MONITORING CONTAMINANTS IN THE NORTHERN SEAS: RECOMENDATIONS AND PROCEDURES

(Results of the Transport and Effects Programme Final Workshop, 22-25 March 2004)

Table of contents

1 EXECUTIVE SUMMARY

This report presents recommendations and procedures for monitoring contaminants in the Barents Sea. Monitoring of contaminants will be an part of an overall Norwegian management plan for the Barents Sea. Participants of a workshop, held 22-25 March 2004 at the Polar Environmental Centre in Tromsø, developed a series of recommendations for monitoring of persistent organic pollutants and mercury, radionuclides, and modeling.

Persistent Organic Pollutants and Mercury

Persistence, bioaccumulation, potential for long-range environmental transport, and adverse effects are the key criteria used to establish recommendations and select compound, species, organs etc. This is in accordance with the Arctic Monitoring and Assessment Programme (AMAP) and the Stockholm Convention. Sampling and analytical procedure are based on JAMP protocols. The most important compounds identified are: 10 AMAP PCBs, HCH (α-, β- and γ-isomers), DDT ,DDE ,DDD (6 isomers), HCB, 7 Chlordanes, incl. metabolites (Oxy-CD, cis-Hept.chloroepoxide), PBDEs (47, 99, 100, 153), 30 AMAP PCBs, Chlorobornanes (26, 50), and PAH-metabolites (OH-pyrene). For pure time trend analysis, the use of biota may be sufficient in order to find increasing or decreasing tendencies/slopes. However, in order to understand the mechanism for why high levels are present in specific species, monitoring of levels in both abiota (air, sea-water, ice, sediment) and lower trophic levels of the food-chain are recommended.

For screening purposes, the following are recommended:
PAH-metabolites (OH-pyrene), PBDE 209, SCCP/MCCP, Cyclic polysiloxanes, Dicofol, OH-PBDE metabolites, PCB-metabolites (OH-PCB, -MeSO3), PF-sulfonates (incl. PFOS), PF-carboxylic acids, PF-sulfoamides, Endosulfan, PCN, Co-planar PCBs, PCDD/F, HBCD, TeBBPA, and Oil PAH (16 comp. + NPD).

Radionuclides

There is a need for the documentation of distributions, levels and trends of radioactive contamination in both the abiotic and biotic components of the Barents Sea. This is coupled to a need for strong emergency preparedness so that the impacts of sudden accidents or events on the radiological state of the Barents Sea can be assessed and reported expeditiously. The relevant importance of individual nuclides is a function of the changing nature of source terms for radioactive contamination. However in general, the priority radionuclides are $^{238/239/240}$Pu, ^{241}Am, ^{210}Pb/^{210}Po, radium isotopes, ^{241}Pu, ^{90}Sr , ^{99}Tc, ^{129}I, ^{137}Cs,^{60} Co. Important species commercially and for local populations, in particular, fish species (e.g. cod / saithe/ haddock / capelin) are the highest priority. In addition species that concentrate radionuclides from their environments provide useful indicators of levels of radioactive contamination. Of these, seaweeds are the most widely used.

With respect to screening, the type of site will determine to a large extent which sample types and radionuclides are relevant. However in most cases gamma spectrometry is the analytical method that most often will be used for screening purposes.

Modeling

Integrating modeling into a monitoring programme will provide the opportunity to identify sources and routes of contaminant transport, fill in the sampling programme geographically and temporally, include a bigger part of the ecosystem than is possible by sampling, form the basis to calculate exposure and/or explain effects, contribute to improving the monitoring programme through finding the optimal positioning for sampling stations and the most adequate species/media, and provide day-to-day views of the current physical and biochemical state of the region. In addition, the routine collection of data within a monitoring programme will greatly assist in the continued evolution of modeling tools for contaminant transport.

Sampling Strategy

For the sampling strategy, a plan with 10 stations was presented, taking into consideration the main transport routes in/out of the Barents Sea. The plan includes a combination of fixed and dynamic stations in order to capture important boundary areas including the marginal ice zone, Polar Front, and Central Barents Sea. Sampling of air, ice, water, sediment and biota is necessary to capture important interfaces especially air exchange across the sea surface.

Joint activities

The integration of activities into a single monitoring programme covering both radionuclides and POPs was not recommended by the radioactivity subgroup. However, it would be an advantage to have a closer cooperation between POPs and radioactivity monitoring activities in the Barents Sea. It is recommended that a separate meeting be organized to discuss how such a cooperation may be formulated and conducted.

2 INTRODUCTION

A variety of contaminants are detected in the Northern Seas. Long-range transport of contaminants from hemispheric to global scales has been identified as a key process leading to increased concentrations of anthropogenic hazardous chemicals in the northern polar region. Local sources also contribute to the build-up of contaminants in these areas. The widespread distribution of persistent organic contaminants, heavy metals, acidifying gases and radionuclides has been clearly documented in the region (AMAP1997[1], 2002[2,3] and 2004[4]). The Barents Sea is unique relative to other areas of the Arctic due to the large number of actual and potential sources of radioactive contamination located in the region. In the case of certain persistent organic pollutants, low temperatures facilitate the exchange of atmospheric pollutants into the marine environment, resulting in contaminant levels that are higher than in the source regions.

Furthermore, the unique features of high latitude ecosystems may lead to increased vulnerability for organisms from contaminants. These include the seasonal and spatial focus of primary productivity, relatively simple food web structure, strong benthic-pelagic coupling, a prevalence of large mammals as top predators and relatively high lipid contents in some species. Biological, chemical and ecological factors influence to varying degrees the trophic transfer of contaminants through marine food webs.

The Barents Sea is economically important for a number of reasons. It is an important area for harvesting of commercial fish species as well as fish farming in coastal communities along the margins of the Barents Sea. The productivity of the area also gives rise to a high biodiversity and rich populations of e.g. sea birds. Oil and gas exploration and production are underway. Maritime traffic in the region is important as well. At the same time there are many tourism-related activities connected to the region. The Seas surrounding the Barents Sea region are marine transport pathways for the supply of contaminants to the Barents Sea.

Monitoring of contaminants will be an important part of the management plan for the Barents Sea, which is now under development by the Norwegian government and aims at balancing economic growth with environmental protection[5]. Monitoring is necessary to ensure that environmental protection policies achieve their stated goals. Data acquired through monitoring provides knowledge of changes to the environment over time and is essential to evaluate risks to organisms and humans. Monitoring of contaminants is also important for development and verification of international treaties and protocols that regulate emissions, like the Stockholm convention, the Aarhus protocols and OSPAR.

This report presents recommendations and procedures for monitoring contaminants with focus on the Barents Sea in support of the establishment of contaminant monitoring programmes for the region. The recommendations include substances, species/media, frequencies and methods, to the degree that is known, and to the extent that they can form the basis for routine monitoring. The recommendations specify substances requiring repeated sampling at regular intervals and screening or baseline investigation.

3 BACKGROUND

3.1 The Transport and Effects Programme

The monitoring recommendations presented in this report were developed during a workshop convened in 2004 (March 22-25), marking the completion of the programme 'Transport and Fate of Contaminants in the Northern Seas (T&E).' The programme was initiated in 2000 by the Norwegian Polar Institute in collaboration with other agencies with financing from the Norwegian Ministry of Foreign Affairs and Ministry of Environment. The programme objectives were:

1. State of the environment:
   Assess the short and long term transport of contaminants to the northern seas and their effects on the environment
2. Monitoring:
   Establish the knowledge base necessary for developing a long term monitoring and assessment programme for contaminants

Numerous reports and peer-review publications documenting the activities and accomplishments of the T&E Programme have been published and can be found at http://npolar.no/transeff/ .

3.2 Objectives

The objective of this project was to give scientific recommendations about monitoring of Persistent Organic Pollutants (POPs), mercury and radionuclides. Heavy metals had not been focused in T&E and was therefore not considered in detail.

The elaboration of future Norwegian monitoring programmes for contaminants will be the responsibility of several ministries. At the moment, it seems most likely that the management plan for the Barents Sea will be the first opportunity to propose an integrated monitoring plan for the region. This work will probably be undertaken in 2005. One intention of this report is to form a scientific basis for the elaboration of contaminants as part of this plan.

At the international stage, the Arctic Monitoring and Assessment Programme (AMAP) has been important for giving recommendations on monitoring of contaminants in the Arctic region. The recommendations given after phase 1 are extensive and have therefore been difficult to follow up for member countries[6]. AMAP has now has resumed phase 2, providing a better basis for revising earlier recommendations. The T&E-programme therefore collaborated with AMAP in order that the T&E-programme recommendations benefit the future work in AMAP and its member countries.

Improved monitoring is also relevant for the work of the bilateral Norwegian-Russian co-operation programme on environmental issues and the Joint Assessment and Monitoring programme (JAMP) of the OSPAR convention.

3.3 Region of focus

The T&E Programme had a geographic focus on the "Northern Seas". In practice, the focus area was the Barents Sea, the Kara Sea and marine areas surrounding Svalbard, though studies especialy of transport processes included the whole Northern Atlantic Ocean and Polar Basin.

The managemant plan for the Barents Sea has a geographic focus as shown in Figure 1. This extends from the North and West of Svalbard to Lofoten and eastwards to the Kola Coast and the western parts of the Barents Sea. It includes the Barents Sea commercial fishing area, the polar front and the highly productive marginal ice zone.

The T&E Programme had a close collaboration with Russian institutions. Since it is desirable to harmonize Russian and Norwegian monitoring of the Barents Sea, it was decided to include the whole Barents Sea in this final project from the programme.

