# Section B - Trend Monitoring Programme

*The following text comprises part of the **AMAP Trends and Effects Programme** documentation. As such, it should be read in conjunction with other sections of the documentation, in particular Section A (Introduction) which includes an explanation of some basic terms and concepts that are used in describing the AMAP programme. Other sections include: Section C (AMAP Effects Monitoring Programme); Section D (Supporting Studies); Section E (Quality Assurance and Quality Control); Section F (Data Reporting Issues); and Section G (Appendices - references, methodologies, etc.).*

## Introduction

This section (Section B) presents the content of the **AMAP Trend Monitoring Programme** according to its five subprogrammes dealing with the atmospheric, marine, freshwater and terrestrial environments, and human health in relation to contaminant monitoring. The information is presented in the form of a series of overview tables. The programme is based on detailed monitoring proposals developed for the various pollution issues. These proposals were initially developed during an AMAP expert meeting in Girdwood, Alaska, in April 1998, and further refined during a number of follow-up meetings and consultations prior to their approval by the AMAP Working Group in November 1999.

Additional references to documentation on, e.g., recommended methodologies concerning specific programme components, sampling frequency, implementation strategies and methodologies, etc., can be found in Section G of this document.

At the end of this section, a series of supplementary tables are included, covering:

- ***Table B.1. Subprogramme harmonisation: An overview of compartments and species common to several subprogrammes.***
- ***Table B.2. Detailed list of POPs to be analysed under the monitoring programme.***
- ***Table B.3. Detailed list of PAHs and petroleum hydrocarbons to be analysed under the monitoring programme.***
- ***Table B.4. Detailed list of heavy metals to be analysed under the monitoring programme.***
- ***Table B.5. List of supporting/interpretational parameters to be measured under the monitoring programme.***
- ***Table B.6. List of areas considered essential for monitoring under subregional programmes..***

## Abbreviations and notes employed in the tables

The following tables include a number of explanatory footnotes. When reading the tables, please refer carefully to any relevant notes. Every attempt has been made to ensure consistent use of footnotes between tables. An overview of notes and abbreviations employed in the subprogramme tables is as follows:

- Status of parameters in monitoring programme (see Section A for further explanation):

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.
ES essential sub-regionally
R recommended
R(ss) recommended for inclusion in screening studies

Footnotes to subprogramme tables:

❶ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).
❶ Measurements of all gamma-emitting radionuclides.
❷ Generally one-time sampling, but chemical determination for as many individual 'year slices' as possible in each core. If repeated, cores should be sampled at intervals of not less than 5 years; in most cases > 10 years.
❸ Water and/or SPM (suspended particulate matter), as appropriate. In marine waters with low contaminant and SPM concentrations methodological considerations imply the need for large volume water samples.
❹ Included in POPs programme for linkage to biological effects monitoring.
❺ PAH metabolites, and Mixed Function Oxidase (MFO).
❻ Whelks - Dogwhelk (*Nucella lapillus*), Whelks (*Nucella lima*), Common whelk (*Buccinum undatum*).
❼ Alternative species in addition to Sculpins and Arctic cod include Cod, capelin, flounder and long-rough dab.
❽ Species undefined (mainly species consumed for food).
❾ River water.
❿ Burbot, lake trout and pike are alternative species for use in temporal trend monitoring studies; the most appropriate species can be selected on the basis of availability and relevance for other ongoing studies, etc.
⓪ Milk from cow, sheep, goat, reindeer - variation between areas.
① As part of food web studies.
② Sampling of other tissues should be continued if part of ongoing trend studies.
③ Soil parameter - to be measured in combined aquatic/terrestrial acidification modelling.
④ In connection with oil spills on snow.
⑤ To characterise episodes (including frequency and length of episodes) of poor urban air quality.
⑥ Water used for drinking water.
⑦ See Table B.4 for Hg species to be monitored.
⑧ MeHg should be measured in fish, birds, mammals and invertebrates (in addition to total Hg) at selected sites (e.g. contaminated sites with a significant contribution of inorganic Hg).
⑨ PAH measurements in fish liver are connected with monitoring around point sources associated with oil discharges (and/or potential oil discharges); relevant QA/QC is related to oil studies.
⑩ Measurement of $SO_x$ is the main priority in connection with (subregional) acidification studies.

- Abbreviations for recommended tissues/species groups to be monitored in biota

B Brain
BB Blubber/blood
BE Berries
BEL Blood/eggs/liver
BL Blubber
EG Eggs
F Feathers
FB Fat/blood
H Hair
K Kidney
L Liver
M Muscle
P Plants in human diet.
TA Terrestrial animals.
TU Tissue undefined

# AMAP Atmospheric subprogramme

## Station Network

A major part of the AMAP atmospheric monitoring subprogramme is based around a network of stations monitoring background contamination levels of POPs and some metals resulting from long-range atmospheric transport. These stations are located in areas remote from the influence of local sources, mainly in the High Arctic but with some stations at lower latitudes. Gaps in the circumpolar network of background monitoring stations remain, in particular in the far eastern part of northern Russia and United States (Alaska).

For **subregional components**, essentially those concerned with acidification, the EMEP monitoring network for acidifying compounds forms the basis of the AMAP monitoring network in northern Europe. Additional monitoring and research activities are required to obtain information for relevant areas not covered by the EMEP network (e.g., Norilsk).

In addition to atmospheric monitoring of contaminants from long-range and (regional) local sources, monitoring of urban air quality in major Arctic population centres is of interest from a human health perspective.

## Sampling Strategies

The main components of the atmospheric monitoring subprogramme concern collection of air/aerosol and bulk precipitation samples for analysis for heavy metals, POPs, and acidification parameters. Because most of the air monitoring activities involve sampling at regular intervals (from pseudo-continuous to monthly) at fixed locations (air monitoring stations), the work is aimed at establishing both **spatial and temporal trends**, and (in connection with modelling work) to provide information on **sources** of long-range transported contamination affecting different regions.

Bulk precipitation and snowpack sampling is conducted both at fixed stations and as part of **one-off surveys** covering wider areas, and provides information for estimating **depositions**; sampling of mosses and soils, etc., that can also be used to estimate depositions, are included under the terrestrial subprogramme. Bulk precipitation sampling is mainly applied in those areas that receive precipitation as rain rather than snow for significant parts of the year (i.e. Low Arctic and subarctic areas). Bulk precipitation and sampling of throughfall (and frozen fog, etc.) are associated, in particular, with **acidification monitoring**. In addition to providing information for estimating contaminant deposition during the snow accumulation season, snowpack sampling is also proposed for monitoring of PAHs in connection with oil spills on snow.

Sampling of **glacial** and **ice cores** (see also terrestrial subprogramme) is mainly associated with **retrospective temporal trend studies**. From a **human health** perspective, air quality in urban areas and in the immediate vicinity of sources such as smelters is of interest. In this connection particle concentrations are of interest, but especially levels measured during episodic events, together with information on the frequency and duration of the events is required.

For new contaminants, such as current use pesticides and other persistent contaminants of potential concern, coordinated **screening studies** are recommended. The main aim of these studies is to provide preliminary information on levels in Arctic air, so that the need for more comprehensive monitoring activities can be properly evaluated and the environmental behaviour of these substances can be better understood.

In addition to implementing improvements in methodology (especially those relating to POPs) that have been developed in recent years, the updated AMAP programme emphasises the need for additional parameters to be introduced at all stations within the circumpolar monitoring network, with highest priority being the inclusion of **mercury and POPs measurements** at all primary background monitoring stations. A recent development in monitoring of mercury in air is the introduction of new instrumentation (Tekran - cold vapour atomic fluorescence sensor) at a number of the main Arctic monitoring stations. This equipment allows continuous air monitoring for mercury, and improved possibilities for studying mercury speciation in air at Arctic sites, information that is essential for process studies and for improved understanding of mercury cycling in the environment.

Further information on recommended methodologies (for sampling, storage, analysis, etc.), QA/QC considerations, data reporting, etc. can be found in sections E, F and G of this document.

