2nd Meeting

Environmental Contamination in Antarctica

St. Petersburg, 7 July 2008

Report

Summary

The Action Group, for Environmental Contamination in Antarctica (ECA), held its meeting in St Petersburg the 7th July 2008. The data collected by the groups formed during the workshop hold in Venice where was presented and discussed.

The workshop was organized to discuss the following themes related to Antarctic enviromnents:

- Contamination in terrestrial water and soil environments.
- Heavy Metals Occurrence in snow and ice.
- Presence and distribution of POPs in environmetal matrices.
- Trace elements in water and sediment of the southern ocean.

In order to integrate and to facilitate access at the collected data and information the organization of the data base of the Joint SCAR-COMNAP Committee on Antarctic Data Management (JCADM) and the Data Management of the ECA Action Group was also discussed.

A literature data survey was also performed on trace and minor elements in biota in Antarctica and other polar regions. The argument did not was discussed during the workshop but is an important argument to be considered in consideration the use of organisms as indicator of the environment quality.

At the end of the workshop were identified the priority for the future activities:

- to support the integration of the ECA data base in the JCADM by construction of one dedicated portal;
- to recognize and separate local sources (bases, aircrafts, ships, traverses) from global contaminant signatures by identifying proxies of the potential sources. In this activity, the national responsible for the application of the Madrid protocol relevant to the environmental impact monitoring of the logistic and scientific activities should be involved;
- to optimize the use of samples collected for environmental characterization purposes and warranty reliable data by:
  - defining the role of specimen banks (international collaboration)
  - organizing proficiency tests for trace contaminant determination in environmental matrices which should take into account the possibility of preparing specific Antarctic reference materials;
- to organize the third ECA workshop aimed at:
  - completing datasets for environmental contaminants;
  - identifying gaps in the existing data;
  - defining topics for joint research projects on environmental contamination in Antarctica.

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Contamination in terrestrial water and soil environments in Antarctica

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A review of the knowledge pertaining to contamination of the terrestrial water and soil environments in Antarctica will provide a comprehensive assessment of the *published* information available on contaminant concentrations, behaviour and trends over time (where available) in the ice-free regions of the Antarctic Continent. The review also seeks to highlight where there are gaps in the existing information, and prioritise requirements for further data collection. A knowledge of contaminant behaviour and trends in terrestrial matrices is of significant interest when predicting the influence of global warming on terrestrial ecosystems. Increased availability and movement of water, and greater biological productivity, will enhance the cycling of many contaminants in this environment.

The principal ice-free areas occur in the Transantarctic Mountains, and include the McMurdo 'Dry Valleys' region (Fig 1). However, smaller areas of ice-free land also occur in the Prince Charles Mountains on the edge of the East Antarctic ice sheet, in Queen Maud Land, the Ellsworth Mountains, on the Antarctic Peninsula and its islands, and in Marie Byrd Land, and there are numerous small seasonally ice-free zones on the coastal fringe of the continent. Consequently this report will focus mainly on the ice-free regions of Transantarctic Mountains but include relevant data from other ice free regions where available.