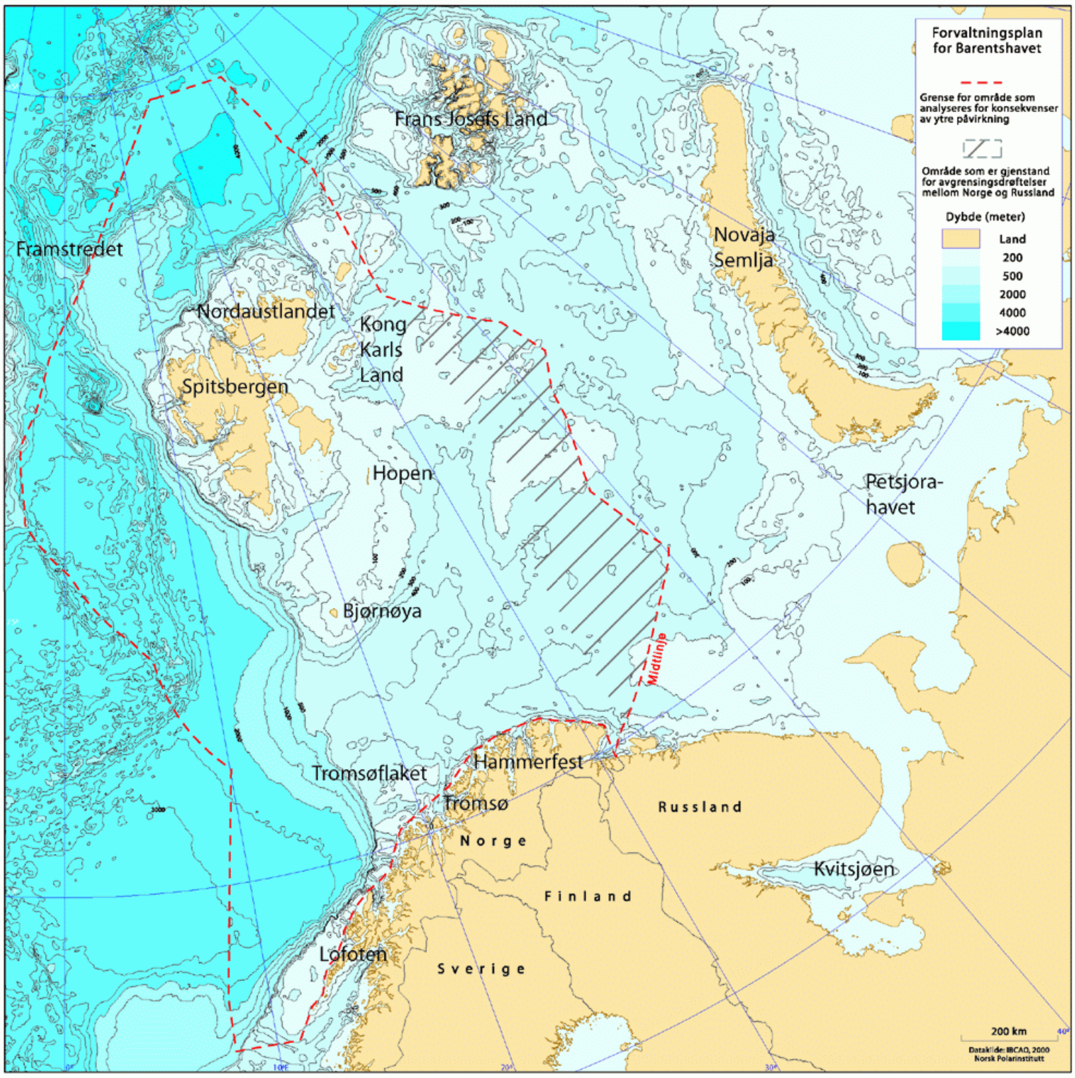

Figure 1: The Barents Sea. The red line shows the influence area used in the strategic environmental assessments in the management plan.

3.4 The workshop

3.4.1 Organisation

The T&E Programme decided to run a workshop in order to develop the recommendations. The workshop was organised and facilitated by Akvaplan-niva AS. Invitation was distributed to individual scientists and institutions in Norway and internationally through AMAP's national experts. The programme and participants of the workshop are listed in appendix 1 and 2.

During the workshop, experts were brought together for information exchange and synthesis of results into a monitoring framework for contaminants in the northern areas. After an initial joint session with presentations, the work proceeded mostly in three separate working groups: POP's and mercury, radionuclides and models. This report represents the final version of a draft report that was prepared by the subgroup leaders at the conclusion of the workshop. The report was distributed to all workshop participants for comment. Workshop leaders were:

- JoLynn Carroll, Akvaplan-niva AS (overall workshop coordinator, Modeling subgroup leader)
- Arntraut Götsch, Akvaplan-niva AS (assistant to the coordinator, assistant to Modeling subgroup leader)
- Roland Kallenborn, Norwegian Institute for Air Research, Kjellar (POPs subgroup leader)
- Eldbørg Sofie Heimstad, Norwegian Institute for Air Research, Tromsø (assistant to POPs subgroup leader)
- Anne-Liv Rudjord, Norwegian Radiation Protection Authority, Østerås (Radioactivity subgroup leader
- Mark Dowdall, Norwegian Radiation Protection Authority, Tromsø (assistant to Radioactivity subgroup leader)
- Gunnar Sander, Norwegian Polar Institute and project leader from the T&E programme.

3.4.2 Background information

In addition to the results of the T&E Programme, workshop participants relied on other sources of information in developing the monitoring recommendations. The "AMAP Trends and Effects Programme 1998 – 2003" and results from AMAP's phase 2 (AMAP 2004[4]) were key sources of information. The Canadian "Northern Contaminants Programme" also has important results and recommendations on methods, as well as JAMP within the OSPAR convention.

The recommendations from the project should meet the needs for:

- Trend monitoring of "old" substances
  Especially from The Stockholm Convention[7], the Aarhus protocols[8] (POPs) and the OSPAR Convention[9].
- Screening of "new" substances:
  The Norwegian State Pollution Control Authority (SFT) contributed with two lists of current substances for screening from OSPAR and the EU's water Framework Directive (WFD)[10].
- Sources, routes of transport and distribution in the ecosystem.

- Potential sources, and their routes of transport and distribution in the ecosystem (mainly relevant for radionuclides)

Together, these sources of information provided the necessary background knowledge for the development of recommendations. Workshop participants were provided overviews of these information sources through presentations during the initial day of the workshop and through the distribution of relevant documents (appendix 3).

3.5 Existing and future monitoring of the Barents Sea

There are several ongoing monitoring activities of contaminants in the Norwegian part of the Barents Sea:

- Radioactivity monitoring in the marine environment.
  This has been run by Norwegian Radiation Protection Authority (NRPA) since 1999 and has been financed by various ministries. It links sources and levels in the marine environment (water, sediments, seaweed, fish and seafood). Models are used with dose calculations for humans.
- Pollution in the Barents Sea
  Run by Ministry of Fisheries and IMR since 2003. Future plans are for sampling every third year. Samples are taken of fish and sediments, which are analyzed for POP's, Heavy metals and radioactivity.
- Monitoring of fish and seafood
  Samples are taken of fish and seafood in order to document consumer quality (IFES). Analyzes of POP's, metals and radioactivity.
- JAMP
  Responsible: Ministry of Environment/SFT with NIVA as operator. Run since 1994 (Barents sea) and 2002 (Russia – Kola coast). Coastal monitoring of selected heavy metals and POP's
- Norwegian Polar Institute
  The institute has a focus on POP's mainly in top predators. Mostly research and screening activities, but also several time trends
- Environmental monitoring of petroleum activities
  This is imposed on the petroleum companies by SFT and is run by several consultants. It deals with hydrocarbons in sediments and the water column. Within the whole Norwegian sector, this is the biggest contaminant monitoring programme.

In his initial overview, Gunnar Sander from the T&E Programme, characterized these programmes as fragmented; Different authorities have different programmes with different foci. As a result, there is not a coherent ecosystem approach or integrated assessment of the results. There is also little institutionalized collaboration between the different programmes, probably leading to lower cost-effectiveness than possible. The question therefore was raised whether there should be one joint monitoring programme for contaminants.

Comparing the programmes for the different groups of contaminants, radioactivity has probably the only coherent programme which in many aspects can serve as a model for monitoring of other substances. POP's and Heavy Metals have up to now mostly been the subject of research, with sparse monitoring and a general lack of time trends. Models have not been developed sufficiently and are not linked to the monitoring activities, as is the case for the radioactivity programme.

In the future, the Barents Sea management plan will conclude with environmental quality objectives, probably a framework for economic activities – and monitoring to ensure that the goals are being achieved. The plan has a holistic approach, assessing all types of environmental pressures on the Barents Sea (Figure 2). It is therefore likely that there will be several sectoral monitoring programmes that will be integrated in order to make better use of resources and accomplish joint evaluation of the state of the environment compared to environmental quality objectives. The work will conclude in 2006.

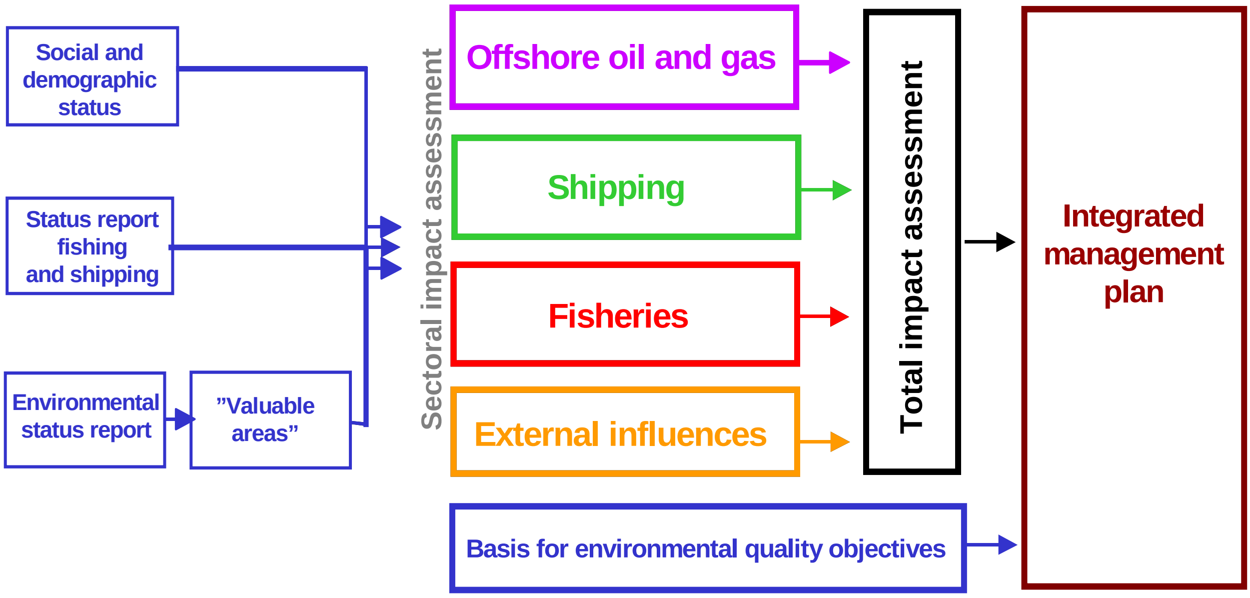

Figure 2: The process leading to the Barents Sea management plan.

3.6 Monitoring, screening and research

Effective environmental monitoring must be built upon solid research. It is from research that we can learn about what is most relevant for monitoring, for example when we want indicator organisms to give us a picture of what happens in the ecosystem as a whole. Research is also the key to find out the correct procedures for conducting monitoring. Finally we need research to interpret and clarify environmental data obtained in monitoring programmes. Therefore it is important that research is integrated together with any monitoring programme (Figure 3).

Figure 3: Environmental monitoring and research should go hand in hand (Drawing from Naturvårdsverket, Sweden)

On the other and, it is also necessary to distinguish between monitoring and research. A definition of monitoring, used by the Norwegian environmental agencies, is:

“Environmental monitoring is systematic sampling of environmental data that is repeated regularly with established methods. It includes evaluation/assessment and reporting of the data to document the state of the environment and environmental change (trends) in time and space in order to differentiate between anthropogenic influence (threats) or to document natural changes.“

Assessments based on monitoring will typically be linked to management systems, leading to recommendations on actions if the documented environmental quality does not meet accepted standards.

