Deposition of atmospheric selenium to the northern Greenland ice sheet during the 1900-1970 AD

이강현¹, 한영철¹, 문장일¹, 전성준¹,², 허순도¹, 홍성민²

¹ KOPRI, ²Inha univ.

Korea Polar Research Institute
INDEX

1. Introduction of Se
2. NEEM ice core, melting, analysis
3. Age dating, Se and trace elements
4. Conclusion & Further study
1. Introduction of Se
2. NEEM ice core, melting, analysis
3. Age dating, Se and trace elements
4. Conclusion & Further study
Essential for health

Deficient vs. Toxic

<http://www.vth.colostate.edu/poisonous_plants/>
Biogeochemical cycle

<http://www.ieg.ethz.ch/research/research-interests.html>
Sources for atmospheric Se

Natural sources
- Marine bio: 46%
- Continental bio (volatile): 24%
- Continental bio (particles): 11%
- Volcanoes: 9%
- Forest fire: 3%
- Sealsalt: 5%
- Crust dust: 2%

Anthropogenic sources
- Coal combustion: 48%
- Metal production: 34%
- Oil combustion: 15%
- Mining: 3%
- Steel production: <1%

<Nriagu and Pacyna, 1989>  
<Nriagu, 1988>
Purpose of the study

<Primary production in North Pacific>

Total chlorophyll (mg/m³)

<Boyce et al., 2010>

<World coal consumption>

Billion of Metric Tons of Oil Eq. Yr.

<BP’s 2012 Statistical Review of World Energy>
**NEEM deep ice core project**

<table>
<thead>
<tr>
<th>International ice core research project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site</strong></td>
</tr>
<tr>
<td>77.45°N, 51.06°W</td>
</tr>
<tr>
<td><strong>Camp</strong></td>
</tr>
<tr>
<td>2007~2011</td>
</tr>
<tr>
<td><strong>Length</strong></td>
</tr>
<tr>
<td>2542 m</td>
</tr>
<tr>
<td><strong>Age</strong></td>
</tr>
<tr>
<td>108000 yr B2K at 2203.3 m</td>
</tr>
</tbody>
</table>
Samples in KOPRI

- **Snow pit (2009)**
  - 0~3.2 m (2003~2009 AD)
  - Present condition of atmospheric environment

- **Firm core (2009)**
  - 2~87.8 m (~194 years BP)
  - Natural vs. anthropogenic influences on atmospheric environment for last 200 years

- **Deep ice core (2007-2011)**
  - 98~2200 m (350~108000 years BP)
  - Climate change impact
Samples in KOPRI

- **Snow pit (2009)**
  - 0~3.2 m (2003~2009 AD)
  - Present condition of atmospheric environment

- **Firn core (2009)**
  - 2~87.8 m (~194 years BP)
  - Natural vs. anthropogenic influences on atmospheric environment for last 200 years

- **Deep ice core (2007-2011)**
  - 98~2200 m (350~108,000 years BP)
  - Climate change impact
Melting process

- 586 samples (16.8~87.8 m)
- Length: 8~18 cm
- Duration: 0.1~0.8 year
Data acquisition