## Media and Parameters

| Media ➔ ↓Contaminant group | | Air/Aerosol | Bulk precipitation | Throughfall | Snowpack | Frozen fog (rime), intensive | Glacial cores❷ |
|---|---|---|---|---|---|---|---|
| POPs (see Tables B.2 and B.3) | PAHs | E | E | | ES ④ | | R |
| | Planar-CB | R | R | | | | E |
| | PCB | E | ES | | | | E |
| | DDT/DDE/DDD | E | ES | | | | E |
| | HCH | E | ES | | | | E |
| | HCB | E | ES | | | | E |
| | Chlordane | E | ES | | | | E |
| | Dieldrin | E | ES | | | | E |
| | Toxaphene | E | ES | | | | E |
| | PCDD/PCDF | R | | | | | |
| | Annual Temporal Trend (POPs) | E | | | | | E ❷ |
| Other persistent chemicals of potential concern (see Table B.2) | PCN | R (ss) | | | | | R (ss) |
| | CPs | R (ss) | | | | | R (ss) |
| | Current use pesticides | R (ss) | R (ss) | | | | R (ss) |
| | Other persistent chemicals ❶ | R (ss) | R (ss) | | | | R (ss) |

| Media ➔ ↓Contaminant group | | Air/Aerosol | Bulk precipitation | Throughfall | Snowpack | Frozen fog (rime), intensive | Glacial cores❷ |
|---|---|---|---|---|---|---|---|
| Oil (see Table B.3) | Hydrocarbons, THC | R | | | | | |
| | Monoaromatics | R | | | | | |
| | PAHs (see POPs) | | | | | | |
| Heavy metals (see Table B.4) | Cd | E | ES | | ES | | |
| | Cu | ES | ES | | R | | |
| | Hg | E ⑦ | E ⑦ | | ES | | |
| | Pb | E | ES | | ES | | |
| | Zn | ES | ES | | R | | |
| | Cr | ES | ES | | R | | |
| | Ni | ES | ES | | R | | |
| | As | ES | ES | | ES | | |
| | Se | ES | ES | | ES | | |
| | Al | ES | ES | | R | | |
| | V | ES | ES | | R | | |
| | Annual Temporal Trend (HMs) | E | | | | | |
| Radioactivity | Gamma spectroscopy ❶ | E | R | | R | | |
| | $^{131}I$ | E | R | | | | |
| | $^{137}Cs$ | E | R | | | | |
| | $^{134}Cs$ | R | R | | | | |
| | $^{90}Sr$ | R | R | | | | |
| | $^{210}Po$ | | | | | | |
| | $^{99}Tc$ | | | | | | |
| | $^{239,240}Pu$ | R | | | | | |
| Acidification | $SO_2$ | ES ⑩ | | | | | |
| | NOx | ES | | | | | |
| | $NH_3$ | ES | | | | | |
| | pH ($H^+$) | R | ES | R | R | R | |
| | $SO_4$ | ES ⑩ | ES | R | R | R | |

| Media ➔ ↓Contaminant group | | Air/Aerosol | Bulk precipitation | Throughfall | Snowpack | Frozen fog (rime), intensive | Glacial cores❷ |
|---|---|---|---|---|---|---|---|
| | $NO_3$ | ES | ES | R | R | R | |
| | $NH_4$ | ES | ES | R | R | R | |
| | DOC | | | R | | | |
| | Mg | | ES | R | R | R | |
| | Ca | | ES | R | R | R | |
| | K | | ES | R | R | R | |
| | Na | | ES | R | R | R | |
| | Al (labile) | | | | | R | |
| | Cl | | ES | R | R | R | |
| | Conductivity | | ES | ES | R | | |
| | Ntot | | R | R | R | | |
| | Ptot | | R | R | R | R | |
| | Particulates | R ⑤ | | | | | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.

ES essential sub-regionally.

R recommended.

R(ss) recommended for inclusion in screening studies.

❶ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).

❶ Measurements of all gamma-emitting radionuclides.

❷ Generally one-time sampling, but chemical determination for as many individual 'year slices' as possible in each core. If repeated, cores should be sampled at intervals of not less than 5 years; in most cases > 10 years.

④ In connection with oil spills on snow.

⑤ To characterise episodes (including frequency and length of episodes) of poor urban air quality.

⑦ See Table B.4 for Hg species to be monitored.

⑩ Measurement of $SO_x$ is the main priority in connection with (subregional) acidification studies.

# AMAP Marine subprogramme

## Station Network

Compared to the other subprogrammes, the marine subprogramme represents a special case in relation to monitoring 'key areas' within the circumpolar region. The concept of 'key areas' as defined for other subprogrammes (see also Section A) cannot be readily applied to marine systems that include the coastal zones and the vast shelf seas of the Arctic, and the Arctic Ocean itself. Consequently, the desired monitoring coverage of the marine system is addressed in relation to 'background' and 'impact' key areas.

- ***background key areas*** are areas where monitoring is intended to produce data on background levels of contamination and the general state of the marine ecosystems, including relevant observations to study climate change and UV-B effects, examples include the Barents and Bering Seas;
- ***impact key areas*** are areas which the previous AMAP assessment (or other information) has identified as being subject to elevated levels of contamination, including those areas that are affected by a combination of pollution issues and thus relevant for the study of combined effects, e.g. the area around Svalbard.

A limited number of background and impact key areas will constitute basic elements of the AMAP marine monitoring subprogramme, and of supporting marine studies where most of long- and short-term monitoring effort should be implemented. They include rather extensive areas containing a number of sampling sites where different elements of the programme may be implemented.

Where possible, the key areas, especially impact ones, are located so as to coincide with terrestrial/freshwater estuarine key areas, to provide the opportunity to assess land-ocean interactions, in particular inter-compartmental transport of contaminants.

**Important fisheries** and areas utilised for **native hunting** of marine resources are prioritised in the monitoring programme, as will areas where conditions for contaminant accumulation occur (sedimentation areas) or areas along important routes of marine pathways (including ice transport routes).

In all cases, selection of specific sampling locations should take account of oceanographic and hydrographic conditions, etc., in relation to the objectives of the monitoring and the compartments being sampled.

***Additional impact stations*** (i.e. outside of impact key areas) should be established in areas where, based on the results of the previous AMAP assessment or other information, the marine environment is, or potentially could be, significantly affected by one or more particular pollution issues (e.g., sites of dumping of radioactive wastes, areas around offshore oil exploration and production platforms, etc.).

***Combined effects marine stations*** should be combined, wherever possible, with key areas. The objective of this type of station is to produce information on combined effects of contaminants (and/or other relevant environmental stressors) on the state of ecosystems. Monitoring programmes may include the following elements:

- impacting factors;
- characteristic ecosystem indicators (diversity and number of indicator species, biomass, etc.);

- contaminant levels in indicator species;
- responses of indicator species to biological effects tests that react to multiple contaminants and stressors.

***Estuarine monitoring stations:*** among the different types of estuaries, river estuaries should be prioritized. The main objective of estuarine stations is to produce information for assessment of the fate of contaminants in the coastal zone, and for estimation of net riverine fluxes (flux of contaminants from the river to the open ocean). It is suggested that this type of station be established in the estuaries of large rivers which are responsible for significant fluxes of priority pollutants, and where riverine flux stations are planned (see Freshwater subprogramme).

In practise, it is recognized that most of the monitoring of the open Arctic Ocean, and to a large extent also the marginal seas, will depend on national and bilateral research cruises and expeditions. Efforts should be made to ensure that during the planning of such cruises, the requirements of the AMAP marine monitoring (and effects) programme are taken into account and to the greatest possible extent implemented through the cruise scientific programmes.

## Sampling Strategies

The marine subprogramme covers monitoring activities in all relevant compartments of the marine environment. The main parts of the programme addressing **spatial trends** and offshore **process studies** will depend on coordination of AMAP work with planned cruise activities. Monitoring to provide information about processes in the coastal zone, riverine fluxes, and contaminant levels in marine food species etc. can be more readily addressed through specific programme activities under AMAP.

Monitoring to establish **temporal trends** involves two main approaches: retrospective trend analyses using dated marine sediment cores taken from areas of net sediment accumulation, and annual sampling of a range of different species of marine biota (shellfish, fish, birds and marine mammals). Temporal trends based on collection of the upper layer of sediments from areas with high rates of sediment deposition (at time intervals depending on sedimentation rates) may provide an alternative approach. All of the approaches mentioned require that there is a good knowledge of the areas and compartments concerned, e.g. to ensure that the same population of fish or mammals are sampled from year to year, that ice scouring is not disturbing sediments, etc.

