen between high PCB levels and increased cytocrome P450 1A activity in Arctic char and glaucous gull from Bjørnøya, and ringed seals and polar bear from Svalbard. In Svalbard harp seal correlations between high toxaphene levels and increased cytochrome P450 3A have been seen. Correlations between high PCB burdens and reproduction and adult survival in Bjørnøya glaucous gull have been revealed, and between high PCB, DDT and mirex, and immune status (measured as parasite intensity) in the same species.

In “capture-vaccination-release-re-capture” experiments with polar bears, high PCB levels were correlated with reduced antibody production, reduced lymphocyte response and decreased IgG levels after immunization. Similar results were obtained in a similar study on Alaskan northern fur seal.

In experimental studies with glaucous gull given “naturally” contaminated food, correlations between high POP levels in the diet and increased frequency of chromosome abbreviations and DNA adducts were found. In Arctic char given the ecologically relevant PCB mixture Aroclor 1254, reduced immune status (measured as disease resistance) and hormonal stress responses were found with increasing PCB doses. In this study, lean char responded to low PCB doses (corresponding to those found in wild char at Bjørnøya), whereas fat char seemed to be much less sensitive.

The conclusion from the participants in the effect discussion group was that the results presented above show that there are associations between several biomarkers and POP levels. The conclusion was hence that biological effects are occurring in some Arctic species and that some of these effects can be related to POP exposure.

4.2 Knowledge gaps and needs

Current knowledge is to a large extent based on correlations between individual POP levels and various effect parameters or biomarkers. However, there are several limitations in this approach: i) is the correlation causative, i.e. does it really reflect an effect of POPs or is the individual POP level a covariate of another parameter which is the real cause for individual variations in the effect parameters and/or biomarker responses and ii) what are the consequences of these effects on an individual and on a population level?

On this background, some knowledge gaps and research needs may be pointed out:

- There is a general lack of knowledge on the physiology of most Arctic species, particularly those with high POP burdens. This includes basal knowledge on the immune system, hormonal regulation, reproduction etc., and the factors that affect and regulate these (e.g. time of day, time of year, nutritional status).
- Many ecotoxicological studies with wild arctic animals are hampered by a lack of knowledge on their ecology. Such knowledge is necessary as a background to understand xenobiotic-related responses.
- Experimental studies are utterly needed to clarify causality. In that respect the Arctic fox was mentioned as an excellent species for combined field and experimental studies to gain information about causality. The Arctic fox could also be used as a model animal to gain more knowledge on POP related responses in polar bears and seals.
- The long-term fasting and concurrent lipid mobilization that many Arctic animals regularly undergo seem to potentiate biomarker responses and sensitivitytoward lipophilic POPs. Such mechanisms make it difficult to know if threshold values determined in other species are valid for Arctic species. Toxicokinetic consequences of long term fasting must therefore be studied more, also in birds and mammals.
- Population vs. individual effects: It was a general agreement that population effects occur much later than individual responses and that responses at cellular or individual levels are warning signals which may be used to reveal species at the

"margin of safety". Nevertheless, there is a need for data that can be used for predications of future population effects.

5. EFFECTS OF POPs ON HUMANS IN THE ARCTIC

New findings from the Faeroe Islands indicate a correlation between mercury and hypertension and persistent organic pollutants (POPs) and neurobehavioral deficits in children. Findings from Finland show association between mercury and ischemic heart disease in adults. Preliminary findings, from a larger cohort study in Nunavik, Quebec, show a correlation between breast-fed babies (versus bottle fed) and respiratory infections. In a non-native female study from James Bay Cree, Quebec, a correlation was found between POPs and hormones (suppression of triiodothyronine, oestrogen, testosterone and thyroid stimulating hormone and elevations in follicle stimulating hormone and luteinizing hormone).

In the Faeroe Islands mercury levels in humans have been reduced by 80% through public health interventions related to consumption of pilot whale meat (POPs levels not reduced).

Statistical analysis of humans have shown extremely strong correlations between all polychlorinated biphenyls (PCB) congeners and weaker (but significant) correlations between PCB congeners and other POPs. This may complicate attempts to evaluate mechanisms, but may simplify the study of causal relationships in epidemiology. There are strong correlations between levels of all POPs in cord plasma lipid, maternal plasma lipid and lipid in breast milk even though there are slight differences in absolute levels (i.e., cord<maternal, breast). A strong correlation was also found between methyl mercury and maternal blood, cord blood and third trimester maternal hair.