- ICP-SF-MS with Apex-ACM

<table>
<thead>
<tr>
<th>Measured</th>
<th>Certified</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>132.3 ± 6.0</td>
<td>138.3</td>
</tr>
<tr>
<td>As</td>
<td>58.2 ± 1.7</td>
<td>59.0</td>
</tr>
<tr>
<td>Ba</td>
<td>547.4 ± 4.4</td>
<td>531.0</td>
</tr>
<tr>
<td>Bi</td>
<td>13.5 ± 0.2</td>
<td>13.8</td>
</tr>
<tr>
<td>Cd</td>
<td>6.7 ± 0.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Co</td>
<td>29.4 ± 1.2</td>
<td>26.4</td>
</tr>
<tr>
<td>Cr</td>
<td>19.7 ± 1.2</td>
<td>19.9</td>
</tr>
<tr>
<td>Cu</td>
<td>21.4 ± 1.8</td>
<td>22.2</td>
</tr>
<tr>
<td>Mn</td>
<td>37.1 ± 1.9</td>
<td>38.0</td>
</tr>
<tr>
<td>Mo</td>
<td>119.4 ± 0.9</td>
<td>118.5</td>
</tr>
<tr>
<td>Ni</td>
<td>56.6 ± 4.7</td>
<td>60.9</td>
</tr>
<tr>
<td>Pb</td>
<td>20.7 ± 6.6</td>
<td>19.2</td>
</tr>
<tr>
<td>Rb</td>
<td>14.8 ± 0.2</td>
<td>13.8</td>
</tr>
<tr>
<td>Sb</td>
<td>57.7 ± 0.6</td>
<td>56.9</td>
</tr>
<tr>
<td>Se</td>
<td>11.7 ± 1.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Sr</td>
<td>340.6 ± 3.2</td>
<td>315.2</td>
</tr>
<tr>
<td>Ti</td>
<td>7.4 ± 0.1</td>
<td>7.3</td>
</tr>
<tr>
<td>V</td>
<td>34.0 ± 3.2</td>
<td>36.9</td>
</tr>
<tr>
<td>Zn</td>
<td>73.7 ± 5.1</td>
<td>76.5</td>
</tr>
</tbody>
</table>

- 322 samples from NEEM ice core
  - 1823 ~ 1975 AD (1902~1975 for Se)
- 38 samples from Euro ice core
  - 1773~1965 AD
- 22 samples from GRIP ice core
  - 500~9000 yr BP
1. Introduction of Se
2. NEEM ice core, melting, analysis
3. Age dating, Se and trace elements
4. Conclusion & Further study
Age dating

Tie-point matching

<Masson-Delmotte et al., 2015>
Dust origin trace elements

Graphs showing concentration trends over time for various elements:
- Al conc.
- Ba conc.
- Mn conc.
- Rb conc.
- Sr conc.
- V conc.
Anthropogenic (Coal) trace elements

- Cr conc.
- Mo conc.
- Sn conc.
- EFc of Cr
- EFc of Mo
- EFc of Sn
Se record of NEEM ice core

<Boyce et al., 2010, Nature, Vol. 466, 591-596>
Air mass trajectories

Table 3. Summary of Source Regions and Transport Routes for 10-day, 700-hPa Back Trajectories to Summit, Greenland

<table>
<thead>
<tr>
<th>Season</th>
<th>North America Zonal (NAz)</th>
<th>North America Meridional (NAm)</th>
<th>North Pacific Zonal (NPz)</th>
<th>Europe Easterly (Ee)</th>
<th>East Asia Zonal (EAz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>70%</td>
<td>2%</td>
<td>19%</td>
<td>7%</td>
<td>–</td>
</tr>
<tr>
<td>Spring</td>
<td>85%</td>
<td>3%</td>
<td>–</td>
<td>–</td>
<td>8%</td>
</tr>
<tr>
<td>Summer</td>
<td>85%</td>
<td>3%</td>
<td>–</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>Autumn</td>
<td>74%</td>
<td>4%</td>
<td>17%</td>
<td>5%</td>
<td>–</td>
</tr>
</tbody>
</table>

a Principally westerly transport.
b Arriving at Summit from the east.

<Kahl et al., 1997>
Year (B2K)

Marine bio source
8.9~9.4 $\times 10^{-3}$
Ellis et al. 1993

GRIP ice core records
Euro ice core records

Se

Se/MSA

EFₚ of Se

Year (AD)
1. Introduction of Se
2. NEEM ice core, melting, analysis
3. Age dating, Se and trace elements
4. Conclusion & Further study
Conclusion

- Se records of Greenland ice core were similar to north Atlantic chlorophyll change

- Se/MSA ratios during 1900~1970s were mostly fit in the range of those for 500~9000 years BP when no significant anthropogenic influence

- High $EF_c$ values of Se (>5,000) represent little influence of crust dust

- The atmospheric Se input during 1900~1970s seemed to be mainly controlled by natural emission from marine biogenic source
Further studies

- Decontamination of most shallow samples
  - Surface ~ 16.8 m

- Completion of high resolution Se record in NEEM ice core
  - Responses of biosphere to the climate event such as AO and NAO

- Se isotope ratios research
  - Fractionation by oxidation/reduction
  - Estimation of fluxes between various reservoirs
Thanks for your attention