In the discussions at the workshop, it proved to be fruitful to distinguish between:

- **Trend monitoring** –
  Documentation of levels of known substances (already in international treaties) with established methods. This is relatively easy to distinguish from research. In order to achieve cost-effective answers, explicit needs for power should be defined, based on statistical analysis of variance in the samples.
- **Screening** should be a part of monitoring programmes. Mostly, screening is perceived as analyzes of new chemicals. However, it can also include analyzes of known substances in new media or new regions, or exploration of a specific problem (approach used by SFT). Screening has stronger elements of research.
- **Research** includes all kinds of activities basically driven by the purpose of achieving new knowledge, e.g. about effects of contaminants.

4 RECOMMENDATIONS ON MONITORING OF POPs AND MERCURY

Participants:
Eldbjørg Sofie Heimstad (Group Leader), Anita Evenset, Tatiana Savinova, Janneche Utne Skåre, Amund Måge, Roland Kallenborn, Anders Ruus, Geir Wing Gabrielsen, Bjørn Munro Jensen, Derek Muir, Frank Farsø Riget , Jon Fuglestad and Gunnar Sander.

4.1 Introduction

The work in the Transport and Effects Programme (T&E) phase 2 concluded with recommendations on POPs monitoring for three top predators[11] and the monitoring of the abiotic environment for both radionuclides and POPs[12]. There is also a method report from T&E phase 1 available with an overview on existing recommendations for monitoring of all types of contaminants in the marine environment in the Arctic[13].

4.2 Recommendations on monitoring

Why do we need to monitor POPs and Mercury in the Barents Sea?
The Barents Sea region is a commercial and economically important area, both in terms of national and international interests of fisheries and oil exploration. Fish resources or fish populations at present are not necessarily at risk. However safety guidelines on food consumption exist due to the presence of co-planar PCBs in cod liver and gull eggs. The health of the ecosystem is therefore an important aspect for future monitoring and management of the Northern Seas ecosystem. In addition, adverse effects on some highly exposed (e.g. polar bear and glaucous gull) or sensitive species have been observed, and several completed studies report the types of effects that have been associated in non-Arctic species with chronic exposure to POPs.

What is unique about the Barents Sea compared to other regions of the Arctic with respect to POPs?
Generally, levels of POPs are higher in top predators from the Barents Sea than in the same species from the Canadian Arctic. Lower in the food chain, e.g. in zooplankton, fish and ice-fauna, levels seem to be comparable within the two regions. Thus, the high levels in top-predators cannot be explained by a higher input to the base of the food chain. However, the food-web structure may differ between the Norwegian and the Canadian Arctic, but no conclusions about this can be drawn based on the current knowledge. The reason for the higher levels in top predators in the Barents Sea region therefore is an obvious knowledge gap.

What should this region-specific monitoring programme necessarily include as a result of its unique characteristics?
A monitoring programme for POPs and Mercury should include matrices and animals that are relevant for the Barents Sea ecosystem. The selection of species therefore should include key species for the Barents Sea ecosystem. Due to the large commercial interest in the Barents Sea fisheries, some commercially important species should also be included. Animals at risk (high levels of contaminants), is another criteria for inclusion. In order to do a risk evaluation of the ecosystem it is necessary to monitor both abiotic and biotic components.

What are the most important constituents to monitor?

The Stockholm Convention criteria were used for identification and selection of constituents (Table 1). Among these four criteria, the susceptibility of constituents for long range transport by air and sea currents was considered to be the most important property for the prevalence in the Barents Sea region. The persistence and lipophilic properties of the compounds are the second most important criteria when potential hazard to the ecosystem is assessed. Adverse effects were considered to be the less important of the criteria. One reason is that chemicals with the three other criteria are likely to result in effects to organisms.

In addition to the Stockholm Convention criteria, the results from AMAP were also important in selecting contaminants. The AMAP results give valuable information on what compounds predominate in the Arctic marine environment and their likely effects on Arctic species. Due to their widespread occurrence in the Artic, HCHs were included on the prioritised list, even though they are not included in the Stockholm Convention. Recent research has shown that levels of brominated flame retardants are increasing in arctic areas, and Polybrominated diphenyl ethers therefore were also considered to be important to monitor (not included in Stockholm Covention).

The Stockholm convention and the Aarhus protocols have selected a suite of legacy compounds (essentially “the dirty dozen”). Given the objective of monitoring the effects of implementing international conventions, a natural choice would be to include these constituents in Arctic trend monitoring of contaminants. However, some of these compounds occur in relatively low concentrations in the Arctic marine environment and were therefore not included among the prioritised chemicals. In addition, the analytical costs for some of the compounds on the Stockholm list are very high (e.g. dioxins and furans). These compounds were therefore only included in the screening programme.

Chemical identity	Structure, including specification of isomers where applicable, and the structure of the chemical class
Persistence	1. The half-life of the chemical in water is greater than two months, or the half-life in soil is greater than six months, or the half-life in sediment is greater than six months. 2. Other evidence that the chemical is sufficiently persistent to justify its consideration.
Bioaccumulation	1. Evidence that the bioconcentration factor or bioaccumulation factor in aquatic species is greater than 5000. 2. The logarithm of the octanol-water partition coefficient (log K_{OW}) is greater than 5. 3. Evidence that a chemical presents other reasons for concern, such as high bioaccumulation in other species, high toxicity or ecotoxicity. 4. Monitoring data in biota indicating that the bioaccumulation potential of the chemical is sufficient to justify its consideration.
Potential for long-range environmental transport	1. Measured levels of the chemical in locations distant from the sources of its release that are of potential concern. 2. Monitoring data showing that long-range environmental transport of the chemical, with the potential for transfer to a receiving environment, may have occurred via air, water, or migratory species. 3. Environmental fate properties and/or model results that demonstrate that the chemical has a potential for long-range environmental transport through air, water or migratory species. 4. The half-life in air is greater than two days.
Adverse effects	1. Evidence of adverse effects to human health or to the environment that justifies consideration. 2. Toxicity or ecotoxicity data that indicate the potential for damage to human health or to the environment.

Figure 4: Criteria for identifying “new” POPs under the Stockholm Convention

Metals were not a main issue for the workshop, but the group agreed that it is important to include some metals in a monitoring program for the Barents Sea region. First of all it is important to monitor levels of mercury and the bioavailable form of mercury (methyl-mercury, Me-Hg). Mercury is removed from the atmosphere and deposits in snow in a form that can become bioavailable. This process is linked to polar sunrise, and is unique to high latitude areas. The resulting enhanced deposition may mean that the arctic plays a previously unrecognised role as an important sink in the global mercury cycle. The fate of these deposits is, to a large degree, unknown. (AMAP 2002).

It was also considered important to include cadmium (Cd) and lead (Pb) on the list of prioritised compounds. The deposition of Pb has declined in Arctic areas since the ban of leaded gasoline was enforced. However, levels in fish and wildlife have not measurably declined, likely reflecting continuous uptake from the large reservoir of Pb deposited in soils and sediments. Cadmium levels in some seabird species are high enough to cause kidney damage, but the monitoring data have so far not provided conclusive evidence of trends or effects. Multi-element analyses of metals will provide levels of up to 30 metals for the same price as analyses of only a few metals. Cd and Pb are included in this multi-elemental analysis package, while the quantification of Hg and Me-Hg requires a separate analytical process.

The 9 compounds/compound groups shown in Table 2 were selected for monitoring of biota, and the 10 compounds/compound groups shown in Table 3 for monitoring of abiotic samples. The compounds were prioritized from 1 to 3, where 1 is the highest priority and 3 the lowest.

The cost of sample analysis includes two components- sample preparation (e.g. purification, dilution) and the actual analysis using the appropriate instrument (e.g. gas chromatograph, mass spectrometer). Because samples within the same analytical group (A or B) undergo a similar sample preparation procedure, the per sample cost (sample preparation + analysis) is reduced when obtaining results for chemical constituents within the same category as compared to obtaining results for constituents from a different category.

Table 2. Compounds/compound groups recommended for monitoring of biota.

Priority	Compound	Analytical group
1	10 AMAP PCBs (PCB 7 + non-ortho PCBs)	A
1	HCH (α, β, γ)	A
1	DDT, DDE, DDD (6 isomers)	A
1	HCB	A
1	7 Chlordanes, incl. metabolites (Oxy-CD, cis-Hept.chloroepoxide)	A
1	PBDE: 47, 99, 100, 153	A
2	30 AMAP PCB	A
2	Chlorobornanes 26, 50	B
2	Hg	E
2	Me-Hg	F

2	Metals - multi-elements (30 - including Cd and Pb)	G
3	PAH-metabolites (OH-pyrene)	C

Table 3. Compounds/compound groups recommended for monitoring of abiotic samples.

Priority	Compound	Analytical group
1	30 AMAP PCBs	A
A	HCH (a, b, g-)	A
1	DDT ,DDE ,DDD	A
1	Chlorobenzenes	A
1	7 Chlordanes, incl. metabolites (Oxy-CD, cis-Hept.chloroepoxide)	A
2	Chlorobornanes multipl. Comp.	B
2	PBDE: multipl. Comp.	A
2	Hg	E
2	Me-Hg	F
2	Metals - multi-elements (30)	G
3	Oil PAH (16 comp. + NPD)	C

Due to differences in physical-chemical properties such as vapour pressure, water solubility etc., compounds that predominate in abiotic media do not necessarily predominate in biotic media. The heavier (higher halogenated) and more lipophilic compounds predominate in biotic matrices, whereas more water-soluble compounds are found in water. The constituents chosen for monitoring of biota and abiota in table 2 and 3 reflect these differences in chemical behaviour.

What media (abiotic and biotic) are the most important to monitor?

For pure time trend analysis, the use of biota may be sufficient in order to find increasing or decreasing tendencies/slopes. Levels are higher in biota and it may therefore be easier to detect changes from an analytical point of view. The presence of higher levels in biota compared to abiotic compartments may also be seen in relation to ecosystem health, risk evaluations of hazards and public awareness. Another point that underlines the importance of using biota in trend monitoring, is the fact that three of the four criteria in the Stockholm Convention (i.e. persistence, bioaccumulation and potential for long-range transport) are fulfilled if a compound is found in higher Arctic biota. These are the reasons why monitoring in higher biota was given the highest priority. However, in order to understand the mechanisms for why high levels are present in specific species, there is a need for knowledge about levels both in lower trophic levels of the food chain and in abiota (sea-water, ice, sediments). Such data are also needed for validation of refined models of bioaccumulation, which may be important future tools for risk assessment of ecosystem health.

Recommendations on species for monitoring of biota are given in Table 4.

The most important criteria for choosing species and organs for monitoring are:

- Representative species for the area
- Species with lowest possible variance; i.e. predominately located in the area and non-diverse food items for easier detecting trends.
- Prioritized species within the AMAP programme and subsequent data (levels and effects) back in time, for instance Ringed Seal.
- Easy to catch and sample

As the first priority for monitoring of biota, the group recommended ***guillemot eggs.*** Seabird eggs are a simple detector in biota for tracing levels in biological media; they are easy to sample, store and process for analysis, have low variance and integrate exposure through the food web.

The second priority was given to ***blubber from ringed seal***. The ringed seal, which is the most important food item for polar bears in the Barents Sea, feeds on both pelagic and benthic species. The polar cod is the most important food item for the ringed seal.

In order to have data to illustrate biomagnification of POPs through the food chain, the group recommended including ***Arctic cod*** and ***Atlantic cod*** as key species from the Barents Sea food chain.

In addition, the group agreed that it will be important to continue to monitor levels in ***polar bears***, since very high levels already have been measured in this species. There are also strong indications that the high POP-levels in polar bears have caused negative effects on i.e. immune function, hormone levels and reproduction.

The kittiwake (***kittiwake eggs***) was the last organism that was prioritised. This gull species mainly feed in the pelagic food chain in the Barents Sea. Non-breeders and immature birds spend most of their time at sea, while mature birds stay close to the breeding areas during summer. The kittiwakes are not true migrants, but disperse widely over the North-Atlantic outside the breeding season. The POP-burden in the kittiwakes will therefore reflect levels in the pelagic food webs from the areas that are visited by this species.

Table 4. Recommendations for monitoring of biota (the 5 highest prioritized organisms).

Priority	**Species**	**Compartment**
1	Black guillemot	Eggs
2	Ringed seal	Blubber
3a	Arctic cod	Whole fish
3b	Atlantic cod	Liver, filet (Me-Hg)
4	Polar bear	Blood
5	Kittiwake	Eggs

Table 5 gives a summary of the compounds and species that were considered in the discussion for monitoring of biota. The final recommendations from the group (summarised in table 4) are also included.

When it comes to abiotic media, it may be possible to monitor levels in water (particulate and dissolved phase), ice and/or sediments. Monitoring of air and precipitation would give a good indication on supply and maybe also sources, but this kind of monitoring should be covered through a different monitoring program. Generally, levels of POPs are several orders of magnitude lower in water and ice than in biota. In sediment, higher levels are usually found. ***Sediment*** is easily collected and allows for repeated sampling by returning to the same geographic location year after year. Some compounds may be feasible to monitor in water. This goes for compounds like e.g. HCH, which has relatively high water solubility. Information about levels in ***water*** is important in studies of bioconcentration and bioaccumulation and may also be a valuable link between modelling of contaminant spread and levels in organisms. Due to the low levels in water of the more lipophilic POPs (e.g. PCBs, PBDEs etc.), monitoring of these compounds in water is considered to be difficult. High water volumes need to be samples in order to be able to quantify POPs. The water measurements that have been carried out so far, have given very diverging results. Therefore, more research needs to be carried out before seawater is included in monitoring programs.

The group wanted to underline the importance of building up a ***specimen bank*** for both biological tissues and abiotic samples (especially sediment). Samples from a storage bank can be used in retrospective analyses to establish time trends. This is especially important when new compounds are discovered.

Table 5. Compounds and species that were considered for monitoring of biota.

group	priority	Time period			Jun/ Aug			Sep/ Nov										May/ Jun		Apr/ May	Apr/ May	Apr/ May
		sampling interval			**Yearly**			**Yearly**				**yearly**						**Yearly**		**Yearly**		
				25 ind.	5 sampl *5 ind			25 ind										5 samp. * 5 Ind.	5 samp. * 5 Ind.	female with cubs		
		Priority (Top 5)			**3a**			**3b**				**2**						**1**	**5**	**4**		
		Compounds POP	**Zoopl. *C. hyperb.***	**Mus-sels**	**Arctic Cod**	**Atl. Cod**			**Harp Seal**			**Ringed seal**			**Beluga**		**Minke Whale**		**B. Guille-mot**	**Kitti-wake**	**Polar bears**	
			pooled	pooled	pooled	Filet	bile	Liver	Blubber	liver	blood	Blubber	liver	blood	Blood	blubber	blubber	muscle	eggs	eggs	blood	adipose tissue	hair (fur)
a	1	10 AMAP PCBs	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
a	1	HCH (α, β, γ-)	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
a	1	DDT ,DDE ,DDD (6 isomers)	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
a	1	HCB	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
a	1	7 Chlordanes, incl. metabolites	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
		(Oxy-CD, cis-Hept.chloroepoxide)																					
a	1	PBDE: 47, 99, 100, 153	x	x	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
a	2	30 AMAP PCB	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
b	2	Chlorobornanes 26, 50	x	X	x	x		x	x	x	x	x	x	x	x	x	X	x	x	x	x	x	
	3	PAH-metabolites (HO-pyrene)					x																
		Priority Metals				**3b**		**3b**					**2**										**4**
e	2	Hg	x	X	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
f	2	Me-Hg	x	X	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
e	2	Multi-elements (30)	x	X	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Co-operative programs	Industry	JAMP	AMAP	HI						AMAP			AMAP				AMAP	AMAP			

What interval of time between sampling is appropriate to properly identify significant changes over time for purposes of detecting trends and early-warning? What is the justification for increasing the sampling frequency?

Monitoring of the temporal trends of contaminants is an essential component of any scientific and regulatory program which is concerned with the effects of pollution on wildlife and human health. Time-series studies provide necessary information for contaminant risk assessments and also allow measurement of the success of any regulatory action to reduce emissions. An important consideration in temporal trend monitoring is ***statistical power***, defined as the probability that the data set of interest is sufficiently sensitive to detect a change or trend of a specified magnitude. Obviously, for any given data set, power should be as high as possible so that the probability of a false negative result (e.g. concluding no trend when a trend is occurring) is as low as possible.

For monitoring of legacy compounds with usually small annual changes in concentrations, annual sampling is recommended. However, statistical power is also influenced by sample size collected each year, the number of years of sampling, between-year variability in contaminant concentrations, and the characteristics of the statistical test being applied. Bignert et al. (2004)[15] evaluated the power of time-series of mercury data available in the Arctic Monitoring and Assessment Program (AMAP). In general, the investigated time-series were too short to possess an acceptable statistical power (in average, 17 years of sampling was required). Similar results have been obtained in other contaminant monitoring programs carried out in the Baltic (Bignert et al. 1997[16]), ICES CMP data series (Fryer and Nicholson 1993[17]). This illustrates the need to optimize the monitoring strategies in order to reach conclusions on trends within acceptable limits of time and economy. Careful analyses of the data are needed in order to elucidate the underlying reasons for variability which reduces power. The variance can then be reduced by standardization of the sampling, e.g. by using individuals of the same age, sex, condition etc. (see Henriksen et al. 2001)[1].

In some cases a lower frequency is appropriate to reflect tendencies. A good example is the detected increasing trend of PBDEs in biota (mothers' milk) seen during the last 10 years. As was seen for PBDE, it can be sufficient to sample less frequently for new emerging compounds with a strong increase for early warning purposes. Also in cases were the variance of the dataset is small, a lower frequency may be sufficient to detect time trends.

4.3 Recommendations on screening

What are the most important constituents to screen?

The Stockholm Convention criteria (Table 1) in addition to the findings of AMAP (AMAP, 2004[4]) on new potential POPs in the Arctic have been used for recommending some constituents into a screening program. In addition, screening will be used to create linkage to effects in the sense that some of the hydroxylated metabolites of PAHs, PCBs and PBDEs are known endocrine disruptors from *in vitro* effect studies. Further, we have chosen to put environmental low-level co-planar PCBs and dioxins/furans in the screening category since

---

[1] Henriksen, E.O., Derocher, A.E., Gabrielsen, G.W., Skaare, J.U., and Wiig, Ø. 2001. Monitoring PCBs in polar bears lessons learned from recent data. *Journal of Environmental Monitoring* **3** 493-498.

they are important toxicity- (TEQ values) and source indicators, but the analyses are very expensive.

The results of the discussions on screening are shown in Table 6.

Table 6. Compounds that are recommended for screening. The compounds in bold are those comprising the top 5-list.

Compound	**Rationale**
PBDE 209	***Potential contaminants***
PCB metabolites (OH-PCB, -MeSO3)	***Effect indicator***
OH-PBDE metabolites	***Effect indicator***
Oil PAH (16 comp. + NPD)	***Source indicator***
Co-planar PCB	***Expensive analysis- high toxicity***
Cyclic polysiloxanes	***Potential contaminants***
PAH-metabolites (OH-pyrene)	Effect indicator
SCCP/MCCP	Potential contaminants
Dicofol	Potential Contaminants
PF-sulfonates (incl. PFOS)	Potential Contaminants
PF-carboxylic acids	Potential Contaminants
PF-sulfoamides	Potential Contaminants
Endosulfan	Cand. for monitoring
PCN	Sparsely investigated
PCDD/F	Expensive analysis- high toxicity
HBCD	Pot. contaminants
TeBBPA	Pot. Contaminants

It is important that the screening list is updated continuously. If levels or usage of some of the compounds on the list are increasing, discharges or emissions are changing, new sources or hot spots are identified etc. it may be correct to move the compounds into the monitoring program. The screening list may also be expanded if new compounds enter the environment.

What media, abiotic and biotic (species-specific), are the most important to screen? What components of organisms (e.g. fat, meat, bones, blood) should be used?

Screening may serve two main purposes:

1) Searching for new contaminants in the Arctic environment and
2) Searching for "old" contaminants in new media.

The group recommended focusing on biota for screening of new contaminants. As mentioned before, the presence of a compound in higher Arctic biota shows that it meets three of the four criteria used in the Stockholm Convention (persistence, bioaccumulation and long-range transport). Screening in the Arctic environment therefore may be of special importance for the further development of international conventions. Species at the top of the food web also have the highest concentrations and hence the largest likelihood for detecting new contaminants. It is also important to consider the metabolic capacity of the species considered; for screening purposes, species with a low ability to transform and secrete xenobiotics should be preferred.

Although Glaucous gull is not the best species for monitoring due to very diverse food items and mobility, it is considered to be a suitable species for screening. The glaucous gull is a relatively poor metabolizer of POPs, as opposed to e.g. the polar bear. This means that most of the POPs that the individual is exposed to can be found in various tissues. High levels of POPs are generally found in glaucous gulls, and new compounds entering the Arctic ecosystem can probably be detected at relatively early state in this species. For cost effective sampling and analysis, eggs from this species are chosen as the first priority for screening.

Other organisms that were considered suitable for a screening programme was ringed seal, polar bears and Atlantic cod (Table 7).

Table 7. Species and matrix recommended for screening programmes (in prioritized order).

Species	Whole organism	Egg	Blubber	Liver
Glaucous gull		x		
Ringed seal			x	
Polar bears	x*		x	
Atlantic cod				x

** only in animals that are found dead or that are killed in self defence*

For screening of "known" substances in new media (2 above), other media also must be taken into consideration. However, when abiotic samples are to be analysed, it is important to be aware of possible analytical problems related to the detection of POPs in abiotic media.

What interval of time between sampling is appropriate if the results are to be used as early-warning signals for managing authorities?

In general, the need for screening of a specific compound will often be driven by the need for documentation in discussions about international or national regulations. Thus, the frequency can often be irregular. If regular screening campaigns are to be implemented, a sampling frequency of every three years in spring and every 6 years in winter is the minimum, based on the recommendations from the modeling group (see chapter 6) and discussions within the POPs group. It is important to be aware of the fact that the compounds screened for may differ between years.

How many sites are required for this region and where should they be placed?

This question is relevant for both monitoring and screening.

The sites for sampling of organisms have to be selected based on the distribution of the species. The sites should be selected in order to detect possible geographic differences within the region.

The stations for abiotic sampling should be chosen in accordance with the recommendations from the Modelling Group. The basic sampling strategy includes 10 stations. Eight stations will be at fixed locations while 2 stations are dynamic- chosen based on the actual location of the marginal ice zone during any given year of monitoring (see Figure 9).

What questions should be asked when making decisions on transferring constituents
-from screening to monitoring?
-removing from the programme completely?
-adding to the programme?

Screening compounds should be transferred into the monitoring program if levels are increasing or if knowledge is present for increased use, discharges or emissions. If hot spots for contaminant sources are known in the region or nearby regions, screening or even monitoring should be performed. Compounds can be added to the screening program if they are susceptible for long range air or ocean transport.

Compounds can be removed from the monitoring program when evidence for decreasing trends are present, but further screened to confirm decreasing trends and less ecosystem risk. Compounds can be added to the monitor program if levels are increasing, indicating increased discharges or persistence in the ecosystem. Increased levels in biota or in the food-chain imply that accumulation or magnification is present. This would be a risk for the eco-system, especially at high trophic levels.

How are the above recommendations for monitoring the Barents Sea supported by other programmes (e.g. AMAP, OSPAR, JAMP etc.)?

The recommendations and selection of compound, species, organs etc. is done in accordance to first and foremost AMAP and the Stockholm Convention. Sampling and analytical procedure should be based on protocols from existing monitoring programs, e.g. the Joint Assessment and Monitoring Programme (JAMP). An overview of existing guidelines for monitoring of different media are given by Evenset et al. (2000)[2]. However, there are no established guidelines for monitoring of seabirds or mammals.

[2] Evenset, A, Dahle, S. and Wolkers, J. 2000. Monitoring in the Arctic. Guidelines for monitoring the marine environment. Akvaplan-niva report 414.1699. 24 p.

5. RECOMMENDATIONS ON MONITORING OF RADIONUCLIDES

Participants:

Anne Liv Rudjord (Group Leader), Lars Føyn, Gordon Christensen, Corine Davids, Mark Dowdall, Justin Gwynn, Morten Sickel, Krisina Rissanen and Dina Solatie.

5.1 Introduction

The Norwegian Radiation Protection authority has elaborated a general plan for the monitoring of radionuclides within the second phase of the Transport and Effects Programme (NRPA 2002[18]). This plan was based upon plans for future bilateral cooperation with Russian authorities, and focused in particular on the most important sources and potential sources of radioactive contamination in the northern areas. Norwegian–Russian cooperation on monitoring started in 1992 with expeditions to the Kara Sea and later to the nuclear waste dumping sites at the east coast of Novaya Zemlya. Joint sampling and analysis has also been carried out at river estuaries and several contaminated sites. A programme for monitoring of radionuclides in fish has been in operation since 1994 that includes 2 locations in the Barents Sea. A national programme for monitoring of radionuclides in the marine environment was established in 1999. Two projects within the EU 5th framework programme have also given recommendations about the choice of reference organisms toward developing a framework for protection of the environment – not only human beings - from radiation effects (the EU-projects EPIC and FASSET). This issue is also highlighted in the 6th Framework Programme ERICA.

5.2 Recommendations on monitoring

Why do we need to monitor radionuclides in the Barents Sea?

The Barents Sea constitutes a financially important resource on both a national and local level for a number of countries. Because of the importance of the Barents Sea much media attention has been and continues to be focused upon it. A second reason for this attention is because of the vulnerability of the area to nuclear contamination from a wide variety of sources both within the Barents Region and from sources outside the region as far away as Western Europe.

The large number of potential and actual sources of nuclear contamination and the factors already mentioned have led to a high level of sensitivity regarding current and future levels of radioactive contamination in the Barents Sea and an acute awareness of the vulnerability of the area. The Barents Sea is also within the Arctic Region and as such its ecosystems are especially vulnerable to contamination due to Arctic specific processes such as high biological production, low species diversity, short food chains and limited periods of intense biological production.

As a result of these factors there is a need for the documentation of distributions, levels and trends of radioactive contamination in both the abiotic and biotic components of the Barents Sea. This is coupled to a need for strong emergency preparedness so that the impacts of sudden accidents or events on the radiological state of the Barents Sea can be assessed and reported expeditiously. The information obtained provides the basis for assessments of radiation doses to humans and biota. Predictions of the future situation can also be assessed.

What is unique about the Barents Sea compared to other regions of the Arctic with respect to radionuclides?

The Barents Sea is unique relative to other areas of the Arctic due to the large number of actual and potential sources of radioactive contamination. Radioactive inputs to the Barents Sea arise from a number of sources including but not limited to atmospheric nuclear weapon tests in the 1950s and 1960s (this source being common to all of seas of Europe):

- Chernobyl fallout originating mainly from Baltic Sea outflow into the Norwegian Coastal Current;
- Discharges from European reprocessing facilities Sellafield and La Hague, inputs via the Norwegian Coastal Current;
- Real and potential runoff from Siberian rivers;
- Possible leakage from underground nuclear weapon tests on Novaya Zemlya;
- Potential leakage of dumped nuclear reactors and other solid radioactive waste in Novaya Zemlya fjords.
- Potential leakage from military waste storage sites and activities in the area
- Potential nuclear accidents or
- Future potential of accidents related to plans for sea transport of high level nuclear waste
- Potential accidents/leakages from Radioisotope Thermoelectric Generators (RITEGs)

The concentration of such a number of sources in such a small area makes the Barents Sea not only unique in the Arctic Region but also perhaps on a global level. As already mentioned, the Barents Sea constitutes a food resource of economic importance for a number of countries as much of the sea is ice-free all year round and it exhibits a high level of productivity. As such it is both an important fishing ground for a number of countries and in recent years, an important fish farming area in the Barents Region.

What should this region-specific monitoring programme necessarily include as a result of its unique characteristics?

A monitoring programme for radioactivity should include such matrices and materials as are judged to be of relevance to the ecosystems of the region or that may be used to demonstrate levels of contamination in the Barents Sea. It is therefore obvious that both abiotic and biotic components are necessary. Recent research has highlighted the possibility of transport mechanisms for radioactive materials that may not be of importance to other areas of the Arctic (such as transport of contamination within sea ice sediments) and it is therefore assumed that monitoring of the Barents Sea may include matrices that would not normally be included in monitoring programmes for other regions.

What are the most important constituents to monitor? What are the relative benefits of including more contaminants to the list?

It should be noted that the primary radio-analytical technique of high resolution gamma ray spectrometry is inherently a multi-isotope method and that analysis for any one gamma emitting radionuclide by this method will theoretically produce at least a threshold of detection for other gamma emitting radionuclides. For some gamma emitting radionuclides, a pre-concentration step is required to produce an analytical signal of sufficient intensity to allow quantification and in this context the method reverts to being a single isotope procedure.

In selecting a top 10 list of candidate nuclides, a suite of contaminant nuclides has been divided according to the nature of their emissions:

- Alpha emitters: $^{238/239/240}Pu$, ^{241}Am, ^{210}Pb/^{210}Po, radium isotopes
- Beta emitters: ^{241}Pu, ^{90}Sr , ^{99}Tc, ^{129}I
- Gamma emitters: ^{137}Cs,^{60}Co

The relevant importance of individual nuclides is to some extent governed by the contribution of different source terms and is therefore a function of the changing nature of source terms for radioactive contamination. The list is generally a minimum. In some cases, not all the nuclides may be of importance, but at any time, the chosen nuclides will depend on the actual source term and the status of relevant potential sources. For alpha and beta analysis, element specific chemical preparation is needed before the analysis can be carried out.

What media (biotic and abiotic) are the most important to monitor?

Three factors need to be considered when deciding on which media to monitor. The first of these are obviously the species and materials that constitute food items to local or wider populations and the economically important fisheries. For all sampling, a range of relevant parameters, such as salinity for sea water and age-/size information on biological samples must be recorded.

Important species commercially and for local populations:

- Fish species : Cod / saithe/ haddock / capelin (very high priority)
- Shrimp
- Clams, mussels
- Minke whale
- Seal
- Sea weed (Laminaria)
- Kamchatka crabs

The second group is composed of species that concentrate radionuclides from their environments as a result of their biochemistry or physiology and therefore provide useful indicators of levels of radioactive contamination. Of these, seaweeds are the most widely used and studied indicator organism, but sampling is limited to coastal areas.

Indicator species:

- Seaweeds (fucus) (Most relevant radionuclides)
- Blue mussels (Pu, Am, Tc, Po, Cs, Co. Ra)
- Polychaetes (Pu, Am, Tc)
- Brittle star (Pu, Am, Tc)

Also of concern is the level of contamination in the ecosystem as a whole and in this context the following species or materials constitute useful monitoring matrices in addition to the species mentioned above.

- Sediment
- Sea water
- Plankton
- Polar bear
- Whale species
- Birds eggs

What components of organisms (e.g fat meat, bones, blood) should be used?

None of the mentioned radionuclides accumulate in fat tissue and blood samples are not helpful for estimating radionuclide content either. The decision of which components of organisms should be used for monitoring purposes is to some extent dependant upon ongoing research into the distribution of radionuclides within the tissues of various organisms. The preferential sampling and analysis of the edible portion of some commercially fished species is also of some concern, in light of the fact that by-products of the industrial processing of these species may ultimately enter food chains where humans occupy the top trophic level. An example of this would be the inclusion of by-products in fish meal that may be fed to cattle. A matter that also requires attention is the shift in focus from the concept of doses to man alone, to the consideration of doses to biota as well. Regarding cesium, concentration in most components can be estimated for concentrations in the flesh. For other radionuclides, direct analysis of the various relevant parts/organs are needed,

With respect to these considerations and in relation to individual nuclides, the following recommendations are presently the most important:

All recommended radionuclides - macroalgae, should be sampled and analysed in their entirety.

^{90}Sr : Fishbones, mussel shells,

^{137}Cs: (γ-spec): fish flesh, cod liver

Alpha-Pu/Am, radium isotopes: mussel shells, edible portions, fish bones, brittle stars/starfish

^{210}Po/^{210}Pb: flesh, edible portions, fish bones

What interval of time between sampling is appropriate to properly identify significant changes over time for purposes of detecting trends and early-warning? What is the justification for increasing the sampling frequency?

It is envisaged that annual sampling is sufficient (see section 4.2), except at coastal stations where more frequent sampling should be performed (monthly or quarterly). However, depending on the nature of the source term and of the contamination more frequent sampling in other selected areas and for selected sample types may be required. In addition, information on seasonal variations, salinity dependence on uptake and other causes of variability are important in many cases.