5.1. Current knowledge status

- Ring tests of POPs and mercury have shown good laboratory harmonization and methodology improvements. This enables increased confidence in inter-comparability of data.
- Preliminary data emerging on food consumption show a correlation with OC levels in populations living in remote western and eastern Russia.
- Evidence from analyses of banked blood samples from Norway (non-Arctic donors) show an exponential increase of polybrominated diphenyl ethers (PBDEs) since 1977.
- There is reasonable strong evidence of perturbation by POPs at the physiological/molecular level (hormones, enzyme induction, enzyme inhibition) in human populations.
- There is limited evidence of measured health-related effects in Arctic populations (associations are weak or preliminary, but generate concern).
- There are similarities in the findings between animal species (laboratory and field studies) and human populations; the observed effects are stronger in experimental animalsexposed at

5.2 Knowledge gaps and needs

- There are no trend data established for human exposure or body burdens in the Arctic, due to the short period of monitoring to date (1994 to 2000). There are also few available archived Arctic population samples for back analyses. Further, prospective blood monitoring (and of other biological samples as specified in AMAP protocols) and tissue banking are essential to establish these time trends in various Arctic populations. To assess changes in dietary patterns, information needs to be collected by way of a questionnaire and concomitant plasma polyunsaturated fatty acids (PUFA) high concentrations.
- At the population level, there is no established evidence of adverse effects (mortality, morbidity); however, based on all available evidence within and outside the Arctic there is reason for concern and a need to continue to reduce human exposure.
- There is evidence that fear of the effects of POPs (i.e. publicly perceived risk) has lead to reduced intake of traditional foods, which may lead to a reduction in the nutritional, spiritual, social and cultural benefits of these foods.measurements.
- There is still paucity on population health effects data for humans living in the Arctic (reproductive health outcomes, neurobehavioral development, immune system response, hypertension and cardiovascular disease, etc.). It is essential to complete ongoing cohort studies in Quebec, the Faeroe Islands, Greenland and Finland. Meta-analyses of these studies may be possible and would increase the statisticalpower of the findings. Additional studies may be warranted when these are complete.
- There are difficulties scientifically to compare the benefits and risks of consuming a traditional or subsistence diet. It is important to quantify this, as dietary intakes are changing across the Arctic due to social pressures; this perceived threats of contaminants and the availability of store-bought foods.
- Public health information differs in different areas of the Arctic due to different exposures, cultures and public health practices, and is not commonly evaluated for its effectiveness. There is a need for an evaluation of the type, role and impact of public health messages or interventions.
- Little attention is being paid to the collection of blood samples from fasted (versus non-fasted) individuals and the potential for perturbations of circulating POPs levels that complicate comparisons between studies. There is a need to set clear protocols for the collection (and analysis) of human tissue samples to minimize biological and analytical variability.

Even though there have been efforts to evaluate the weight-of-evidence (i.e. from cellular effects, animal experiment to epidemiological outcomes) for effects on human populations exposed to POPs and metals through various AMAP and national activities, there is a need to continue this process and to conduct the relevant research needed to support this approach.

6. EFFECTS OF MERCURY ON ARCTIC WILDLIFE AND HUMANS

6.1 Current knowledge status

Based on today's knowledge it can be concluded that high Hg contamination of the natural diet for Arctic indigenous peoples most likely has a negative influence on their health.

6.2 Knowledge gaps and needs

- Due to official dietary recommendations in order to reduce Hg exposure, traditional dietary habits have change in several circum-Arctic countries causing additional and often unexpected negative effects on public health. Thus, new intervention studies and investigations on nutritional alternatives are urgently needed on Hg contamination consequences for Arctic indigenous peoples.
- The role of Hg depletion during the polar sunrise needs further elucidation. Studies on reaction mechanisms, reaction

products, global atmospheric Hg cycle and atmospheric Hg transport are, thus, of utmost importance for the complete understanding of the ecotoxicological potential of Hg in the Arctic.
- The relative importance of re-emitted Hg to the overall transport and deposition of Hg to the Arctic is still not completely elucidated.
- Substantial lacks in data for temporal trend studies are obvious. Based on the existing data no reliable information on changes in trace metal concentrations for biota and abiota can be extracted.
- Scientific studies related to the spatial circumpolar trend of Hg (also in a global perspective) are important and should be given high priority in national Arctic environmental research programmes.
- The role of biological Hg transport via marine fish species (e.g. salmon) and transfer of the contaminants into food webs needs further and thorough investigations.