A particular strategy proposed for certain marine mammals (e.g., ringed seals and polar bears) is that of **coordinated international surveys**, conducted according to agreed methodologies, etc. A one-off circumpolar survey is also proposed for TBT (levels and effects), in order to characterise TBT contamination in the Arctic marine areas, and provide a baseline for possible evaluation of the effectiveness of agreed TBT reduction measures.

The need to establish better linkages between contaminants monitoring and **effects studies** is reflected in the selection of several species of marine mammals and birds which were identified during AMAP phase 1 as exhibiting levels of contaminants, in particular POPs, that were associated with threshold for possible biological effects.

For new contaminants, such as current use pesticides and other persistent contaminants of potential concern, coordinated **screening studies** are recommended. The main aim of these studies is to provide preliminary information on levels in the Arctic marine environment, so that the need for more comprehensive monitoring activities can be properly evaluated and the environmental behaviour of these substances can be better understood.

In relation to **human health** studies, attention is focussed on marine species used as foods by, in particular, indigenous peoples. These species should be collected in the same areas, and at the same time of year, as they are taken by indigenous peoples, sampling the same groups of animals (age, size, etc.) as those used for food. Involvement of indigenous peoples in providing the necessary information on consumed foods is critical to this work, and native hunters involved in sampling work, etc. should receive appropriate training in sample handling to avoid contamination, etc.

Further information on recommended methodologies (for sampling, storage, analysis, etc.), QA/QC considerations, data reporting, etc. can be found in sections E, F and G of this document.

## Media and Parameters - Marine (abiotic media)

| Media ➔ ↓Contaminant group | | Surficial sediment | Sediment cores❷ | Seawater | Sea ice |
|---|---|---|---|---|---|
| POPs (see Tables B.2 and B.3) | PAHs (see also Oil/PAH) | E | E | R ❸ | |
| | Planar-CB | R | E | E ❸ | |
| | PCB | R | E | E ❸ | |
| | DDT/DDE/DDD | R | E | E ❸ | |
| | HCH | R | E | E ❸ | |
| | HCB | R | E | E ❸ | |
| | Chlordane | R | E | E ❸ | |
| | Dieldrin | R | E | E ❸ | |
| | Toxaphene | R | E | E ❸ | |
| | PCDD/PCDF | R | R | | |
| | Annual Temporal Trend (POPs) | R | E ❷ | R ❸ | |
| Other persistent chemicals of potential concern (see Table B.2) | PCN | | R (ss) | R (ss) | |
| | CPs | | R (ss) | R (ss) | |
| | Current use pesticides | | | R (ss) | |
| | Other ❶ | | R (ss) | R (ss) | |
| TBT | TBT | ES | | | |
| Oil/PAH (see Table B.3) | Hydrocarbons, THC | ES | | R ❸ | ES |
| | Monoaromatics | | | R ❸ | R |
| | PAHs (see also POPs) | E | | R ❸ | ES |

| Media ➔ ↓Contaminant group | | Surficial sediment | Sediment cores❷ | Seawater | Sea ice |
|---|---|---|---|---|---|
| Heavy metals (see Table B.4) | Cd | R | ES ❷ | | |
| | Cu | R | ES ❷ | | |
| | Hg | R | ES ❷ | | |
| | Pb | R | ES ❷ | | |
| | Zn | R | ES ❷ | | |
| | Al | R | ES ❷ | | |
| | As | R | ES ❷ | | |
| | Annual Temporal Trend (HMs) | R | ES ❷ | | |
| Radioactivity | Gamma spectroscopy ❶ | E | | E | |
| | $^{90}Sr$ | ES | | E | |
| | $^{99}Tc$ | | | ES | |
| | $^{239,240}Pu$ | ES | | ES | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.

ES essential sub-regionally.

R recommended.

R(ss) recommended for inclusion in screening studies.

❍ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).

❶ Measurements of all gamma-emitting radionuclides.

❷ Generally one-time sampling, but chemical determination for as many individual 'year slices' as possible in each core. If repeated, cores should be sampled at intervals of not less than 5 years; in most cases > 10 years.

❸ Water and/or SPM (suspended particulate matter), as appropriate. In marine waters with low contaminant and SPM concentrations methodological considerations imply the need for large volume water samples.

## Media and Parameters - Marine (biotic media)

| Media ➔ ↓Contaminant group | | Macro -algae | Blue mussels | Whelks ❻ | Marine sculpin | Arctic cod / Cod | Ringed seal ❹ | Harbour porpoise ❹ | Beluga ❹ | Pilot whale | Walrus | Arctic fox ❹ | Polar bear ❹ | Eider | Black guillemot/ Alcids | Kittiwake | Glaucous gull ❹ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | Soft tissue | Soft tissue | Liver | Liver | (see notes) | (see notes) | (see notes) | (see notes) | (see notes) | Liver | (see notes) | (see notes) | (see notes) | Eggs | (see notes) |
| POPs (see Tables B.2 and B.3) | PAHs (see Oil/PAH) | | | | | | | | | | | | | | | | |
| | Planar-CB | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | PCB | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | DDT/DDE/DDD | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | HCH | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | HCB | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | Chlordane | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | Dieldrin | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | Toxaphene | | R | | E | ES | E (BB) | ES (BL) | E (BL) | ES (BL) | ES (BL) | E | E (FB) | | E (EG) | ES | E (BEL) |
| | PCDD/PCDF | | | | R | R | R (BB) | R (BL) | R (BL) | R (BL) | R (BL) | R | R (FB) | | R (EG) | R | R (BEL) |
| | Annual Temporal Trend (POPs) | | | | E | ES | E (BB) | | E (BL) | ES (BL) | | E | E (FB) | | E (EG) | | |
| Other persistent chemicals of potential concern (see Table B.2) | PCN | | | | | | R (ss) | | R (ss) | | | | | | | | |
| | CPs | | | | | | R (ss) | | | | | | | | | | |
| | Current use pesticides | | | | | | R (ss) | | | | | | | | | | |
| | Other ⓪ | | | | R (ss) | | R (ss) | | R (ss) | | | | | | | | |
| TBT | TBT | | R | E | | | R (L, BL, K, M) | R (L, BL, K, M) | R (L, BB) | | | | | R (EG, M) | | R | R (EG) |
| Oil/PAH (see Table B.3) | Hydrocarbons, THC | | R | | R ❼ | R ❼ | | | | | | | | | | | |
| | PAHs | | E | | ES ❺❼⑨ | ES ❺❼⑨ | | | | | | | | | | | |
| Heavy metals (see Table B.4) | Cd | | ES | | E | | E (L) ES (K) | ES (L) | ES (L, K) | ES (L, K) | ES (L, K) | R | ES (L) | ES (K) | E (L) ES (K) | | ES (L) |
| | Hg ⑧ | | ES | | E | | E (L) ES (B) | ES (L) | ES (L, B, BB) | ES (L, B) | | R | ES (L, K, H) | | E (L) R (F) | | ES (L) R (F) |

| Media ➔ ↓Contaminant group | | Macro -algae | Blue mussels | Whelks ❻ | Marine sculpin | Arctic cod / Cod | Ringed seal ❹ | Harbour porpoise ❹ | Beluga ❹ | Pilot whale | Walrus | Arctic fox ❹ | Polar bear ❹ | Eider | Black guillemot/ Alcids | Kittiwake | Glaucous gull ❹ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | Soft tissue | Soft tissue | Liver | Liver | (see notes) | (see notes) | (see notes) | (see notes) | (see notes) | Liver | (see notes) | (see notes) | (see notes) | Eggs | (see notes) |
| | Pb | | R | | | R | R (L) | | | | | R | | | | | R (L) |
| | Se | | | | E | | E (L) ES (B) | ES (L) | ES (L, B, BB) | ES (L, B) | | R | ES (L, K, B) | | E (L) | | ES (L) |
| | Annual Temporal Trend (HMs) | | ES | | ES | | ES (L, K, B) | | ES (L) | | | | | | | | |
| Radioactivity | Gamma spectroscopy ❶ | | E | | E ❽ (TU) | | E ❽ (TU) | | | | | | | | R | | R |
| | $^{90}$Sr | | ES | | E ❽ (TU) | | ES ❽ (TU) | | | | | | | | | | |
| | $^{99}$Tc | ES | ES | | ES ❽ (TU) | | ES ❽ (TU) | | | | | | | | | | |
| | $^{239,240}$Pu | | R | | | | | | | | | | | | | | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.
ES essential sub-regionally.
R recommended.
R(ss) recommended for inclusion in screening studies.
❍ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).
❶ Measurements of all gamma-emitting radionuclides.
❹ Included in POPs programme for linkage to biological effects monitoring.
❺ PAH metabolites, and Mixed Function Oxidase (MFO).
❼ Alternative species in addition to Sculpins and Arctic cod include Cod, capelin, flounder and long-rough dab.
❻ Whelks - Dogwhelk (N. lapillus), Whelks (N. lima), Common whelk (B. undatum).
❽ Species undefined (mainly species consumed for food).
⑧ MeHg should be measured in fish, birds, mammals and invertebrates (in addition to total Hg) at selected sites (e.g. contaminated sites with a significant contribution of inorganic Hg).
⑨ PAH measurements in fish liver are connected with monitoring around point sources associated with oil discharges (and/or potential oil discharges); relevant QA/QC is related to oil studies.

