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Ocean Pathways in the Arctic

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INTRODUCTION

The Arctic Monitoring and Assessment Programme (AMAP), established in 1991, was given the responsibility to monitor the levels and assess the effects of selected anthropogenic pollutants in all compartments of the Arctic. The results from the first phase of AMAP are published in two reports. Firstly, a popular version called «Arctic Pollution Issues: A State of the Arctic Environment Report» and secondly, in the scientific volume: «The AMAP Assessment Report: Arctic Pollution Issues» This presentation summarise some results on transport mechanisms in the ocean as described in the AMAP reports.

The sources of contaminants of interest to AMAP generally lie outside of the Arctic region. Pathways within the three major compartments, the atmosphere, the terrestrial/freshwater and the marine compartments all contribute to the delivery of contaminants to the Arctic. Consequently, an understanding of pollution pathways to- and within- the Arctic are of special concern. The objective of this presentation is to provide a brief summary of the physical processes and pathways, both within and between the main compartments, which determine the fate of contaminants in the Arctic environment as described in chapter 3 of the AMAP Assessment Report (AAR). Special emphasis is given to the conclusions, including lack of knowledge, and recommendations.

RESULTS

Atmospheric pathways are important in the overall context of the delivery of contaminants to the Arctic. Atmospheric winds deliver contaminants to the north. The mean flow in winter is out of Eurasia into the Arctic, and out of the Arctic into North America. In summer, the transport from mid-latitude to the Arctic decreases. Deposition of contaminants occurs when contaminants are incorporated into rain or snow which subsequently falls to the ground, by particle deposition and by gas exchange between atmosphere and ocean's surface.

Atmospheric deposition of contaminants is a major source of many contaminants to the Arctic. Contaminants deposited to the terrestrial/freshwater environment are readily transported to and within the freshwater system. However, even in the largest rivers, flows, sediment and total organic carbon loads, let alone the associated contaminant loads are poorly quantified. Rivers enter the ocean through estuaries and deltas along the coastal zone. The physical, chemical and biological processes in these environments have a major impact on the fate of contaminants carried by river water and river ice. Deltas and estuaries play a major physical role as traps for particulate matter and associated contaminants in river water.

The oceans in the Arctic receive contaminants from air, rivers, mid-latitude oceans and from direct discharge. The fate of these contaminants is determined both by the circulation pattern and the stratification of the ocean waters. The major inflow of ocean water comes from the North Atlantic, but there is also some inflow from the Pacific. The ocean transport of contaminants is slow, taking years to transport waters from industrialised, temperate region to the Arctic Ocean. The residence time in the Arctic Ocean itself, varies from 10 to 300 years, with increasing residence time with increasing depth. The shallow continental shelves are important for the physical transport within the Arctic for two reasons: they are the primary areas of ice formation and ice melt; open water during part of the years allows for direct exchange of contaminants between water and air.

Recent studies indicate that sea ice pays a role in transport and redistribution of contaminants, although little concrete information is available on the quantitative significance of this pathway. The process of retaining particles/contaminants during transport and releasing them at the sea surface far away, makes sea ice a unique transport mechanism. Local and long-range atmospheric sources contribute to the sea ice surface by both wet and dry deposition. Because many dissolved pollutants are excluded with salt during the freezing process, sea ice without incorporated sediments or organic material may be less contaminated than the water from which it was formed. Most particles and associated contaminants are probably released at the sea surface along the marginal ice zone. Because of biological activity in this region, it is possible that contaminants released here enter the food chain. Sea ice transport could provide a link between pollutants source areas and distant wildlife. The biological communities that seem to be most at risk from long-range pollutant transport by sea ice are those along the marginal ice zones, where large amounts of ice melts.

LACK OF KNOWLEDGE

Knowledge of the general ocean circulation and associated transport of contaminants in the Arctic has improved over the past decade. However, there are still a lot of questions that need to be answered to more fully understand the processes of contaminant transport in sea water under Arctic conditions. Some of these questions are:

- how much water is exchanged between the different seas and how does the residence time for contaminants vary?
- how does variability in river discharge influence ocean circulation and how important is redistributed river water in long-range contaminant transport?
- how are contaminants transported from surface water and coastal zones to the deeper part of the ocean?

- how important is sea ice in the transport of contaminants and what are the most important processes for retaining and releasing contaminants during transport

CONCLUSIONS

A number of steps are required to better understand the pathways of contaminants into and within the Arctic. The following general conclusions are relevant to all compartments:

i) Tracers are important in determining and confirming pathways. To date these have been used in the atmospheric and ocean pathway studies, but greater use needs to be made of natural and anthropogenic tracers in all compartments. Emphasis should be placed on tracers that mimic the major contaminants or are representative of groups of contaminants thereby enhancing pathway studies.

ii) The understanding of Arctic processes and the ability to quantify them is inadequate. In particular, it is essential that transport processes and their relative importance or magnitude within and between compartments be determined.

iii) The transformation and fate of different contaminants or groups of contaminants under varying Arctic conditions is not well understood. While a considerable amount of information is available on this subject for many of the contaminants under temperate conditions, there is still little or no understanding as to how, for example, the factors of temperature and light affect the rate of these processes. In order to be able to fully assess the magnitude and direction of pathways, a better understanding of transformation and fate of pollutants in the Arctic is required.

iv) Despite the fact that ice is a dominant multi-compartment medium of the Arctic, the role of ice in modulating contaminant fate and controlling pathways is poorly understood.

v) There is ample evidence of the limited effectiveness of sporadic and poorly integrated process, pathway and flux studies. Through the use of multi-media models, a great deal can be achieved efficiently by integrating processes and observations. Models are also essential in assessing the sensitivity of individual linked processes, which in turn can be instructive in assigning priorities to often complex questions.