Should there be indications of an accident, incident or leakage etc., for early warning purposes it is considered that intensive screening around the identified source is required. In this case air monitoring may also be used for early warning in certain areas. In general, collection of abiotic samples and important edible species (fish) will be the highest priority in the early phase.

Special investigations, i.e. at source sites like dumping/ storage / test sites with potential for leaking / leaching, sampling should preferably be carried out at about 5 year intervals. Such sites are mainly located in Russia or in Russian waters, and therefore any such investigations will depend on the future cooperation with Russian authorities on radionuclide monitoring.

5.3 Recommendations on screening

What are the most important constituents to screen?

With respect to area screening in the case of actual accidents or potential source terms, the type of site will determine to a large extent which sample types and radionuclides are relevant. In most cases gamma spectrometry will be used for screening purposes, the most usual indicators for a release of radioactive contamination being ^{137}Cs, ^{60}Co , ^{131}I, and many other short-lived radionuclides, and with respect to NORM, radium isotopes and ^{210}Po.

In general the decision upon what to screen must take into consideration:

- The source term
- Bioaccumulation factors
- The radio toxicity of different nuclides
- The half-lives of different nuclides

In special cases it should also be considered that one may need to screen for hot particles.

What media (biotic and abiotic) are the most important to screen?

In most accident situations involving the potential or actual release of radioactive contamination, sampling of water, sediment and possibly air will be important. At a later stage, samples will be collected to ensure that radioactivity concentrations in foodstuffs and such species as have been introduced earlier are below relevant limits. Bioindicators such as seaweed might also be used.

What components of organisms (e.g fat meat, bones blood) should be used?

The selection of organism components for screening is a function of the time of year, the nature of the release with respect to the actual event (for example: leakage of nuclides from a sunken submarine reactor or accidental release of liquid wastes to surface waters) and the nuclide signature of the event. Organism components will also change with time after releases.

What interval of time between sampling is appropriate to properly identify significant changes over time for purposes of detecting trends and early warning?

The time spans involved for sampling/screening vary from minutes to years depending on the nature of the event, the location of the release and the nuclides involved. The overall priority is to sample and analyse required materials to give as early an estimate of risk and effect as soon as is practicable after the event.

What is the justification for increasing the sampling frequency?

Sampling frequency (with respect to a release situation) is governed by two factors. The first of these is the actual risk. Increasing frequency is therefore justified by an assessment of the actual risk involved indicating significant actual risk or a potential for significant actual risk in the future. A second factor that justifies an increase in sampling frequency is the perceived risk. Given the unique nature of the Barents Sea as a seafood resource, sampling frequency may be dictated by the publics' perceived risk and opinion or the amount and kind of attention paid to the event by the media. Such considerations therefore preclude advance planning of sampling regimes with respect to early warnings.

How many sites are required for this region and where should they be placed?

For the purposes of monitoring the general levels of radionuclide contamination in the Barents Sea it is necessary to have both off-shore/open-sea sampling locations and permanent coastal stations for both monitoring and the establishment of time series. The 15 stations suggested below take into consideration the prevailing ocean currents of the region and the location of potential and actual source terms contributing to radioactive contamination of the area.

- Five open sea stations
  - A minimum of two stations in the central Barents Sea are necessary as this is a commercial fishing area, samples to include sea water, sediments and such fish species as discussed previously.
  - A station in the international waters of the northeastern part of the Barents Sea.
  - A station off the west coast of Svalbard
  - A station off the coast of Spitsbergen , marginal ice zone

- Coastal stations, (6 are along the Norwegian coast)
  - Priority stations
    - Hillesøy
    - Ingøy
    - Grense Jakobselv
    - Jan Mayen
    - Spitsbergen (Ny Ålesund)
    - *Indre Kiberg*
    - *Vikna*
    - *Vestvågøy*
    - *Bear Island*
    - *Hopen*

The 'Top 5' priority stations would be the first five stations given in the above list.

In addition to the suggested sites in Norwegian waters, sites on the Russian side should be monitored when possible. The following are suggested:

- The Kara Sea Region Fjords (Tests /dumping)
- Kola coastal areas (waste storage sites)
- Chernaya bay (contaminated by underwater nuclear testing)
- Ob / Yenisey area (potential inputs from Russian nuclear facilities)

These fixed stations/areas are not enough to keep an updated overview of the situation and to be able to cope with situations with new sources. Therefore it is essential that as situations develop with respect to accidents or new source terms, the number and location of sampling stations can be changed to accommodate changes in circumstance. In addition to the fixed stations, a survey covering the entire Barents Sea should be conducted on regular cruises at least every third year. Should the list be reduced to 10, the list is the same as above but removing those sites marked in italics. The group considers that it is not possible to effectively monitor the Barents Sea for radioactive contamination using 5 sites.

What questions should be asked when making decisions on transferring constituents from screening to monitoring, removing from the program completely or adding to the program?

These topics may be discussed if new information on the various radionuclides arises, or if new research shows that a radionuclide is more or less of a problem than was expected or the perceived or actual risk level has changed. The factors that have to be considered include but are not limited to:

- Physical and ecological half-life and radiotoxicity of the radionuclide
- Changes in the source term
- Real or perceived risk associated with the radionuclide contamination
- Biological uptake, accumulation and food web transfer.
- Vulnerability: in which part of the ecosystem or organism does the radionuclide accumulate
- Are there any significant sink processes for the isotope?
- Has there been an alteration with respect to the exploitation of resources, e.g. farming of mussels, changing of the public's food habits ?

If a nuclide has been screened based on the expectation or potential for of a release, it should not be moved to monitoring status prior to an appraisal of the nature and likelihood of a release.

How are the above recommendations for monitoring the Barents Sea supported by other program (e.g. AMAP, OSPAR, JAMP etc.)?

The current activities of the monitoring programme for radioactivity in the marine environment and the suggestions outlined in this document are all supported by the AMAP and OSPAR/JAMP, and the phase II report of the Transport and Effects programme of the radioactivity group. Some additions have been made, especially regarding recommendations on naturally occurring radionuclides. This is due to changes in priorities, for instance within the OSPAR radioactivity committee in recent years. Also, the present report provides some further details regarding biota species that may be used in monitoring. Within the OSPAR JAMP programme temporal trends in defined geographical areas are highlighted. This is related to the reduction in discharges that is required in the objective of the OSPAR Strategy on radioactive substances. The recommendations are also supported by evidence. It is assumed that most real and potential sources are known, although not always well quantified.

What common activities exist among subgroup recommendations?

The radioactivity group discussed the proposal to develop joint monitoring programmes covering organic contaminants and trace metals. It was concluded that a single national programme covering all contaminants would not be the most efficient way forward. The challenges associated with radionuclides differ in many ways from the situation regarding other contaminants. This is also reflected in the way other programmes are organized, for example AMAP and the OSPAR work. Monitoring programmes for radioactive contamination have to take into account the large number of very significant potential sources of contamination, and the priorities may change due to the changing status of these sources. The monitoring activities therefore must be closely linked with the nuclear emergency preparedness system in Norway.

However, it was recognized that cooperation on the operational level could be very useful. Information should be exchanged regularly, and it was also suggested to organize seminars or meetings focusing on monitoring results and priorities, future plans etc. Cooperation regarding the use of models in the assessments may be improved. In radiation protection, assessment models are commonly used. The NRPA box model is used to predict effect over longer time scales. Oceanographic type models can be used within an acute phase to make predictions on the scale of days / weeks, and are suited for accident or leakage situations. Exchange of information on available data can be useful for development and validation of all types of transport models.

There may also be a potential for joint organization of sampling campaigns, when this is cost effective, and the objectives of the various monitoring programmes can be fulfilled this way.

6 RECOMMENDATIONS ON MODELS

Participants:

JoLynn Carroll (Group Leader), Mikhail Kulakov, Bruce Hacket, Paul Budgell, Alexey Gusev, Knut Breivik, Katrine Borgå and Vladimir Pavlov.

During the workshop, the status on the development of models for transport and distribution of contaminants was elaborated. The use of existing models in addition to monitoring in the Barents Sea (predominantly) was debated and the direction for future development in conjunction with the needs of the monitoring programme was outlined.

6.2 Status of models, use of models in monitoring

What is the current status of developments in models for contaminant transport?

A variety of different types of models are currently under development for use in contaminant transport investigations. These include:

1. Statistical Ice Model
2. Freshwater transport and spreading model (Ob/Yenisey)
3. Food web models
4. Individual-based pharmeco- models for higher organisms
5. Atmospheric emission models
6. Atmospheric transport models
7. Operational short-range forecasting models
8. Coupled ice-ocean models (Global and regional)
   i. off-line contaminant module
9. Compartmental models for contaminant transport
   ii. Atmosphere-ice-ocean (hemispheric, regional)
   iii. ice-ocean
10. Fully coupled physical-biological model
   iv. General
   v. Region specific (Barents Sea)

Presently, models can be used for the following purposes:

1. Circulation patterns in the Barents Sea
2. Annual/interannual variability in ice exchange in and out during different seasons
3. Trajectories of different sources of contaminants
4. Back & forward in ice/travel times
5. Probabilities of polluted ice
6. Ice fluxes through straits
7. Back trajectories and origin of samples with elevated concentrations
8. Total loadings during different seasons/annually
9. Prediction of concentrations in organisms from water concentrations, exposure of top predators but not effects

10. Cruise planning through short-range forecasting
11. Relative contributions from different regions
12. Reconstruction of fields of contaminant concentrations over greater spatial distributions
13. Optimization techniques in sampling (OSSE – observing system simulation experiments)
14. Preparation of chemical dossier
15. Evaluation of temporal variations of concentrations in various compartments
16. Evaluation of scenarios and projections
17. "What-if" scenarios
18. Areas of contaminant accumulation in bottom sediments
19. Day-to-day predictions of the physical situation

What is the current status of development in models focusing on the Barents Sea region?

1. Atmospheric transport models for heavy metals (Pb,Cd,Hg) are of rather good quality, particularly for predication of concentrations and deposition loads (within a factor of 2 in comparison with observations). Multicompartment models for POPs are more uncertain. With regard to concentrations in air and in precipitation the uncertainties are within a factor of 3-5. Computed concentrations of POPs in other media, in particular, seawater, soil and vegetation, are more uncertain
2. More and more data sets (ocean, atmosphere) are being made accessible to the world community of modelers which will help fuel better use of models as predictive tools (scenario testing, historical reconstructions)
3. The development of modeling tools for ecosystem elements (i.e. biota) is a frontier science
4. The continued improvement in LRT models is a positive development toward helping to identify future problems for the Arctic e.g. which new contaminants are likely to pose greatest risk of harm to Arctic ecosystems)
5. MIZ is important area in Barents Sea, and we have achieved improvements in data availability and modeling capabilities in recent years
6. Large-scale ocean circulation models are doing well, efforts to scale down to regional seas is a work in progress
7. Passive tracer experiments would be useful for purposes of developing better modeling tools
8. In general the spatial and temporal scales used in simulations performed by physical models are much higher than what is available in data sets of contaminant observations. This poses problems when attempting to use physical models to simulate contaminant transport.
9. Operational ocean models for short-range forecasting are very recent, currently restricted to physical variables. Much more work is needed before we will achieve fully integrated physical –chemical-biological models that can be used for forecasting purposes.