| | | | | | |
|---|---|---|---|---|---|
| M | Muscle | BB | Blubber/blood | EG | Eggs |
| L | Liver | FB | Fat/blood | F | Feathers |
| K | Kidney | BL | Blubber | H | Hair |
| B | Brain | BEL | Blood/eggs/liver | TU | Tissue undefined |

# AMAP Freshwater subprogramme

## Station Network

***Freshwater/Terrestrial subprogramme integration***

Although the freshwater and terrestrial components comprise two separate and distinct subprogrammes they are, for assessment purposes, often considered as a joint environment. To assess pathways and transport of contaminants and other interactions, freshwater and terrestrial activities should be integrated and implemented within the boundaries of the same key areas and/or monitoring stations. Atmospheric monitoring should also be included as an integrated activity where, for example, significant local sources of atmospheric emissions exist.

A limited number of 'background' and 'impact' key areas are planned to form the basic elements of the AMAP freshwater/terrestrial monitoring subprogrammes, and of supporting studies where most long- and short-term monitoring programmes should be implemented. These key areas (see Section A) comprise rather extensive areas within which different elements of the programme can be implemented at a number of sampling sites/stations. Where possible, freshwater monitoring activities should be co-located at the sites of existing stations, including those operated as part of other national and international initiatives, that can provide supplementary data and information on parameters such as river discharge, etc.

Concerning the two types of key areas:

- ***background key areas*** are areas where monitoring is intended to produce data on background levels of contamination and the general state of the freshwater ecosystems, including relevant observations to study climate change and UV-B effects;
- ***impact key areas*** are areas which the previous AMAP assessment (or other information) has identified as being subject to elevated levels of contamination, including those areas that are affected by a combination of pollution issues and thus relevant for the study of combined effects.

Areas used by indigenous peoples for fishing/hunting are prioritised in the monitoring programme, as will lakes where conditions for contaminant accumulation occur (sedimentation areas) or areas along important routes of freshwater pathways.

***Riverine flux stations*** should be established to provide information for the assessment of pollutant fluxes into the Arctic, and to the marine environment via riverine/freshwater systems. They should be established on large rivers, at locations:

- in the area of the southern boundary of the AMAP region, in order to assess riverine fluxes into the Arctic;
- at the (hydrological observation network) station closest to but upstream of the river mouth/estuary, in order to assess fluxes into the estuarine area (gross riverine flux).

Where possible, riverine flux stations should be located in freshwater/terrestrial key areas.

***Additional impact stations*** (i.e. outside of impact key areas) should be established in areas where, based on the results of the previous AMAP assessment or other information, the freshwater/terrestrial environment is, or potentially could be, significantly affected by one or more particular pollution issues (e.g., areas of oil exploration and production, pipeline routes, etc.).

***Combined effects freshwater stations*** should be integrated, wherever possible, with key areas. The objective of this type of station is to produce information on combined effects of contaminants (and/or other relevant environmental stressors) on the state of ecosystems. Monitoring programmes may include the following elements:

- impacting factors;
- characteristic ecosystem indicators (diversity and number of indicator species, biomass, etc.);
- contaminant levels in indicator species;
- responses of indicator species to biological effects tests that react to multiple contaminants and stressors.

## Sampling Strategies

The freshwater subprogramme covers monitoring activities in all relevant compartments of the freshwater environment and addresses spatial trends (mainly through studies in lakes), process studies, and temporal trend studies.

Monitoring to establish **temporal trends** involves two main approaches: retrospective trend analyses using dated sediment cores from undisturbed lakes, and annual sampling of a range of different species of fish. Both approaches require that there is a good knowledge of the lake or river systems concerned, e.g. to ensure that the same population of fish are sampled from year to year, etc. Fish species recommended include those caught for food; both anadromous and landlocked char are included in the programme, however, the latter are better suited for temporal trend studies.

**Spatial trends** should be conducted to fill gaps in geographical coverage, but also in connection with **subregional studies of acidification**, based on regional lake surveys and process studies in selected lakes, including intensive studies in small streams and lakes, e.g. to investigate the effects of spring flushing and acidic pulses.

**Process studies** included in the subprogramme focus in particular on riverine **transport and fluxes**, and **food-web studies** (including those species used as traditional or local foods).

In relation to **human health** studies, attention is focussed on freshwater species used as foods by, in particular, indigenous peoples. These species should be collected in the same areas, and at the same time of year, as they are taken by indigenous peoples, sampling the same fish (age, size, etc.) as those used for food. Freshwater bodies used for drinking water supply are also included, in particular in relation to studies concerning the health effects of radioactivity. Where possible, these studies should be combined with temporal trend monitoring work, in order to assess both changes over time in environmental contamination and also human intakes. Involvement of indigenous peoples in providing the necessary information on consumed foods is critical to this work.

Further information on recommended methodologies (for sampling, storage, analysis, etc.), QA/QC considerations, data reporting, etc. can be found in sections E, F and G of this document.

## Media and Parameters - Freshwater

| Media ➔ ↓Contaminant group | | Surficial sediment | Sediment cores ❷ | Lake and River water / SPM | Stream/ lake, intensive | Lake, regional | Lake, surveys | Ice | (Land-locked) Arctic char ❹ | Burbot ❿ | Lake trout / Pike ❿ | Loon (chicks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | | | | | | | Muscle | Liver | Muscle | Feathers |
| POPs (see Tables B.2 and B.3) | PAHs (see Oil/PAH) | | | | | | | | | | | |
| | Planar-CB | | E | ES | | | | | E | E | | |
| | PCB | | E | ES | | | | | E | E | | |
| | DDT/DDE/DDD | | E | ES | | | | | E | E | | |
| | HCH | | E | ES | | | | | E | E | | |
| | HCB | | E | ES | | | | | E | E | | |
| | Chlordane | | E | ES | | | | | E | E | | |
| | Dieldrin | | E | ES | | | | | E | E | | |
| | Toxaphene | | E | ES | | | | | E | E | | |
| | PCDD/PCDF | | R | R | | | | | R | R | | |
| | Annual Temporal Trend (POPs) | | E ❷ | | | | | | E | E | | |
| Other persistent chemicals of potential concern (see Table B.2) | PCN | | R (ss) | | | | | | | | | |
| | CPs | | R (ss) | R (ss) | | | | | | R (ss) | | |
| | Current use pesticides | | | R (ss) | | | | | | | | |
| | Other ⓪ | | R (ss) | R (ss) | | | | | | R (ss) | | |
| Oil/PAH (see Table B.3) | Hydrocarbons, THC | ES | | R | | | | R | R | | | |
| | Monoaromatics | | | R | | | | R | | | | |
| | PAHs | ES | E | R | | | | R | ES ❺ | ES ❺ | | |
| Heavy metals (see Table B.4) | Cd | | E ❷ | | | | | | | | | |
| | Cu | | E ❷ | | | | | | | | | |
| | Hg ⑧ | | E ❷ | | | | | | E | ES | ES | ES |
| | Pb | | E ❷ | | | | | | | | | |
| | Zn | | E ❷ | | | | | | | | | |
| | Cr | | E ❷ | | | | | | | | | |
| | Ni | | E ❷ | | | | | | | | | |

| Media ➔ ↓Contaminant group | | Surficial sediment | Sediment cores❷ | Lake and River water / SPM | Stream/ lake, intensive | Lake, regional | Lake, surveys | Ice | (Land-locked) Arctic char ❹ | Burbot ❿ | Lake trout / Pike ❿ | Loon (chicks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | | | | | | | Muscle | Liver | Muscle | Feathers |
| | As | | E ❷ | | | | | | | | | |
| | Se | | E ❷ | | | | | | E | ES | ES | |
| | Al | | R ❷ | | | | | | | | | |
| | Fe | | R ❷ | | | | | | | | | |
| | Annual Temporal Trend (HMs) | | E ❷ | | | | | | ES | | ES | |
| Radioactivity | Gamma spectroscopy ❶ | E | R | ES ❾ | | | | R | E ❽ | | | |
| | $^{137}Cs$ | | | ES ⑥ | | | | | | | | |
| | $^{90}Sr$ | | | ES ❾ | | | | | | | | |
| | $^{239,240}Pu$ | ES | | ES ❾ | | | | | | | | |
| Acidification | pH ($H^+$) | | | | ES | ES | ES | | | | | |
| | $SO_4$ | | | | ES | ES | ES | | | | | |
| | $NO_3$ | | | | ES | ES | ES | | | | | |
| | $NH_4$ | | | | ES | ES | ES | | | | | |
| | DOC | | | | ES | ES | ES | | | | | |
| | Mg | | | | ES | ES | ES | | | | | |
| | Ca | | | | ES | ES | ES | | | | | |
| | K | | | | ES | ES | ES | | | | | |
| | Na | | | | ES | ES | ES | | | | | |
| | Al labile | | | | ES | ES | ES | | | | | |
| | Cl | | | | ES | ES | ES | | | | | |
| | Conductivity | | | | ES | ES | ES | | | | | |
| | Si | | | | R | | R | | | | | |
| | Alkalinity | | | | ES | ES | ES | | | | | |
| | Ntot | | | | ES | ES | ES | | | | | |
| | Ptot | | | | ES | R | ES | | | | | |
| | CEC | | | | ES ③ | | | | | | | |

| Media ➔ ↓Contaminant group | | Surficial sediment | Sediment cores❷ | Lake and River water / SPM | Stream/ lake, intensive | Lake, regional | Lake, surveys | Ice | (Land-locked) Arctic char ❹ | Burbot ❿ | Lake trout / Pike ❿ | Loon (chicks) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | | | | | | | Muscle | Liver | Muscle | Feathers |
| | BS | | | | ES ③ | | | | | | | |
| | Corg | | | | ES ③ | | | | | | | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.
ES essential sub-regionally.
R recommended.
R(ss) recommended for inclusion in screening studies.
❶ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).
❶ Measurements of all gamma-emitting radionuclides.
❷ Generally one-time sampling, but chemical determination for as many individual 'year slices' as possible in each core. If repeated, cores should be sampled at intervals of not less than 5 years; in most cases > 10 years.
❾ River water
❹ Included in POPs programme for linkage to biological effects monitoring.
❺ PAH metabolites, and Mixed Function Oxidase (MFO).
❽ Species undefined (mainly species consumed for food).
❿ Burbot, lake trout and pike are alternative species for use in temporal trend monitoring studies; the most appropriate species can be selected on the basis of availability and relevance for other ongoing studies, etc.
③ Soil parameter - to be measured in combined aquatic/terrestrial acidification modelling.
⑥ Water used for drinking water.
⑧ MeHg should be measured in fish, birds, mammals and invertebrates (in addition to total Hg) at selected sites (e.g. contaminated sites with a significant contribution of inorganic Hg).

# AMAP Terrestrial subprogramme

## Station Network

***Terrestrial/Freshwater subprogramme integration***

Although the terrestrial and freshwater components comprise two separate and distinct subprogrammes they are, for assessment purposes, often considered as a joint environment. To assess pathways and transport of contaminants and other interactions, terrestrial and freshwater activities should be integrated and implemented within the boundaries of the same key areas and/or monitoring stations. Atmospheric monitoring should also be included as an integrated activity where, for example, significant local sources of atmospheric emissions exist.

A limited number of 'background' and 'impact' key areas are planned to form the basic elements of the AMAP terrestrial/freshwater monitoring subprogrammes, and of supporting studies where most long- and short-term monitoring programmes should be implemented. These key areas (see Section A) comprise rather extensive areas within which different elements of the programme can be implemented at a number of sampling sites/stations. Where possible, terrestrial monitoring activities should be co-located at the sites of existing stations, including those operated as part of other national and international initiatives, that can provide supplementary data and information.

Concerning the two types of key areas:

- ***background key areas*** are areas where monitoring is intended to produce data on background levels of contamination and the general state of the terrestrial ecosystems, including relevant observations to study climate change and UV-B effects;
- ***impact key areas*** are areas which the previous AMAP assessment (or other information) has identified as being subject to elevated levels of contamination, including those areas that are affected by a combination of pollution issues and thus relevant for the study of combined effects.

Areas used by indigenous peoples for hunting and gathering of traditional foods are prioritised in the monitoring programme.

***Additional impact stations*** (i.e. outside of impact key areas) should be established in areas where, based on the results of the previous AMAP assessment or other information, the terrestrial/freshwater environment is, or potentially could be, significantly affected by one or more particular pollution issues (e.g., areas of oil exploration and production, pipeline routes, etc.).

***Combined effects terrestrial stations*** should be integrated, wherever possible, with key areas. The objective of this type of station is to produce information on combined effects of contaminants (and/or other relevant environmental stressors) on the state of ecosystems. Monitoring programmes may include the following elements:

- impacting factors;
- characteristic ecosystem indicators (diversity and number of indicator species, biomass, etc.);

- contaminant levels in indicator species;
- responses of indicator species to biological effects tests that react to multiple contaminants and stressors.

## Sampling Strategies

The terrestrial subprogramme covers monitoring activities in all relevant compartments of the terrestrial environment and addresses spatial trends, process studies, and temporal trend studies.

Monitoring to establish **temporal trends** involves two main approaches: retrospective trend analyses using peat and ice cores, and annual sampling of reindeer/caribou. Both approaches require that there is a good knowledge of the system/reindeer population concerned.

**Spatial trends** should be conducted to fill gaps in geographical coverage, especially for reindeer, but also in connection with **subregional studies for acidification**, based on regional soil surveys and more intensive soil (and soil water) studies in selected areas (effects of acidification on vegetation are covered under the effects programme - see Section C).

**Process studies** included in the subprogramme focus in particular on and **food-web studies** (including those species used as traditional or local foods), and studies concerning biological effects in terrestrial birds. Information on uptake of contaminants and their movement through terrestrial food chains is a key requirement for the exposure/dose modelling work being conducted as part of the AMAP radioactivity assessment work.

The need to establish better linkages between contaminants monitoring and **effects studies** is reflected in the selection of species of birds which were identified during AMAP phase 1 as exhibiting levels of contaminants, in particular POPs, that were associated with threshold for possible biological effects.

In relation to **human health** studies, attention is focussed on reindeer and bird and plant species used as foods by, in particular, indigenous peoples. These species should be collected in the same areas, and at the same time of year, as they are taken by indigenous peoples, sampling the same groups of plants/animals (age, size, etc.) as those used for food. Milk is also included, in particular in relation to studies concerning the health effects of radioactivity. Where possible, these studies should be combined with temporal trend monitoring work, in order to assess both changes over time in environmental contamination and also human intakes. Involvement of indigenous peoples in providing the necessary information on consumed foods is critical to this work.

Further information on recommended methodologies (for sampling, storage, analysis, etc.), QA/QC considerations, data reporting, etc. can be found in sections E, F and G of this document.