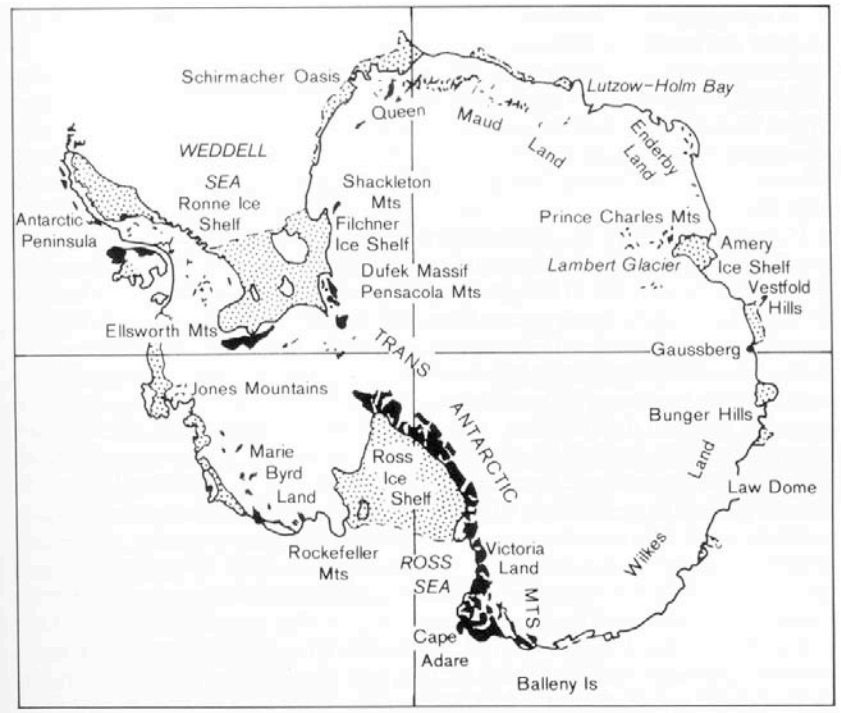

Figure 1. Distribution of ice free regions of Antarctica (Campbell & Claridge, 1987).

The review is being been undertaken in two parts; the first focussing on locally derived contaminants (i.e., from human activity on the continent), and the second on the measurement

of global contaminants in terrestrial environments. The review excludes marine systems, including coastal and tidal marine sediments and waters, and terrestrial biota (including aquatic biota) as both are to be covered in other reviews undertaken by ECA. It also excludes literature on the developments of improved analytical methods for the analysis of low level contaminants in Antarctic samples.

Part I: Contamination due to human activity on the continent

Data is being compiled on the concentrations of various locally-derived contaminants in meltwaters (lakes, pond and streams) and soils/sediments in ice-free terrestrial environments, specifically for:

i) Fuel and hydrocarbon derivatives (e.g., PAHs)
ii) Trace elements
iii) Synthetic organic molecules (e.g., POPs)
iv) Natural organic substances
v) Nutrients
vi) Radioactive elements

The most comprehensive datasets are for PAH and trace element contamination of soils in the vicinity of stations. Geographical coverage is good, with representative research undertaken at Indian, Australian, New Zealand, Italian, US and Argentine bases. In the ice-free regions of Transantarctic Mountains, there are data available for trace element concentrations in meltwater drainage systems, particularly the lakes of the McMurdo Dry Valleys, further south, and at Terra Nova Bay. However, there is little or no evidence of contamination in these lakes, and these data are being used to establish baseline conditions and to understand factors affecting trace element behaviour and mobility in these drainage systems.

There appears to be little information available on locally generated synthetic organic contaminants, other than a study of PCB and PBDE in soils at a single base. Similarly, the effects of natural organic substances (such as those contained in sewage) on terrestrial environments appear to have received little attention. The effects of local anthropogenic nutrient (nitrogen and phosphorous) enrichment are largely unknown, although nitrogen flux into the Taylor Valley as a consequence of localised fossil fuel burning has been investigated. Given the likely sensitivity of terrestrial aquatic ecosystems to the addition of nutrients, this would appear to be an important focus for future research. The effects of sewage discharge on the marine environments close to coastal bases have, of course, received more attention.

There appears to be very limited data available for the concentrations of locally derived radioactive elements in the water and soil components of terrestrial environments.

Interim conclusion: An immediate gap in the current knowledge base is information on the concentrations of organic contaminants and nutrients entering the environment as a result of human activity on the continent. POPs in particular should receive attention, given their presence in Antarctica as a global scale pollutant (see below), and the consequent importance of being able to identify local sources. However, anthropogenic nutrient enrichment is more likely to have an immediate effect on terrestrial ecosystems. For contaminants that are naturally present in the Antarctic environment, it is advisable to first select certain sites and monitor them carefully over time, in order to distinguish between natural variability, both

temporal and spatial, and anthropogenic input, before attempting to identify trends in contaminant concentrations or the appearance of pollution events.

Part II: Contamination by global-scale pollutants

Data is being compiled on the concentrations of various global-scale contaminants in the meltwaters (lakes, pond and streams) and in the soils/sediments of terrestrial environments, specifically for:

i) Trace elements
ii) Synthetic organic molecules (e.g., POPs)
iii) Radioactive elements

Although there have been a number of studies undertaken on trace elements in the terrestrial Antarctic environment, and in the McMurdo Dry Valleys in particular, there has been little attempt to distinguish between local, regional and global input to an area. Potential sources of trace elements include marine spray (particularly in coastal regions) and other aerosol deposition, as well as the natural weathering of rocks and sediments, and local contamination events. The geographic position of the sites, particularly latitude and proximity to the sea or mountains, the nature of the trace element, and local geology will all influence the contribution made by each source.

The two trace elements considered most likely to become elevated in Antarctic systems as a consequence of global-scale pollution are mercury and lead. Although there is data available for mercury levels in air and snow, data for soils appears limited to the Terra Nova Bay region and the McMurdo Dry Valleys. Data for lead in soil, other than in the vicinity of bases (as noted above), is also limited, but does appear as a corollary in studies of marine animals (e.g., the incorporation of lead into coastal soils via penguin droppings). For both of these elements there has been considerable research undertaken in the Arctic polar region, and comparison with Antarctic systems would be timely.

For the synthetic organic contaminants that are known to persist in the global environment, the research emphasis has again been on their accumulation in marine animals and marine environments. There appears to be very little information available for their concentrations in soil or water in terrestrial environments, although a recent study has provided data for DDT flux from the West Antarctic Ice Sheet. This would be essential information to have available if elevated concentrations of these chemicals become apparent in terrestrial ecosystems.

For radioactive elements, there are some data available for selected elements in terrestrial environments, mainly as included in ecosystem studies.

Interim conclusion. Greater emphasis on distinguishing between local and global sources in all contaminant studies is desirable. In the immediate future, a more complete dataset for the concentrations of mercury, and lead in terrestrial soils and waters would allow comparison with Arctic environments. When combined with data available for Antarctic air and snow, such data could also be used to learn more about the cycling of these elements in Antarctic systems. Data collection for synthetic organic contaminants for comparison with Arctic systems would also be beneficial. Again, for those contaminants which are naturally present at low levels in Antarctic systems, characterisation of natural variability is essential.

Heavy Metals Occurrence in Antarctic Snow and Ice; recent results

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Antarctic snow and ice have been shown to preserve detailed records of past atmospheric environments, dating back over hundreds of thousands of years. During recent decades, investigations of these frozen archives have provided useful data that help in studying anthropogenic large-scale atmospheric heavy metal pollution dating back to ancient times. These studies provided clear evidence that environmental pollution for various heavy metals has become a global problem. We present here highlights of the comprehensive and reliable records obtained from Antarctic snow and ice and a comparison with other area of the world. As an examples, these studies has provided the first comprehensive time series of various heavy metals in Antarctic snow, during the past ~150 years, allowing also to obtained detailed information on seasonal variations of heavy metals in polar snow.
In order to put in the right perspective the recent trends in atmospheric contamination as revealed by the analyses of shallow snow core, we recently investigated long time trends of heavy metals back to 650 yr BP from the Holocene back to Marine Isotopic Stage (MIS) 16.2. When combined with data previously obtained, it gives detailed record of past natural variations in the concentrations of these heavy metals during the last eight climatic cycles
The findings from polar snow and ice archives help to extend our understanding of the history of the impact of human activity on Earth's atmosphere over decades to millennial time scales.

Presence and distribution of POPs in environmetal matrices

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Recent literature

Since 2000 there have been approximately 45 publications reporting POP contaminant burdens in Antarctic biotic and abiotic matrices, about 27 in the period 2005-2008 (see list enclosed).