What are the expected developments in this field of investigation?

During the next 5-10 years we expect to see improvements in the following areas:

1. Fully coupled model compartments with nesting of global – regional –local scales
2. Better archives of information for scenarios of contaminants in the environment

3. Conventions/regulatory framework will help speed up higher quality of emission data
4. Better information on climate change
5. Improvements in multidisciplinary cross-fertilization
6. Sampling technologies will improve (development of proxies)
7. Improved prediction skill through better use (assimilation) of observations
8. Improvements in box models through greater use of high-resolution 3-D models
9. Operational forecast models will work to increase timescales of predictions from days to weeks, supplemented by seasonal trend prognoses
10. Better understanding of fundamental biogeochemical processes associated with contaminant cycling in the environment.

Given the current status of models, how can current models effectively be incorporated into a monitoring programme?

Integrating modeling into a monitoring programme will provide the opportunity to

1. Provide a geographically and temporally complete framework for viewing the state of contaminants in the Barents Sea
2. Contribute to monitoring programme planning through observing system simulation experiments (OSSE)
3. Contribute to periodic (annual) situation assessments through hindcast exercises incorporating all available observations
4. Contribute to day-by-day monitoring of the bio-geo-physical state through operational forecasting, also providing for response to unexpected events

Sampling Strategy:

Routine collection of data will greatly assist in the continued evolution of modeling tools for contaminant transport, providing much needed validation data sets. A basic sampling strategy should include 10 stations based on considerations of:

- Locate stations in boundary areas, Marginal Ice Zone (MIZ), Polar Front, Central Barents Sea
- Use a combination of fixed and dynamic stations
- Conduct abiotic and biotic sampling to capture important interfaces

Key elements of the suggested sampling strategy are as follows:

1. Sampling locations (10 stations)
    - a. Fixed stations (8 stations)
        - i. Entry/exit points to Barents Sea
        - ii. Central Barents (average MIZ location)
    - b. Dynamic stations (2 stations)
        - i. Actual location of MIZ
2. Environmental Compartments
    - a. Seawater
    - b. Bottom Sediment
    - c. Suspended Particulate Matter
    - d. Air

e. LTL organisms

f. Sea Ice/Snow

3. Frequency/Timing

Using a Power Analysis approach, the POPs group recommends an annual sampling frequency for monitoring of contaminants. The Modeling group agrees that annual sampling would provide the best measure of control over variability in the system. However the Modeling group also considered that conducting annual field campaigns in the Arctic is not practical and that it is more important to conduct less frequent but more comprehensive sampling (multiple types of sample media and support data). Therefore a more conservative sampling frequency was suggested:

a. 10 stations every 3 years during spring

b. 3 stations every 6 years during winter

4. Contaminants

As noted in Chapters 4, in order to understand the mechanisms for why high contaminant levels are present in specific species, there is a need for knowledge about levels in abiota (air, sea-water, ice, sediments). Such data are also needed for validation of refined models of bioaccumulation, which may be important future tools for risk assessment of ecosystem health. The modeling group agrees with the specific recommendations established by the POPs and Radioactivity groups regarding the selection of compounds to be measured in the various environmental compartments. With few exceptions, there are difficulties in sampling dissolved concentrations of POPs in seawater. The modeling group therefore recommends that samples be collected at the designated stations only for those compounds that can practically be measured. Presently, HCHs can be reliably detected in seawater. However, the list should be re-evaluated periodically to determine if analytical improvements or changes in the environmental levels of certain POPs over time warrant the inclusion of additional compounds for seawater analysis. Dissolved concentrations of ^{137}Cs, ^{99}Tc, and ^{129}I are extremely valuable as tracers in the development of numerical models for applications in contaminant transport. On the other hand, sediment is easily collected and allows for repeated sampling by returning to the same geographic location year after year. In order to interpret the timescale of integration for surface sediment samples, it is necessary to evaluate sediment accumulation rates at the various stations at a recommended frequency of every 9 years.

5. Additional support data

a. CTD station profiling (at each station/time point)

b. Sediment characterization (grain size, POC/PON content, water content) (at each station/time point)

c. Sedimentation rate (every 9 years)

6. Methodology - according to AMAP and other relevant international guidelines

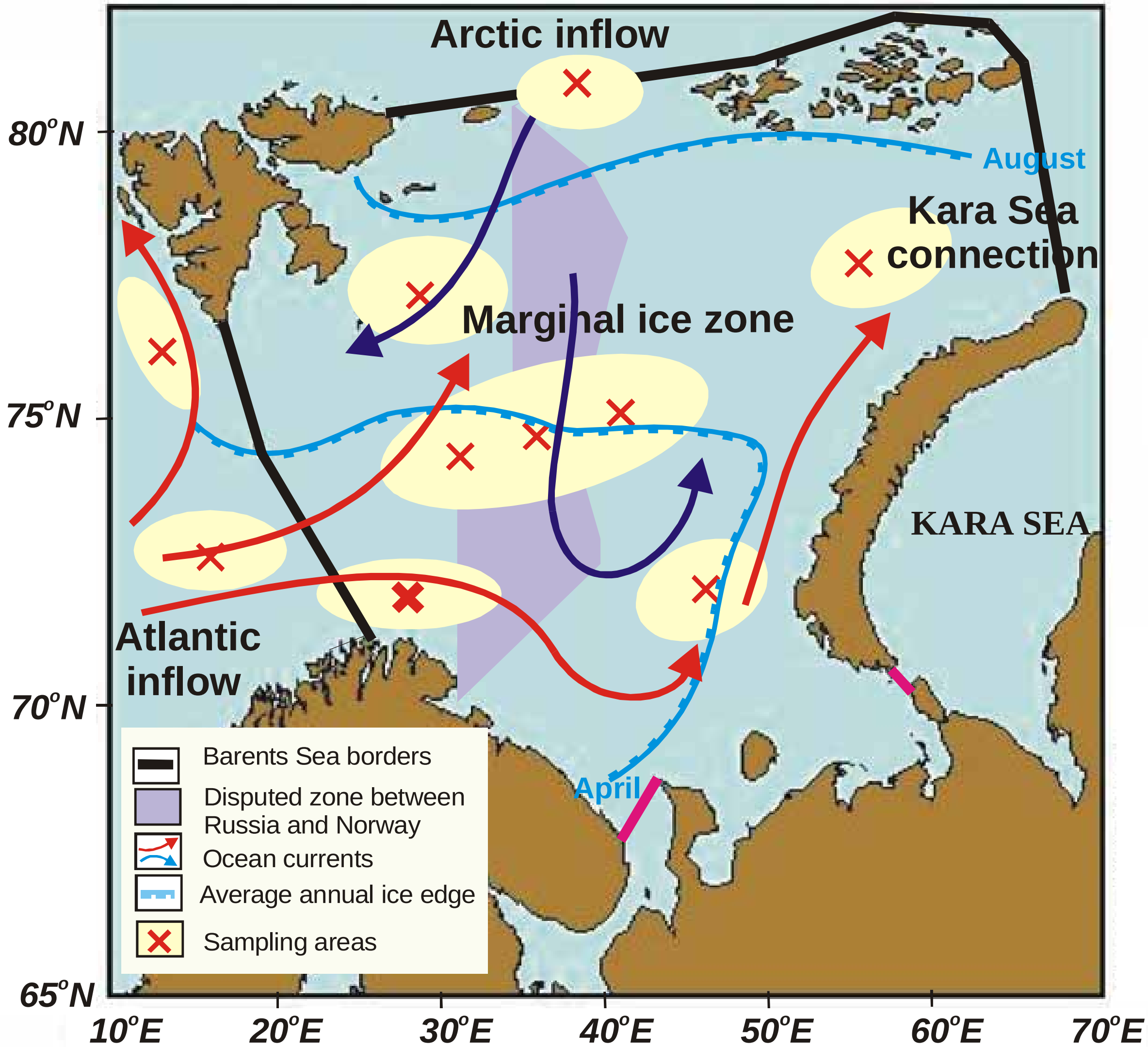

Figure 9: The Barents Sea region with recommended sampling stations identified.

7 INTEGRATION OF MONITORING PROGRAMMES

What are common needs for monitoring POP's and radionuclides? Can we and is it possible to develop a common monitoring programme?

The working groups discussed to what degree the recommendations on radioactivity are concordant with those for POP's and how the monitoring of POP's and radionuclides may be combined into joint sampling programs. The radioactivity group concluded that a single joint programme would not be helpful in achieving the objectives of the radioactivity monitoring programme. However it was recognized that more effort should be done in order to increase cooperation between monitoring programmes for POP's and radionuclides, e.g. logistics and modeling. For modeling purposes, it would be useful to have some information on both POP's and radioactivity from parallel samples. For example, it could be useful to have similar stations for trend monitoring. Because cost effectiveness is an important objective, options for collaboration should be considered further. The groups agreed that a meeting to discuss the issue in detail should be a recommendation of this workshop.

8 REFERENCES

[1]AMAP 1997: Arctic Pollution Issues: A state of the Arctic Environment report. Arctic Monitoring and Assessment Programme (AMAP) Oslo, 188 pp.

[2]AMAP 2002: Arctic Pollution 2002

[3]AMAP 2002: AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic.

[4]AMAP 2004: AMAP Assessment 2002: Radioactivity in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xi+100 pp.

[5] See information with all relevant links at http://npweb.npolar.no/ under "Miljøovervåking og rådgivning/Forvaltningsplan for Barentshavet" (only in Norwegian).

[6]AMAP Trends and Effects Programme 1998 – 2003". Can be downloaded at: http://amap.no/documents/search.cfm?collection=description&q=trends

[7] See: http://www.pops.int/ . Entered into force in 2004.

[8] Two protocols from 1998 about POP's and heavy metals: http://www.unece.org/env/lrtap/status/lrtap_s.htm . Both entered into force in 2003.

[9] See http://www.ospar.org/eng/html/welcome.html

[10] "OSPAR and WFD list of chemicals for priority action" and "OSPAR 1998 List of Candidate Substances" - Ministerial Meeting of the OSPAR Commision, Draft Summary Record OSPAR 98/14/1, Annex 34.

[11] See a project description at: http://npolar.no/transeff/Effects/Phase2/Prosjektbeskrivelse%20effekt%20fase%202,%20godkjent.doc

[12] See a project description at: http://npolar.no/transeff/Transport/Phase%202/Phase%202%20%20Overview.doc

[13] See the report at: http://npolar.no/transeff/Effects/Monitoring/Monitoring-APN.htm

[14]Pedersen, G. and Heimstad, E. Beskrivelse og vurdering av forurensning fra kilder utenfor norsk del av Barentshavet. Tromsø, Akvaplan-niva, *Rapport APN-421.2871* (2004).