7. FUTURE MONITORING AND STUDIES

7.1 Levels and trends

The Arctic is a unique habitat with many extremes in e.g. temperature, light and seasonal food availability. It has very few, local sources of pollution and should be regarded as a pristine area. As such, it serves in itself as a sentinel and "early warning site" for pollution, i.e. the detection of industrial substances in the Arctic is an alarm signal. Substances found in significant amounts in biota in the Arctic can be said to demonstrate persistence, bioaccumulation and long range transport potential, i.e. three of the criteria for candidate POPs according to the Stockholm Convention. The AMAP monitoring programme could therefore be of critical value to the Stockholm Convention in several ways. Firstly, it could be used to identify possible candidate POPs in the Arctic before they are found elsewhere. Secondly, it could be utilized to follow temporal trends in POPs levels and to evaluate the effectiveness of measures taken in accordance with the requirements of the Stockholm Convention.

However, there are some drawbacks in the present AMAP programme that need to be addressed. At the moment the programme is best described as a collection of independent national research data. There is little standardization of sampling and analysis. Another challenge is that different studies often focus on different substances or different congeners, making comparisons difficult. Protocols for sampling and storage of samples need to be established, and there is also a need for intercalibration programs for analyses. Since most present data are related to individual research projects there is also a general lack of metadata, i.e. the circumstances and conditions surrounding measurements. Thus, a comprehensive harmonisation programme from sample handling, storage to analysis and quantification must be established to ensure proper comparability of the results. In addition, tissue or specimen banks need to be established or utilized better where they exist. More long-term consistent monitoring programmes need to be set up.

Analyses are expensive and it is often discussed if a single or a selection of substances can be used as indicator(s) for pollution. However, it is obvious that substances behave differently between species and in different environments, so it is not realistic to believe that a single substance or group of substances could substitute for POPs as a whole. However, there is a move towards measuring a small number of PCB isomers, dioxins/furans and toxaphene. This should be encouraged. It would increase comparison and compatibility if all studies measure the same isomers. In order to set priorities for the future it might be useful to consider the Japanese approach, i.e. to perform broad surveys on a large number of substances in the environment at long intervals, and in between each survey focus on those that appear in concentrations giving rise to concern.

In addition to polybrominated diphenylethers (PBDE), which have been extensively investigated in the Arctic environment in the recent years, a large number of other new contaminants have been identified as relevant contaminants for the Arctic environment. Chemical groups like selected pharmaceuticals, phthalate esters, alkyl phenols, synthetic musks, perfluorinated alkyl derivatives (e.g., Perfluorooctane sulfonate: PFOS), perfluorinated telomer-alcohols and perfluoro carboxylates as well as current used pesticides, alkyltin-derivatives, triaryl phosphates and short- and medium chain chlorinated paraffins are included in this list of priority components for future studies. Several of the substances mentioned above have clear POPs like characteristics, i.e. lipophilic, low vapour pressure, and express persistence and bioaccumulation potential. Others that are more water-soluble exhibit moderate persistence in the environment and/or biota and moderate bioaccumulation, but releases to the environment are substantial as well continuously occuring and, thus, give rise to persistent exposure. Many of the above mentioned compound groups were investigated in the vicinity of settlements and harbours in the circum-Arctic countries. Perfluorinated organic contaminants seem to be of special concern, since surprisingly high levels were determined recently in polar bear livers (Alaska) and ringed seal (Svalbard).

- Protocols for harmonization and standardisation of sampling and storage should be prepared for both abiotic and biotic samples.
- Monitoring and surveillance of contaminants in Arctic regions need better international co-ordination (sites, number and types of analytes, methodology, sampling frequency etc.) and quality assurance in order to gain the best possible information for risk assessments.
- Air samples have been monitored over long time in many locations. Air shows the most rapid response to any changes in emissions and could be used as reference indicator.
- Ice cores can be used to monitor temporal trends and to identify new POPs, as well as other, more water-soluble compounds in an early phase. Ice cores have an excellent geographical coverage in the Arctic, and they give a clean atmospheric signal. The drawback is that there still are problems related to sample volume, resolution and dating.
- Snow can also be used in monitoring programmes, but the variability of snow and the re-volatilisation of lighter components over time complicate analysis.
- Passive sampling devices for the water and gaseous (air) phase offer some opportunity for monitoring and effect studies.
- Stationary species are to be preferred since it is easier to establish links between sources, intake, levels and effects. Good spatial trends have been obtained through Mussel Watch.
- The temporal trend issue is very important and archived material for selected species should preferably be available.
- The selected indicator species should be abundant and circumpolar (Arctic) or otherwise have a wide geographical distribution. The longhorn sculpin was suggested as a suitable indicator fish species in the Arctic. It is found all over the Arctic, is truly circumpolar and also stationary. Available data shows that it accumulates phthalates and other substances.
- The trophic level of indicator species should be known or easily be determined. Arctic data show a good relationship between