## Media and Parameters - Terrestrial (abiotic media)

| Media ➔ ↓Contaminant group | | Topsoil | Soil mineral layer, intensive | Soil humus layer, intensive | Soil solution, intensive | Soil, regional | Peat cores | Snowpack | Ice cap cores |
|---|---|---|---|---|---|---|---|---|---|
| POPs (see Tables B.2 and B.3) | PAHs | ES | | | | | R / ES | R ④ | |
| | Planar-CB | | | | | | R | | |
| | PCB | | | | | | R | | |
| | DDT/DDE/DDD | | | | | | R | | |
| | HCH | | | | | | R | | |
| | HCB | | | | | | R | | |
| | Chlordane | | | | | | R | | |
| | Dieldrin | | | | | | R | | |
| | Toxaphene | | | | | | R | | |
| | PCDD/PCDF | | | | | | R | | |
| | Annual Temporal Trend (POPs) | | | | | | R ❷ | | |
| Oil/PAH (see Table B.3) | Hydrocarbons, THC | R | | | | | R | R④ | |
| | Monoaromatics | R | | | | | R | R④ | |
| | PAHs (see POPs) | | | | | | | | |
| Heavy metals (see Table B.4) | Cd | ES | | | | | ES ❷ | | ES ❷ |
| | Cu | ES | | | | | ES ❷ | | ES ❷ |
| | Hg | ES | | | | | ES ❷ | | ES ❷ |
| | Pb | ES | | | | | ES ❷ | | ES ❷ |
| | Zn | ES | | | | | ES ❷ | | ES ❷ |
| | Cr | ES | | | | | ES ❷ | | ES ❷ |
| | Ni | ES | | | | | ES ❷ | | ES ❷ |
| | As | ES | | | | | ES ❷ | | ES ❷ |
| | Se | ES | | | | | ES ❷ | | ES ❷ |
| | Annual Temporal Trend (HMs) | | | | | | ES ❷ | | ES ❷ |
| Radioactivity | Gamma spectroscopy ❶ | E | | E | | | ES | | |

| Media ➔ ↓Contaminant group | | Topsoil | Soil mineral layer, intensive | Soil humus layer, intensive | Soil solution, intensive | Soil, regional | Peat cores | Snowpack | Ice cap cores |
|---|---|---|---|---|---|---|---|---|---|
| | $^{137}Cs$ | | | | | | | | |
| | $^{90}Sr$ | R | | | | | | | |
| | $^{239,240}Pu$ | R | | | | | | | |
| Acidification | pH ($H^+$) | | ES | ES | ES | R | | | |
| | $SO_4$ | | | | ES | | | | |
| | $NO_3$ | | | | ES | | | | |
| | $NH_4$ | | | | R | | | | |
| | DOC | | | | ES | | | | |
| | Mg | | | ES | ES | R | | | |
| | Ca | | | ES | ES | R | | | |
| | K | | | ES | ES | R | | | |
| | Na | | | | R | | | | |
| | Al (labile) | | | | R | | | | |
| | Cl | | | | R | | | | |
| | Conductivity | | | | ES | | | | |
| | Si | | | | R | | | | |
| | Alkalinity | | | | R | | | | |
| | Ntot | | ES | ES | | R | | | |
| | Ptot | | | ES | R | R | | | |
| | CEC | | ES | R | | ES | | | |
| | BS | | ES | R | | ES | | | |
| | Corg | | ES | ES | | R | | | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.
ES essential sub-regionally.
R recommended.
❶ Measurements of all gamma-emitting radionuclides.
❷ Generally one-time sampling, but chemical determination for as many individual 'year slices' as possible in each core. If repeated, cores should be sampled at intervals of not less than 5 years; in most cases > 10 years.
④ In connection with oil spills on snow.

## Media and Parameters - Terrestrial (biotic media)

| Media ➔ ↓Contaminant group | | Milk | Biota (unspecified) | Lichens | Mosses | Mushrooms | Higher plants | Reindeer/ caribou | Rock ptarmigan / Grouse | Peregrine falcon ❹ | Merlin | White-tailed sea eagle ❹ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | | | Whole | Green parts | | | (see notes) | (see notes) | Eggs/ Blood | Eggs | Eggs |
| POPs (see Tables B.2 and B.3) | PAHs | | R (TU) | | | | | | | | | |
| | Planar-CB | | | | | | | E (L) ② | | ES | ES | ES |
| | PCB | | | | | | | E (L) ② | | ES | ES | ES |
| | DDT/DDE/DDD | | | | | | | E (L) ② | | ES | ES | ES |
| | HCH | | | | | | | E (L) ② | | ES | ES | ES |
| | HCB | | | | | | | E (L) ② | | ES | ES | ES |
| | Chlordane | | | | | | | E (L) ② | | ES | ES | ES |
| | Dieldrin | | | | | | | E (L) ② | | ES | ES | ES |
| | Toxaphene | | | | | | | E (L) ② | | ES | ES | ES |
| | PCDD/PCDF | | | | | | | R (TU) | | R | R | R |
| | Annual Temporal Trend (POPs) | | | | | | | E (L) ② | | | | |
| Oil/PAH (see Table B.3) | PAHs (see POPs) | | | | | | | | | | | |
| Heavy metals (see Table B.4) | Cd | | | E ① | E ① | ES ① | | E (L) ES (K) | E (L) ES (K) | | | |
| | Hg ⑧ | | | E ① | E ① | ES ① | | E (L) | E (L) ES (K) R (F) | | | |
| | Se | | | E ① | E ① | ES ① | | E (L) ES (K) | E (L) ES (K) | | | |
| | Annual Temporal Trend (HMs) | | | | | | | ES (L) ES (K) | | | | |
| Radioactivity | $^{137}$Cs | E ⓪ | E (TA❽) | E | | E | R (P) E (BE) | E | | | | |
| | $^{90}$Sr | E ⓪ | R (TA❽) | E | | | R (P) | R | | | | |
| | $^{210}$Po | | | | | | | E | | | | |
| | $^{239,240}$Pu | | | ES | R | | R (P) | | | | | |
| | | | | | | | | | | | | |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.

ES essential sub-regionally.

R recommended.

❶ Measurements of all gamma-emitting radionuclides.

❹ Included in POPs programme for linkage to biological effects monitoring.

❽ Species undefined (mainly species consumed for food).

⓪ Milk from cow, sheep, goat, reindeer - variation between areas.

① As part of food web studies.

② Sampling of other tissues (e.g. kidney, muscle) should be continued if part of ongoing trend studies.

⑧ MeHg should be measured in fish, birds, mammals and invertebrates (in addition to total Hg) at selected sites (e.g. contaminated sites with a significant contribution of inorganic Hg).

P Plants in human diet.

BE Berries.

TA Terrestrial animals.

L Liver.

K Kidney.

F Feathers.

TU Tissue undefined.

# AMAP Human health subprogramme

## Station Network

To facilitate efficient integration of information from the human health monitoring subprogramme with that on, e.g., contaminant intake from consumed foods, communities monitored under the human health subprogramme should be geographically co-located with key areas designated for contaminant monitoring activities.

Additional human health monitoring should be conducted in other important areas of settlement of indigenous and local populations; again, where possible, these should studies be combined with those at additional terrestrial/freshwater and/or marine impact stations.

## Sampling Strategies

The basic strategy for the subprogramme, as developed by the AMAP human health expert group, involves integration of the human health studies with other components of the AMAP Trends and Effects Programme, the main focus being assessment of the **effects of contaminants or pollution issues** (both individually and combined) on human health. The other components of the programme, therefore provide supporting information from studies of species used for food, etc. Dietary surveys conducted as part of the human health studies will to some extent determine the animals and plants included in the of activities under subprogrammes.

Ethical considerations have been fully taken into account in development and implementation of the subprogramme.

The main media sampled is blood (maternal and cord blood, preferably from mother-child pairs); some analyses (e.g. dioxins/furans) require large volumes of blood and thus pooling of samples, hence their inclusion only as recommended parameters.

The studies should cover both indigenous and non-indigenous (i.e. local) Arctic populations, however, due to the high intakes of contaminants by some indigenous peoples as a result of their traditional diets, the human health work in many countries focuses on indigenous peoples.

A main effort of the human health subprogramme continues to be the establishment of **spatial trends** in contaminant levels in humans, and linking this, through specific **epidemiological and dietary surveys**, etc., to possible health effects and routes of exposure. Information on nutrition status, drinking water quality and air quality, etc. are required for assessment purposes, but should be based, as far as possible, on existing information and new activities should only be initiated where such information is lacking. Efforts are being made to harmonise key questions to be included in regionally-tailored human health questionnaires.

Monitoring of contaminant levels in consumed species to assess exposure is a priority issue in integrated work linking the human health and marine, freshwater and terrestrial monitoring subprogrammes.

Repeated studies in some areas are used as the basis for **temporal trend** assessments, in particular for POPs and, on a subregional basis, for heavy metals.

The human health studies are typically looking at sustained exposures and contaminant accumulation by individuals over long periods of time; the lag-time between exposure and effects is a confounding issue that needs to be taken into account and that temporal trend information may help to resolve.

## Media and Parameters

| Media ➔ ↓Contaminant group | | Human | Human | Human | Human | Human | Human | Other |
|---|---|---|---|---|---|---|---|---|
| Tissue ➔ | | Maternal Blood | Cord Blood | Breast milk | Urine | Hair | Wholebody | - |
| Persistent Organic Compounds (see Tables B.2 and B.3) | PAHs | R | | | | | | |
| | Planar-CB | R | R | R | | | | |
| | PCB | E | R | R | | | | |
| | DDT/DDE/DDD | E | R | R | | | | |
| | HCH | E | R | R | | | | |
| | HCB | E | R | R | | | | |
| | Chlordane | E | R | R | | | | |
| | Dieldrin | E | R | R | | | | |
| | Toxaphene | E | R | R | | | | |
| | PCDD/PCDF | R | R | R | | | | |
| | Temporal Trend (POPs) | E | | R | | | | |
| Other persistent chemicals of potential concern (see Table B.2) | PCN | | | R (ss) | | | | |
| | CPs | | | R (ss) | | | | |
| | Current use pesticides | | | R (ss) | | | | |
| | Other ⓪ | | | R (ss) | | | | |
| Heavy metals (see Table B.4) | Cd | E | | | R | | | |
| | Hg (total Hg) | E | R | | | R | | |
| | Pb | E | R | | | | | |
| | Ni | | | | ES | | | |
| | As | | | | R | R | | |
| | Se | E | R | | | R | | |
| | Temporal Trend (HMs) | ES | | | | | | |
| Radioactivity | $^{137}Cs$ | | | | | | E | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Human Health | Dietary/lifestyle questionnaire | | | | | | | E |
| | Contaminants in species/tissues relevant to local dietary habits, Including drinking water | | | | | | | E |

E essential for all countries and key Arctic sites. These components of the programme are highlighted in the table by shading.
ES essential sub-regionally.
R recommended.
R(ss) recommended for inclusion in screening studies.
⓪ Other persistent chemicals of potential concern, e.g., PBDE, PCDE, PCP, TCPM, BCPS, etc. (see Table B.2 for abbreviations).

## *Table B.1. Subprogramme harmonisation: An overview of compartments and species common to several subprogrammes.*

Considerable efforts have been made to rationalise the components of the AMAP Trends and Effects Programme, especially with respect to sampling media and species. Recommendations made by the groups dealing with different pollution issues have thus been harmonized to allow samples to be collected that will meet the requirements of several programme elements, as indicated in the following table.

E - includes 'Essential' measurements
ES or R - includes 'Essential Subregional' or 'Recommended' measurements

| **Subprogramme** | **Media/Species** | **Contaminants** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *POPs* | *Heavy metals* | *Radio-activity* | *TBT* | *Oil* | *PAH* | *Acidific-ation* |
| *Atmosphere* | Air/aerosol | E | E | E | | ES or R | ES or R | E |
| | Bulk precipitation | ES or R | ES or R | ES or R | | | E | ES or R |
| | Snowpack | | ES or R | | | | ES or R | ES or R |
| | Glacial cores | E | | | | | | |
| *Marine* | Surface sediment | ES or R | ES or R | E | ES or R | ES or R | E | |
| | Sediment cores | E | ES or R | | | | E | |
| | Seawater / SPM | E | | E | | ES or R | ES or R | |
| | Sea ice | | | | | ES or R | ES or R | |
| | Macro-algae | | | ES or R | | | | |
| | Blue mussels | ES or R | ES or R | E | ES or R | ES or R | E | |
| | Whelks | | | | E | | | |
| | Sculpin | E | E | E | | ES or R | ES or R | |
| | Other fish (cod, capelin, flounder, etc.) | ES or R | ES or R | E | | ES or R | ES or R | |
| | Ringed seal | E | E | E | ES or R | | | |
| | Harbour porpoise | ES or R | ES or R | | ES or R | | | |
| | Pilot whale | ES or R | ES or R | | | | | |
| | Beluga | E | ES or R | | ES or R | | | |
| | Walrus | ES or R | ES or R | | | | | |
| | Polar bear | E | ES or R | | | | | |
| | Arctic fox | E | ES or R | | | | | |
| | Eider | | ES or R | | ES or R | | | |
| | Black guillemot/Alcids | E | E | ES or R | | | | |
| | Kittiwake | ES or R | | | ES or R | | | |
| | Glaucous gull | E | ES or R | | ES or R | | | |
| *Freshwater* | Surface sediment | | | E | | ES or R | ES or R | |
| | Sediment cores | E | E | ES or R | | | E | |
| | Lake / river water / SPM | ES or R | | ES or R | | ES or R | ES or R | ES or R |
| | Ice | | | ES or R | | ES or R | | |
| | Arctic char | E | E | ES or R | | | ES or R | |
| | Burbot / Lake trout / Pike | E | ES or R | ES or R | | | ES or R | |
| | Loon | | ES or R | | | | | |

| **Subprogramme** | **Media/Species** | **Contaminants** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *POPs* | *Heavy metals* | *Radio-activity* | *TBT* | *Oil* | *PAH* | *Acidific-ation* |
| *Terrestrial* | Topsoil | | ES or R | E | | ES or R | ES or R | ES or R |
| | Soil (mineral / humic) layers | | | E | | | | |
| | Peat cores | ES or R | ES or R | ES or R | | ES or R | ES or R | |
| | Snowpack | | | | | ES or R | ES or R | |
| | Ice cores | | ES or R | | | | | |
| | Lichens | | E | E | | | | |
| | Mosses | | E | ES or R | | | | |
| | Mushrooms | | ES or R | E | | | | |
| | Higher plants | | | ES or R | | | | |
| | Reindeer/caribou | E | E | E | | | | |
| | Other terrestrial animals | ES or R | ES or R | E | | | | |
| | Ptarmigan / Grouse | | E | | | | | |
| | Peregrine falcon | ES or R | | | | | | |
| | Merlin | ES or R | | | | | | |
| | White-tailed sea eagle | ES or R | | | | | | |
| *Human health* | Blood | E | E | | | | ES or R | |
| | Other human media | ES or R | ES or R | ES or R | | | | |
| | Traditional food items (marine, freshwater, terrestrial) | E | E | E | | | ES or R | |

## *Table B.2. Detailed list of POPs to be analysed under the monitoring programme.*

| Group | Individual components | Programme status | Notes |
|---|---|---|---|
| *Chlorobenzenes* | HCB | E | |
| | Pentachlorobenzene | R | |
| | Tetrachlorobenzenes | R | 2-isomers |
| *Hexachlorocyclohexanes* | α-HCH, β-HCH, γ-HCH | E | |
| *Chlordanes* | *cis*- & *trans*-chlordane | E | |
| | *cis*- & *trans*-nonachlor | E | |
| | oxychlordane | E | |
| | MC4, MC5, MC6 | R | major components of technical chlordane |
| *Heptachlor* | heptachlor | R | |
| | heptachlor epoxide | E | |
| *DDT* | 4,4'-DDE, -DDD, -DDT | E | |
| | 2,4'-DDE, -DDD, -DDT | R | |
| *Mirex* | mirex | R | |
| | photomirex | R | |
| *Toxaphene* | toxaphene | E | quantified with standard of technical material |
| | Parlar congeners 26, 50, 62 | R | quantify in marine mammals and piscivorous fishes |
| *Dieldrin/endrin* | dieldrin | ES | lost during H2SO4 cleanup; also has programme status E and R for certain components |
| | endrin | R | lost during H2SO4 cleanup; also has programme status E and R for certain components |
| *PCDD/PCDF* | 2,3,7,8-substituted tetra- to octachloro dibenzo-p-dioxins and dibenzofurans | R | analysis by HRMS recommended |
| *Non-ortho PCBs (coplanars)* | CB77, 126 and 169 | R | analysis by HRMS recommended |
| *PCB congeners ($\Sigma PCB_7$)* | CB 28/31,52,101/90,118, 138, 153, 180 | E | “ICES 7" |

| Group | Individual components | Programme status | Notes |
|---|---|---|---|
| *PCB congeners ($\Sigma PCB_{30}$)* | 8/5, 18, 28, 31, 44, 49, 52, 95/66, 87, 99, 101, 105/132, 110, 118, 128, 146, 149, 151, 153, 138/163, 156, 183, 187, 201/157, 170, 180, 194,195, 206, 209 | R | Based on congeners certified in NIST cod liver SRM1588 and whale blubber SRM1945<br><br>PCB 8/5 can be omitted for air monitoring where they are probably not possible to sample with a high-volume sampler |
| *Current use pesticides* | atrazine, chlorpyrifos, α- and β-endosulfan, pentachloroanisole, pentachlorophenol (PCP) | R | Mainly in air and water, not biota |
| *Other POPs* | Polybrominated diphenyl ethers (PBDE)<br>Polychlorinated diphenyl ethers (PCDEs)<br>*Tris* (4-chlorophenol)methane (TCPM)<br>*Tris* (4-chlorophenol)methanol (TCPMOH)<br>PCB sulfones<br>*Bis*-(4-chlorophenol)sulfone (BCPS) | R<br>R<br>R<br>R<br><br>R | Analytical standards and methods not widely available |
| *Polychlorinated naphthalenes* | PCNs | R | Analytical standards and methods not widely available |
| *Short chain chlorinated paraffins (CP)* | C10-C13 chlorinated alkanes | R | Analytical standards and methods not widely available |