[15]Bignert, A, Riget F, Braune B, Outridge P, Wilson Simon. 2004. Recent temporal trend monitoring of mercury in Arctic biota – how powerful are the existing data sets? J. Environ. Monit., 6:351-355

[16]Bignert, A, Cleeman M, Dannenberger D, Gaul H, Roots O. 1997. Baætic Sea Environmental Proceedings. Helsinki Commission, 64B, 130-138

[17]Fryer, RJ, Nicholson MD. 1993. The power of a contaminant monitoring programme to detect linear trends and incidents. ICES J. Mar Sci 50:161-168.

[18]NRPA 2002: Radioactivity monitoring programme for the Northern Seas

9 APPENDICES

Appendix 1 – Workshop agenda

WORKSHOP ON MONITORING CONTAMINANTS IN THE NORTHERN SEAS

TROMSØ, 22 MARCH – 25 MARCH 2004)

POLAR ENVIRONMENTAL CENTRE

Monday 22 March INTRODUCTION

13:00-13:20 Workshop Opening (JoLynn Carroll)
13:20-13:50 Perspectives of monitoring of the Barents Sea (Gunnar Sander)
13:50-14:10 Northern Contaminants Programme (Derek Muir)
14:10-14:30 AMAPs Monitoring Programme
14:30-14:50 Joint Assessment and Monitoring Programme (Anders Ruus and Tatiana Savinova)
14:50-15:10 How is EMEP using modelling as a support technique for monitoring?
(Alexey Gusev)
15:10-15:30 Screening related programs from SFT (Jon Fuglestad)
15:30-15:50 COFFEE
15:50 – 16:20 Review of Meeting Plan for Day 2
19:30 Dinner/Icebreaker (POMI, Akvaplan)

Tuesday 23 March SUBGROUP MEETINGS

8:30 – 10:20 Meeting of subgroups
10:20 – 10:40 COFFEE
10:40 – 12:30 Meeting of subgroups
12:30-13:30 Lunch (at POMI)
13:30-15:30 Meetings of subgroups
15:30-16:00 COFFEE
16:00-16:30 General Assembly
Status Reports:
POPs/mercury subgroup (10 minutes)
Radioactivity subgroup (10 minutes)
Modelling subgroup (10 minutes)
16:30 – 17:00 Discussion/Planning for next day
17:00-18:00 Group leaders' meeting
19:00 – joint dinner (Arctandria)

Wednesday 24 March SYNTHESIS & CROSS-FERTILIZATION

8:30 – 10:30 Subgroups meet to finalize results and discuss integration ideas
10:30-10:50 COFFEE
Final Reports:
10:50-11:30 POPs/mercury subgroup

11:30-12:00 Radioactivity subgroup
12:00-12:30 Modelling subgroup
12:30-13:30 Lunch (at POMI)

13:30-15:00 Integration discussion – Entire group meets to combine individual programs
15:00-15:30 Final Consensus Agreement

Thursday 25 March REPORT PREPARATION (Group leaders only)

8:30 – 15:00 Preparation of workshop report
15:00 -15:30 Final Commentary
15:30 Workshop ends

Appendix 2 – List of participants

	Name	Institute/organisation	e-mail adress	Phone number
	Gunnar Sander	NP	gunnar.sander@npolar.no	+47 79 02 26 22
	Jon Fuglestad	SFT	jon.fuglestad@sft.no	+47 22 57 37 26
	Modelling			
Group leader	JoLynn Carroll	ApN	jc@akvaplan.niva.no	+47 77 75 03 14
	Mikhail Kulakov	AARI	mod@aari.nw.ru	+7 812 352 31 29
	Bruce Hackett	DNMI	Bruce.Hackett@met.no	+47 22 96 33 39
	Paul Budgell	HI	paul.Budgell@imr.no	+47 55 23 86 28
	Alexey Gusev	MSC east	alexey.gusev@msceast.org	+7 095 128 9098
	Knut Breivik	NILU	knut.breivik@nilu.no	+47 63 89 80 88
	Katrine Borgå	NP	katrine.borga@npolar.no	
	Vladimir Pavlov	NP	pavlov@npolar.no	+47 77 75 05 16
	POPS/Mercury			
Group leader	Eldbjørg Sofie Heimstad	NILU	esh@nilu.no	+47 77 75 03 84
	Anita Evenset	ApN	ae@akvaplan.niva.no	+47 77 75 03 11
	Tatiana Savinova	ApN	ts@akvaplan.niva.no	+47 77 75 03 47
	Janneche Utne Skåre	National Veterinary Institute	janneche.skaare@vetinst.no	+47 23 21 62 00
	Amund Måge	NIFES	amund.maage@nifes.no, amund.maage@asa-odda.no	
	Roland Kallenborn	NILU	roland.kallenborn@nilu.no	+47 63 89 82 37
	Anders Ruus	NIVA	anders.ruus@niva.no	+47 22 18 52 27
	Geir Wing Gabrielsen	NP	geir@npolar.no	+47 77 75 05 29
	Bjørn Munro Jensen	NTNU	Bjorn.Munro.Jenssen@bio.ntnu.no	+47 73 59 62 67
	Derek Muir	The National Water Research Institute, Canada	Derek.Muir@ec.gc.ca	+1 905 319 6921
	Frank Farsø Riget	National Environmental Research Institute, Denmark	ffr@dmu.dk	+45 46 30 19 48

	Radionuclides			
Group leader	Anne Liv Rudjord	NRPA	Anne.Rudjord@nrpa.no	
	Lars Føyn	HI	lars.foeyn@imr.no	
	Gordon Christensen	Institutt for Energiteknikk	gordon.christensen@ife.no	+47 63 80 64 28
	Corine Davids	NRPA	corine.davids@nrpa.no	
	Mark Dowdall	NRPA	mark.dowdall@nrpa.no	+47 77 75 03 07
	Justin Gwynn	NRPA	justin.gwynn@nrpa.no	
	Morten Sickel	NRPA		
	Kristina Rissanen	Radiation and Nuclear Safety Authority, Finland	kristina.rissanen@stuk.fi	
	Dina Solatie	Radiation and Nuclear Safety Authority, Finland	dina.solatie@stuk.fi	

Appendix 3 – Background

Background Information distributed with the invitation

The programme, 'Transport and Fate of Contaminants in the Northern Seas,' was initiated in 2000 by the Norwegian Polar Institute with financing from the Norwegian Ministry of Foreign Affairs and Ministry of Environment. The programme objectives have been to:

1) Identify consequences for both the environment and health of continuous releases and acute discharges of contaminants into the Northern Seas.
2) Develop a national monitoring programme for contaminants based on contemporary scientific understanding of contaminant-environment interactions and consequences.

The project will conclude with a workshop where a small number of invited national experts will convene to accomplish the following main goals:

1) Information exchange and synthesis of results on transport and effects components of the programme, 'Transport and Fate of Contaminants in the Northern Seas.'
2) Harmonization of results into a single monitoring framework for contaminants in northern areas

Norway has established the polar bear, cod, and glacous gull as key indicator species for contaminant effects in the Northern Seas.

There is a significant overlap between Norway's national interests toward developing a monitoring programme for the Northern Sea areas with the interests of the Arctic Monitoring and Assessment Programme (AMAP). Participation in the workshop by AMAP experts is simultaneously being elicited by the AMAP Secretariat to the Heads and Delegation of the Arctic Monitoring and Assessment Programme. In addition, the results of the workshop will be conveyed to other parallel programmes, e.g. the Bilateral Norwegian-Russian Environmental Cooperation Programme, OSPAR, and MOSJ. Therefore the workshop's working language will be English.

Additional Information on Working Groups:

Perspective

The work in the Transport and Effects Programme (T&E) Phase 2 will shortly conclude with detailed recommendations on POPs monitoring for three top predators[6] and the monitoring of the abiotic environment for both radionuclides and POPs[7]. The Norwegian Radiation Protection Authority has further elaborated a general plan for the monitoring of radionuclides (NRPA 2002). Furthermore there is a method report from phase 1 available with an overview on existing directives for monitoring of all type of contaminants in the marine environment in the Arctic[8].

T&E is only part of the background information that should be considered as part of this work, further building on other related national and international programmes.

Organic contaminants and mercury
There is a need for recommendations on monitoring that encompasses the entire marine ecosystem including key edible fish species. AMAP Phase 2 is a key source of information on monitoring recommendations. The Canadian "Northern Contaminants Programme" also has important results and recommendations on methods, as well as OSPAR and JAMP. The AMAP recommendations for member countries are extensive and will therefore be difficult to implement as a routine monitoring programme[2]. After AMAP resumes Phase 2, there will be a better basis to identify parts of the marine environment that are most important for monitoring. Thus it will be possible to update former recommendations and adapt them to Norway's marine areas of interest. It will be important as well to determine whether there is new knowledge about relevant monitoring methods that address *inter alia* AMAP needs for a better international standardization.

For this reason it is desirable to develop monitoring recommendations for organic contaminants and mercury in order to:

- Address the Stockholm Convention[3] and the Aarhus[4] protocols to document whether the ratified measures are effective (monitoring of "old substances")
- Identify new substances that should be included in the conventions (screening and monitoring of these "new substances"). The Norwegian State Pollution Control Authority will contribute with a list about the most current substances for screening.
- Document sources, routes of transport and distribution in the ecosystem.
- Document effects provided that it's reasonable to do it as monitoring. The monitoring of effects (biomarkers) as a method to find unknown substances may enter here

Final recommendations should include substances, species/media, frequencies and methods to the degree that is known and to the extent that it can form the basis for routine monitoring. The recommendations should specify substances requiring repeated sampling at regular intervals and screening or baseline investigation. Problems requiring research or problems where research is necessary to develop or interpret monitoring data may be pointed out, but should not be in the focus of the recommendations.

The recommendations should be ranked.

Radionuclides
The Norwegian Radiation Protection Authority has, as mentioned above, elaborated recommendations on the monitoring of radionuclides in the northern seas. For the moment there are several ongoing international processes that will result in new recommendations. These are important for the future monitoring. Two EU-projects have given recommendations about the choice of reference organisms toward developing a framework to protect the environment - not only human beings - from radiation effects (the EU-projects EPIC and FASSET).

Once of the main goals of the workshop will be to determine to what degree the recommendations for radioactivity are concordant with those for POP's and how the monitoring of POPS and radionuclides may be combined into joint sampling programs.

The use of models in monitoring
Monitoring in the northern seas should be supplemented by models that can:

- Identify sources and routes of transport.
- Complete the sampling area geographically.
- Include a bigger part of the ecosystem than is possible to cover by sampling.
- Form the basis to calculate exposure and/or explain effects on organisms, and possibly humans.
- Contribute to improve the monitoring programme through finding the optimal positioning for sampling stations and the most adequate species/media.

During the workshop, it should be determined the status on the development of models for transport and distribution of contaminants. Which models exists that can be used additionally to monitoring in the Barents Sea (predominantly) and which direction should the future development take to address these needs.

Appendix 4 – Workshop Participants