PCB concentrations and trophic levels.
- Ratios between compounds/isomers/congeners should be used as indicators/informations of species or sample specific metabolism/transformation capabilities. And signals with may yield more information on sources and origin of the compounds (e.g. new vs. old releases).
- Monitoring of seabird eggs represent many advantages; they are easy to sample, store and process for analysis and they also integrate exposure through the food web.

7.2 Effect studies

A major conclusion from the meeting and discussions was the need for more information on causality between levels and effects of contaminants. In this respect the Arctic fox was suggested as a promising indicator species for future effect studies because

i) the levels of POPs in this species in Svalbard is high (i.e. comparable to those detected in polar bear),
ii) this species exhibit profound seasonal cycles of fattening and emaciation,
iii) the species is numerous in Svalbard and a sufficient number of animals can be killed and
iv) it is possible to perform experimental studies with Arctic fox. Studies with Arctic fox could also strengthen the causality of inferences from other studies with Arctic mammals (e.g. polar bear). It was also concluded that experimental studies on glaucous gull and Arctic char should be continued.

In general, criterias for the selection of indicator species for future ecotoxicological studies should include:

- High levels of persistent organic contaminants and mercury
- Laboratory experiments can be performed easily
- Circumpolar distribution known
- Easy to monitor organisms

7.2.1 Thresholds and sensitivity

There are major species differences in susceptibility to the toxic effects of POPs. Hence, knowledge on dose-response thresholds for different Arctic animals should be available for future risk assessment. In this respect standardized and repeatable sampling protocols should be worked out. Dose-response thresholds must be related to biotic (e.g. ontogeny, sex) and abiotic factors (e.g. season) that might be expected to influence the bioavailability of POPs and mercury toward targets and target sensitivity.

7.2.2 Effect measures

Targets for POPs and mercury toxicity includes a vast number of biochemical, physiological and ecological mechanisms. Effect studies should preferably include several of these at a time, if possible. Targets of importance include:

- mutagenic effects
- oxidative stress
- immunotoxicity
- enzyme induction
- receptor interactions
- endocrine disruption
- development of hormone and immune system
- eggshell thickness

7.2.3 Biomarkers

Having in mind the limitations of biomarker measurements, such tools would still be valuable in the future, not least if these biomarkers are measured together with effect parameters. Such biomarkers may include e.g. cytochrome P450 activities, Vitamin A and thyroid hormone levels.

In addition, genomics (gene induction) and proteomics (protein output) are extremely promising methods for pollutant response screening in the future.

7.3 Risk assessment

Ecological risk assessment of OCs in marine animals in the Arctic would comprise assessments of exposures and effects, and risk characterization. To identify possible effects of OC exposure in free ranging animals in remote areas, two approaches are generally used. The first involves extrapolation and comparison. Possible effects are then determined by comparing levels of OCs in the species of interest to levels known to cause toxic effects in laboratory species or from observations on affected animals in the wild. These types of comparisons have, however, inherent weaknesses. The second approach investigates biological and potential toxic effects by studying biomarkers (indicators of biological responses) to contaminants. Such studies may reveal subtle biological changes/disturbances associated with low concentrations of OCs.

However, the significance of such effects for the health of the individual is often not obvious, and validity of extrapolating between biomarker responses measured in individuals and some higher-level effect at a population level is not easily established. Thus, ecological risk assessment of contaminant exposure in free-ranging species will always be rather difficult without captive studies to demonstrate direct cause and effects.

8. IMPACT OF CLIMATE CHANGE ON POPS IN THE ARCTIC

Short and long term climate changes may influence the levels of POPs in the Arctic but also sources may be affected e.g. river flows may shift as well as ocean currents. In Alaska there are visible changes e.g. the availability of prey has decreased. In this area black guillemots could be used as sentinels. Grey whales and cod are also affected. In Lake Ontario it has been demonstrated that the food webs have shifted but DDT levels stay the same. The impact of climate change on levels on POPs in biota is obvious and, thus, should be clarified.