History of heavy metal accumulation in the Svalbard area: distribution, origin and transport pathways

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Heavy metals

**Natural sources**: rock weathering and erosion, volcanic activity

**Anthropogenic sources**: industrial, agricultural, domestic effluents, and atmospheric sources: transportation, mining, metallurgy and industry

Since the beginning of XX century – increase of emission due to the industrial revolution


Since 1990 decrease of heavy metal emission due to ban for leaded gasoline use and industrial purification techniques
Transport of contaminants to the Arctic

MacDonald et al., 2005
Geology of Svalbard

Blomeier et al., 2006; https://www.geo.uni-bremen.de
Study area

Water mass profiles:
A. Beszczyńska-Möller
Methods

Field work:
14 cores (~50cm) - 7 fjords (2012-2016),
5 cores (~20cm) – Barents Sea (2004-2005)

Laboratory work:
- $M_{\text{org}}$ content,
- $^{210}\text{Pb}$ dating (LAR, MAR),
- concentration of $\text{Pb, Cd, Zn, Cu}$ (ICP – MS)
and $^{206}\text{Pb}/^{207}\text{Pb}$, $^{208}\text{Pb}/^{206}\text{Pb}$ (ICP – MS)

Quality control: 3x measurement, 7 reference materials

Data analysis:
- Enrichment Factors (Fe)
- Metal deposition rate (MAR x concentration)
- Contribution of anthropogenic Pb
  (end-members method)
- $^{206}\text{Pb}/^{207}\text{Pb}$ ratio of anthropogenic Pb
  (end-members method)
- Statistics
<table>
<thead>
<tr>
<th>Stn</th>
<th>Fjord</th>
<th>LAR (cm·yr⁻¹)</th>
<th>MAR (g·m⁻²·yr⁻¹)</th>
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</thead>
<tbody>
<tr>
<td>H1</td>
<td>Hornsund</td>
<td>0.17</td>
<td>1800</td>
</tr>
<tr>
<td>H2</td>
<td>Hornsund</td>
<td>0.23</td>
<td>1970</td>
</tr>
<tr>
<td>H3</td>
<td>Hornsund</td>
<td>0.32</td>
<td>3070</td>
</tr>
<tr>
<td>H4</td>
<td>Hornsund</td>
<td>0.66</td>
<td>6250</td>
</tr>
<tr>
<td>A</td>
<td>Adventfjorden</td>
<td>0.27</td>
<td>3210</td>
</tr>
<tr>
<td>K1</td>
<td>Kongsfjorden</td>
<td>0.22</td>
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<tr>
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<td>M</td>
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<tr>
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<td>Smeerenburgfjorden</td>
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<tr>
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<tr>
<td>R2</td>
<td>Rijpfjorden</td>
<td>0.11</td>
<td>650</td>
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<tr>
<td>ST</td>
<td>Storfjorden</td>
<td>0.07</td>
<td>400</td>
</tr>
</tbody>
</table>
Regions:
H\textsubscript{out}: outer Hornsund
H\textsubscript{in}: inner Hornsund
A: Adventfjord
K\textsubscript{out}: outer Kongsfjord
K\textsubscript{in}: inner Kongsfjord
M: Magdalenefjorden
SM: Smeerenburgfjorden
R: Rijpfjorden
B: Barents Sea
ST: Storfjorden
Background metal concentration - based on metal concentrations in sediment layers dated for <1850 r.

\[ \text{Pb}_{\text{nat}} \]
\[ 12 - 24 \text{ mgkg}^{-1} \]
\[ \text{Cd}_{\text{nat}}: \]
\[ 0,10 - 0,15 \text{ mgkg}^{-1} \]
\[ \text{Zn}_{\text{nat}} \]
\[ 60-90 \text{ mgkg}^{-1} \]
\[ \text{Cu}_{\text{nat}} \]
\[ 10-15 \text{ mgkg}^{-1} \]
PCO
a. stations