Current Research Limitations

- Number of research outputs still limited.
- Studies have predominantly been restricted to the Antarctic Peninsula and the Ross Sea (circum-polar collaboration should be encouraged).
- Inconsistencies in sampling and analytical methods, target analytes and reporting information often prevents satisfactory comparison between studies and regions.
- Lack of long term monitoring programs despite knowledge that progress of developing southern hemisphere nations and legislations are changing global emission patterns.

These limitations have further prevented progress in the comprehension of global diffusion process of POPs in the hydrosphere and in the atmosphere, as well as in the biosphere (parameterised transfer models, species specific toxicology and associated environmental risk assessment).

Current Monitoring Programs

There are many national environmental monitoring programmes which include POPs. Nations are mentioned in the list of publications, and the topics are well described by the titles. An inventory is in progress which should be available soon.

There are currently no concerted international Antarctic POP monitoring programs (in contrast to e.g. AMAP). The ECA may be an opportunity for circum-polar collaboration and communication on this issue which in turn may lead to a more structured approach to meeting international obligations.

Expected Results in the Near Future

- In progress and near future ECA activities (see report of the ECA workshop, 14th-16th June 2007, Venice)
  - Action Item 1 (2007/2008)
    To compile an inventory of existing published information on environmental contamination in Antarctica (defined as the area beyond 60°S).
  - Action Item 2 (2008/2009)
    To identify gaps in the existing data, with respect to:
    • Complete contaminant datasets for “natural” environments
    • Complete contaminant datasets for “contaminated” environments
  - Action Item 3 (2009/2010)
    To identify directions for future environmental contaminant research, to prioritize these and to provide clear objectives for further research and data collection.
    Topics (preliminary):

- Mechanisms and processes controlling distribution and transport of POPs in polar environments, including mass transfer at the environmental interfaces (air-water, air-snow, air-biota, water-biota, etc.).
- Effects of global climatic changes on processes controlling the dispersion and transport of POPs.
- Environmental effects of POPs on polar regions.
- Quality Control and Quality Assurance (QC/QA), including proficiency test and Antarctic Environmental Reference Materials.
- Antarctic Environmental Specimen Bank (http://www.bcaa.unige.it/)

In progress research activities and related topics on which research papers are expected to be published soon (list not exhaustive):

1) POP paleo-records in snow/firn cores from Talos Dome and sediment cores from Ross Sea. Temporal profiles should cover about five centuries (1500-2000)
2) POPs in the Antarctic atmosphere
3) Long Range Atmospheric Transport (LRAT) of PBDEs
4) Antarctica: A source or a sink for POPs?
5) Persistent Organohalogen Contaminant Burdens in Antarctic Krill (*Euphausia superba*) From the Eastern Antarctic Sector: A Baseline Study
6) Mobilised Organic Contaminant Burdens in Migrating Antarctic Humpback Whales (*Megaptera novaeangliae*); Concentration Effects and Associated Toxicity Response
7) TRENZ: The TRophic Ecology of the Antarctic Nearshore Zone: local and global constraints on patterns and processes (focus on biogeochemical cycling of POPs).
8) Ecology of marine birds and relationships between ecological variables and flow of contaminants in polar food webs.
9) Flows of POPs between PoLar Abiotic and Biotic Compartments (POP-LAB).

Trace elements in water and sediment of the southern Ocean

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This review provide the assessment of the published information available on concentration and behaviour of trace metals in marine environment in the Antarctic region. The review also seeks to highlight where there are gaps in the existing information, and prioritise requirements for further data.

Studies have predominantly been restricted to five areas of the southern ocean (see figure 2).

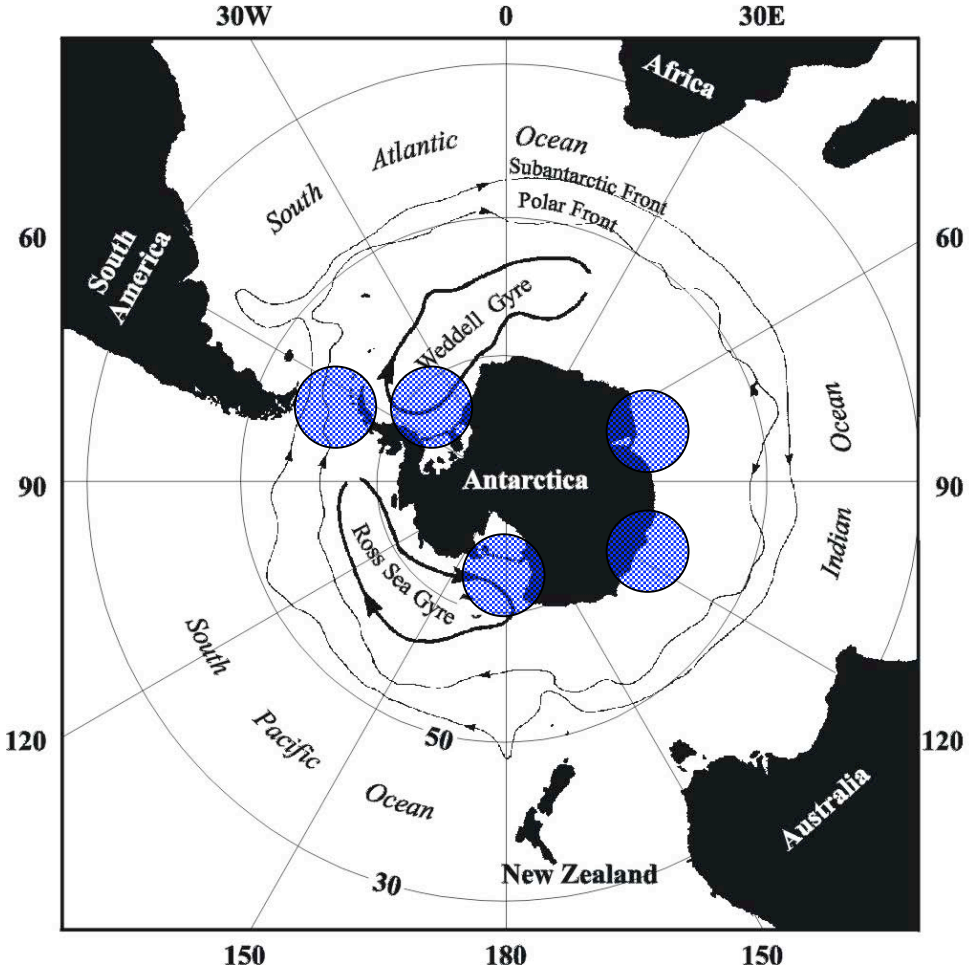

Figure 2. Areas of the Southern Ocean interested by studies on the distribution of trace elements in marine environments.

The review is being been undertaken in two parts; the first focussing on studies carried out in open sea regions and the second in coastal areas more affected by local sources of contaminants.

Open Sea areas

Data is being compiled on the concentrations of a number of bioactive elements. Aims of studies carried out in seawater were preferentially to analyze the element biogeochemical

cycle in relation with their involvement with the biological activity and the climate change implication. Studies were carried out in the Ross Sea, Weddell Sea and the Indian sector of the Southern Ocean to determine the distribution and the partition dissolved/particulate of Al, Cd, Co, Cu, Mn, Ni, Zn and specially iron for its implication as limiting factor of the primary production in HNLC zones. Some hundred papers have been published to verify the iron hypothesis on limitation of nitrogen uptake in HNLC areas.

The direct observation of the anthropic contribution at the contamination by trace elements in seawater is complicated by the system variability in relation with hydrodynamic and biological processes and natural sources (hydrothermal and volcanic activity). Although there is the evidence of increase of concentration of elements which dispersion may be significantly affected by the human activities, essentially only two papers were present in literature emphasizing the contamination of southern ocean by lead, using its isotopic composition as proxy of the sources.

More data are available on the metal concentration in sediments in consideration to their conservative characteristics used to reconstruct sedimentation processes as a function of time and the implication with climate changes.

Studies carried out in northern hemisphere are significantly more numerous and there are evidence of global contamination signatures for elements prone to contamination (e.g., lead and mercury).

Although the cycling and the bioavailability of trace elements is strongly affected by their speciation, very few studies are actually available. Therefore for a better knowledge of pollutant elements also information about their speciation should be available.

Coastal areas

Data is being compiled on the concentrations in sediments and organisms gathered in coastal areas contaminated by local sources. Studies normally consider a large number of elements for a better description of the chemical and geochemical characteristics of the area and to estimate the impact of base activities on the marine environment. Larger part of available data are interesting the east Antarctica (McMurdo sound, Newcomb Bay, Larsemann Hills, Terra Nova Bay), and the Antarctic peninsula (King George Island, Admiralty Bay), which are potentially at high environmental risk, due to the presence of extensive human activities related at the presence of numerous research stations. Although there have been several studies undertaken there has been little attempt to distinguish between local, regional and global input to an area. A raw approach is normally used to distinguish human impact, this is estimated by comparison the concentration respect to control sites or the natural baseline level established in the basement rocks. Detecting anthropogenic metal contamination in regional surveys by this approach can be particularly difficult when there is a lack of pre-disturbance data, especially when trying to differentiate low to moderate levels of contamination from background values. Therefore the utility of these methods is uncertain in areas with a significant heterogeneous composition.

Interim conclusion. Greater emphasis on distinguishing between local and global sources by using adequate proxies in all contamination studies is desirable. The dataset should be completed by the concentrations of contaminant elements (e.g. mercury and lead) in seawaters and sediment covering larger regions of the southern ocean and specially the coastal areas. The combination with data available for Antarctic air and snow, can give a significant contribution to learn more about the transport and cycling of contaminants in the Antarctic environment. A better knowledge of behaviour of trace elements also in relation with organic components can give also a significant contribution to the understanding the mechanisms contributing at the dispersion of organic pollutants.

Minor and Trace Elements in Antarctic Biota

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A survey was performed of the scientific literature (papers, reports and other informative material made publicly available) on trace and minor elements in biota in Antarctica. For the sake of comparison, also the Arctic and related polar regions were taken into account. The search was conducted over the period 1978 – 2008, with particular reference to the last ten years. Selection criteria were developed and the major data bases were consulted using key-words such as biota, trace elements, minor elements, heavy metals, polar science, Antarctica, certified reference materials, proficiency testing, quality control and quality assurance as well as any combination thereof, as appropriate. The published material was also ranked on the basis of compliance of experimental results with quality requirements.

Of the 825 records scanned, 167 were focused on Antarctic research, while 121 were concerned with Arctic studies. A further screening revealed that in the first set 61 records out of the 167 examined were actually dealing with trace/minor elements in biota. On the other hand, in the case of Arctic research, the records on biota were found to be 38 out of 121.

The majority of the Antarctic studies were devoted to marine mammals, fish (molluscs, krill, birds, sponges, lichens, mosses and microbial communities. The organisms more frequently investigated were seals, penguins and marine species such as *Trematomus bernacchii*, *Chinodracus hamatus*, *Adamussium colbecki* and *Laternula elliptica*. In a couple of cases, also studies on human subjects were carried out to elucidate the adverse effects of living and working in a hostile environment.

Arctic investigations were primarily devoted to marine mammals (seals, whales, belugas, narwhals), birds (ducks), terrestrial mammals (bears, reindeers, foxes, wolves), fish (sharks), algae, fungi and bacteria. Human populations were also investigated (12 records) to better assess the effects of exposure to potentially toxic elements.

The trace/minor elements more frequently considered were Al, As, Cd, Co, Cu, Fe, Hg, Mn, Ni, Pb and Zn. Radionuclides were also often studied, especially in the Arctic regions.

Due considerations being given to obvious differences existing between the fauna and flora of the Antarctic and Arctic regions, current trends in polar research appear to be clearly oriented to investigate the impact of environmental contamination on living organisms as well as to assess the role they can play in effectively monitoring ongoing pollution phenomena where the need for reliable, comparable and updated experimental information turns out to be keenly felt.

Addendum
Publications used to prepare the report

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