## *Table B.3. Detailed list of PAHs and petroleum hydrocarbons to be analysed under the monitoring programme.*

| **Petroleum hydrocarbons** |
|---|
| **Total hydrocarbons (THC)** |
| **Monoaromatic hydrocarbons** |

Target parent and alkylated PAH (including some oil-derived sulphur heterocyclic compounds) for environmental monitoring. The 6 PAHs listed in bold represent the priorities in (sediment) monitoring programmes designed to investigate levels and trends.

| **Compound** | **MW** | **Compound** | **MW** |
|---|---|---|---|
| Naphthalene | 128 | $C_2$- Phenanthrenes/Anthracenes | 206 |
| **$C_1$-Naphthalenes** | 142 | $C_3$- Phenanthrenes/Anthracenes | 220 |
| $C_2$-Naphthalenes | 156 | **Fluoranthene** | 202 |
| $C_3$-Naphthalenes | 170 | Pyrene | 202 |
| $C_4$-Naphthalenes | 184 | $C_1$- Fluoranthenes/Pyrenes | 216 |
| Acenaphthylene | 152 | $C_2$- Fluoranthenes/Pyrenes | 230 |
| Acenaphthene | 154 | Benz[*a*]anthracene | 228 |
| Biphenyl | 154 | Chrysene | 228 |
| **Fluorene** | 166 | 2,3-Benzanthracene | 228 |
| $C_1$-Fluorenes | 180 | Benzo[*a*]fluoranthene | 252 |
| $C_2$-Fluorenes | 194 | Benzo[*b*]fluoranthene | 252 |
| $C_3$-Fluorenes | 208 | Benzo[*j*]fluoranthene | 252 |
| Dibenzothiophene | 184 | Benzo[*k*]fluoranthene | 252 |
| $C_1$-Dibenzothiophene | 198 | Benzo[*e*]pyrene | 252 |
| $C_2$-Dibenzothiophene | 212 | **Benzo[*a*]pyrene** | 252 |
| $C_3$-Dibenzothiophene | 226 | Perylene | 252 |
| **Phenanthrene** | 178 | Indeno[1,2,3-*cd*]pyrene | 276 |
| Anthracene | 178 | Benzo[*ghi*]perylene | 276 |
| **$C_1$-Phenanthrenes/Anthracenes** | 192 | Dibenz[*ah*)anthracene | 278 |

## *Table B.4. Priority list of heavy metals to be analysed under the monitoring programme.*

| **Metals** | **Atmospheric media** | **Marine media** | | **Freshwater media** | | **Terrestrial media** | | **Human media** |
|---|---|---|---|---|---|---|---|---|
| | | abiotic | biotic | abiotic | biotic | abiotic | biotic | |
| *Cd* | x | x | x | x | | x | x | x |
| *Cu* | x | x | | x | | x | | |
| *Hg** | x | x | x | x | x | x | x | x |
| *Pb* | x | x | x | x | | x | | x |
| *Zn* | x | x | | x | | x | | |
| *Cr* | x | | | x | | x | | |
| *Ni* | x | | | x | | x | | x |
| *As* | x | x | | x | | x | | x |
| *Se* | x | | x | x | x | x | x | x |
| *Al* | x | x | | x | | | | |
| *Fe* | | | | x | | | | |
| *V* | x | | | | | | | |

* see table below for Hg speciation considerations

**Mercury speciation measurement selection**

| Compartment | $Hg^{o}_{g}$ | $Hg^{\#}_{g}$ | $Hg^{TOT}_{p}$ | THg | MeHg |
|---|---|---|---|---|---|
| Air | X | X | X | | |
| Precipitation | | | | X | |
| Sediments | | | | X | |
| Fish | | | | X | X[*1] |
| Birds | | | | | X[*1] |
| Mammals | | | | X | X[*1] |
| Invertebrates | | | | X | X[*1] |
| Plants | | | | X | |
| Other biota | | | | X | |

$Hg^{o}_{g}$ elemental mercury in gaseous form
$Hg^{\#}_{g}$ bivalent mercury in gaseous form
$Hg^{TOT}_{p}$ total mercury on particles
THg total mercury
MeHg methyl mercury
*1 relates to measurements at selected sites, e.g. contaminated sites with significant contribution of inorganic mercury

## *Table B.5. List of supporting/interpretational parameters to be measured under the monitoring programme.*

**All components**: Location (at least approximate geographical coordinates) and time (date at least) of sample collection, information on methodologies employed.

**Biological samples**: Parameters including age, sex, size (length, weight, shell size, blubber thickness, etc.), condition of animal, nutritional status, sexual maturity, reproductive status, lipid content, etc.

**Sediment studies**: Normalization parameters such as grain size, organic carbon, lithium, aluminium, etc.

**Water samples**: Suspended particulate matter concentration; temperature, salinity, pH, etc., if relevant.

**Air samples**: Temperature, wind direction, particle concentrations, etc., if relevant.

**Core sample analysis**: Sample dating parameters (radioisotope analyses, etc.), observations of state of sediment (top layer present/intact/disturbed, etc.), estimated deposition rates, etc.

**Food-web studies**: Trophic level of organisms, e.g. stable isotope ratios.

## *Table B.6. List of areas considered essential for monitoring under subregional programmes*

**POPs:**

*Marine biotic media*

Arctic cod / cod - Norway, Iceland

Harbour porpoise - Norway

Pilot whale - Faeroe Islands

Walrus - Canada, Norway

Kittiwake - Norway

Glaucous gull - Norway (in connection with effects studies)

*Freshwater abiotic media*

Lake and river water - Russia

*Terrestrial biotic media*

Peregrine falcon - Sweden, Canada, US

Merlin - Norway

Sea eagle - Sweden, Norway

**Heavy metals:**

*Atmospheric media*

Air/aerosol - background air monitoring network stations, areas with local sources of heavy metal pollution

Bulk precipitation - areas with local sources of heavy metal pollution

Snowpack - northern Russia

*Marine abiotic media*

Sediment cores - Russian shelf-seas, Beaufort Sea, Canadian Arctic Archipelego, Arctic Ocean, Davis Straight/Baffin Bay, Nordic Seas, Barents Sea.

*Marine biotic media*

Blue mussels - all coastal areas where blue mussels are found/sampled

Ringed seal, harbour porpoise, beluga, pilot whale, polar bear - areas where these species are found/sampled

Glaucous gull - areas where this species is found/sampled

*Freshwater biotic media*

Freshwater fish (and loon) - northern Russia, areas where freshwater fish are important to local diet

*Terrestrial abiotic media*

Topsoil - northern Russia

Peat cores - northern Russia, Alaska, northern Canada

Ice cap cores - Arctic Island archipelegos, Greenland

*Terrestrial biotic media*

Mushrooms - northern Russia

Reindeer and ptarmigan kidney - areas where these species are important to local diet

**Acidification:**

Kola peninsula, Norwegian-Finnish-Swedish-Russian border area, Norilsk

**Radioactivity:**

*Marine media*

Sediments - Sr: Ob and Yenisey estuaries, close to dumpsites and nuclear waste storage sites. Pu: European Arctic

Seawater - Pu and Tc: European Arctic

Biota - Tc in seaweed: European Arctic

*Freshwater media*

Rivers - Ob, Yenisey (Russia)

**Oil and petroleum hydrocarbons:**

Areas of oil exploration, exploitation and transport, shipping routes and fishing areas, including ports.

**TBT:**

Harbours and shipping routes

**Human health:**

Ni in urine - northern Norway, Kola peninsula, Norilsk