CAP
b. fjords

c. geology:
BAS basement
CAL basement with granite
DEV Devon
CAR Carboniferous + Perm
TRI Trias
JUR Jura

PCA
d. periods:
Nat: natural (<1900)
Coal: coal (1900-1950)
Gas: gasoline (1950-2015)

Component analysis : M. Włodarska-Kowalczuk
Global Pb emission (thousand metric tons)

Global Pb production (million metric tons)

Hornsund out
Hornsund in
Kongsfjorden out
Kongsfjorden in
Adventfjorden
Magdalene fjorden
Rijpfjorden
Barents Sea
Transport variability

- **Atmospheric transport**
  Variable, modified by AO and NAO
  Main transport from Europe and Russia

- **Precipitation:**
  Variable
  Annual precipitation of coastal areas ~450mm, in more „continental” areas eg. Adventfjorden ~200mm

- **Oceanic currents:**
  Variable, modified by AO and NAO
  Low influx of Atlantic waters (sea ice expansion) ~1910, ~1940, ~1960 and ~1980
  High influx of Atlantic waters 1990-2006

- **Multiyear ice:**
  Variable
  Main transport from northern Siberia
Atmospheric deposition:
Pb: 17-25 mg·m⁻²·yr⁻¹ (in ‘80s)
Headley et al., 1996

Metals in cryoconites:
Pb = 10-142 mg/kg
Cd = 0.1-2.2 mg/kg
Cu = 22-49 mg/kg

¹³⁷Cs = 90-780 Bq/kg
²³⁹,²⁴⁰Pu = 2-17 Bq/kg
Lokas E. + Zaborska A., unpubl
Contribution of anthropogenic Pb

\[ X_{\text{sample}} = \frac{\left( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{sample}} - \left( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{background Pb}}}{\left( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{anthropogenic Pb}} - \left( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{background Pb}}} \times 100\% \]

Natural \( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} = 1.22 \)

Anthropogenic \( \frac{^{206}\text{Pb}}{^{207}\text{Pb}} = 1.17 \)
Source of anthropogenic Pb

\[
^{206}\text{Pb} / ^{207}\text{Pb}_{\text{excess}} = \left[ (^{206}\text{Pb}_{\text{sample}} \times ^{206}\text{Pb} / ^{207}\text{Pb}_{\text{sample}}) - (^{206}\text{Pb}_{\text{ref}} \times ^{206}\text{Pb} / ^{207}\text{Pb}_{\text{ref}}) \right] / (^{206}\text{Pb}_{\text{sample}} - ^{206}\text{Pb}_{\text{ref}})
\]

\[ ^{206}\text{Pb} / ^{207}\text{Pb}_{\text{ref}} = 1.22 \]

\[ ^{206}\text{Pb} / ^{207}\text{Pb}_{\text{ref}} = 12 - 24 \text{ mgkg}^{-1} \]

Ratios of sources: Komárek et al., 2008
$^{206}\text{Pb}/^{207}\text{Pb}$ – oceanic transport
1.17-1.18

$^{206}\text{Pb}/^{207}\text{Pb}$ – atmospheric transport from Europe and Asia
1.14-1.15

$^{206}\text{Pb}/^{207}\text{Pb}$ – atmospheric transport from Northern America
1.19-1.22

Arctic haze layer. Foto: A. Wisthaler, NOAA
Emerging topics concerning contaminants

- **Secondary sources:**
  - Input of contaminants from the land (melting permafrost) and melting glaciers to the coastal waters

- **Influence of global changes to contaminant transport and fate:**
  - Increase in precipitation - increase in contaminant deposition?
  - Increase in Atlantic Current strength - increase in contaminant loads?
  - Changes in animal migration habits – enhanced transfer of contaminants?
  - Increase of human activity in the Arctic – additional contaminant inputs?
Acknowledgments


Special thanks:
• Jola Walkusz-Miotk – heavy metal analyses
• Maria Włodarska-Kowalczuk – statistical analyses
• Agnieszka Beszczyńska - Möller – hydrographical description

Data published: