Record high PCB concentrations in the Arctic due to long-range transport after biomass burning

Sabine Eckhardt
Knut Breivik
Stein Manø
Andreas Stohl

Norwegian Institute for Air Research www.nilu.no
Transport of PCBs
Zeppelin Station

2 episodes of fire influence
PCBs Measurements

Measurements in Western US
Conclusion
Extremely persistent – LRT (persistent organic pollutants)

Toxic, lipophilic – bio-accumulative
→ e.g. problem for polar bears (top of food chain)

Mass production ended several decades ago (max. 1970)

Significant amounts still in use and stored in the environment (vegetation and soils), with decreasing primary emission it is expected that secondary sources become more important
NO42 Spitsbergen, Zeppelin

Site information

- Measurement site: Spitsbergen, Zeppelin
- Country: Norway
- Code: NO42
- Database code: NO0042R
- Geographical coordinates: 78° 54’N, 11° 53’E
- EMEP coordinates (50 km): 69.02, 104.35
- Altitude above sea level: 474
- In operation since: September 1989
- Closest climatological station: 99910 Ny-Ålesund
- Main wind direction: E-S-E
- Contact person: Wenche Aas
- Organisation: NILU

Surroundings

The site is located in an undisturbed Arctic environment. Zeppelin Mountain is an excellent site for atmospheric monitoring, with low contamination from the local settlement due to its location above the inversion layer.
Sampling

1000 m³
48 h
Forests play an important role in trapping airborne semivolatile organic compounds and transferring them to terrestrial ecosystems with falling leaves.

(Wania and Mackay (1996))

(Meijer et al., 2003)
At Zeppelin, new records were set for practically all measured compounds.

Ozone, aerosol optical depth (both measured for about 15 years!)

Carbon monoxide, particulate matter, etc.
Transport simulation

Transport calculated with Lagrangian particle transport model FLEXPART – *Stohl 2006, ACP*

Backward calculation from the samples with the enhanced concentrations

Fire data were taken from MODIS

Fire May 2006

Transport over 3-4 days
Distance 2000 km
Agricultural land burned
Spring (beginning May)
Figure 1: Potential emission sensitivity (PES) footprint map for air arriving at Zeppelin between 1 May 2006 at 10:14 UTC and 3 May 2006 at 8:38 UTC 2006. Black dots show MODIS fire detections on days when the footprint emission sensitivity in the corresponding grid cell on that day exceeded 2 ps kg⁻¹.
PCB Timeseries
Fire emission on satellite images

5. Juli 2004

FLEXPART Total Column

MODIS satellite image
Fire July 2004

Transport over 3-4 weeks
Distance 4000 km

Boreal forest burned
2.7 Mio ha in Alaska
3.1 Mio ha in Canada

Wet Scavenging occurred

Figure 2: Column-integrated potential emission sensitivity (PES) map for air arriving at Zeppelin between 26 July 2004 at 07:13 UTC and 28 July 2004 at 6:33 UTC. Black dots show MODIS fire detections on days when the column-integrated PES value in the corresponding grid cell on that day exceeded 0.5 ns m kg\(^{-1}\).
Transport

Primary Emission

Receptor

Forest Filter

removed

21kt
Transport

Receptor

Transport

Primary Emission

Primary Emission

removed

21kt
Sigler, J. M., Lee, X., and Munger W.: 
**Emission and Long-Range Transport of Gaseous Mercury from a Large-Scale Canadian Boreal Forest Fire**,  

Field observations made at Harvard Forest MA, U.S.A. during early July 2002 show clear evidence of long-range transport of gaseous mercury in a smoke plume from a series of boreal forest fires in northern Quebec.

**Inter- and intra-continental transport of radioactive cesium released by boreal forest fires**,  

Cs, which was released during nuclear testing in the between 1945 and 1980, was re-injected into the atmosphere by combustion during extensive forest fires.
### PCB Statistics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB_28</td>
<td>2.46</td>
<td>2.06</td>
<td>11.32</td>
<td>9.96</td>
<td>4.3</td>
<td>3.6</td>
</tr>
<tr>
<td>PCB_52</td>
<td>1.12</td>
<td>0.56</td>
<td>3.83</td>
<td>4.11</td>
<td>4.8</td>
<td>5.3</td>
</tr>
<tr>
<td>PCB_101</td>
<td>0.47</td>
<td>0.25</td>
<td>1.31</td>
<td>1.92</td>
<td>3.4</td>
<td>5.8</td>
</tr>
<tr>
<td>PCB_118</td>
<td>0.19</td>
<td>0.17</td>
<td>0.37</td>
<td>1.34</td>
<td>1.1</td>
<td>6.6</td>
</tr>
<tr>
<td>PCB_138</td>
<td>0.18</td>
<td>0.21</td>
<td>0.31</td>
<td>1.10</td>
<td>0.6</td>
<td>4.4</td>
</tr>
<tr>
<td>PCB_153</td>
<td>0.29</td>
<td>0.37</td>
<td>0.42</td>
<td>1.64</td>
<td>0.4</td>
<td>3.7</td>
</tr>
<tr>
<td>PCB_180</td>
<td>0.06</td>
<td>0.08</td>
<td>0.09</td>
<td>0.27</td>
<td>0.4</td>
<td>2.6</td>
</tr>
</tbody>
</table>
All PCB congeners

- 2 stddev over mean (2004 forest)
- 2 stddev over mean (2006 agric.)
Emission Factors

\[
\frac{\text{EF}_{\text{PCB}}}{\text{EF}_{\text{CO}}} = \frac{\Delta C_{\text{PCB}}}{\Delta C_{\text{CO}}}
\]

<table>
<thead>
<tr>
<th></th>
<th>( \Delta C_{\text{CO}} )</th>
<th>( \Delta C_{\text{PCB}} )</th>
<th>( \text{EF}_{\text{CO}} )</th>
<th>( \text{EF}_{\text{PCB}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>27 ( \mu g/m^3 )</td>
<td>33 ( \text{pg/m}^3 )</td>
<td>107 ( \text{pg/kg} )</td>
<td>130 ( \mu g/kg )</td>
</tr>
<tr>
<td>2006</td>
<td>62 ( \mu g/m^3 )</td>
<td>45 ( \text{pg/m}^3 )</td>
<td>92 ( \text{pg/kg} )</td>
<td>66 ( \mu g/kg )</td>
</tr>
</tbody>
</table>

PCB (wood) 8.37 \( \mu g/kg \) (Gullett et al., 2003)

16/8 times higher PCB concentration measured than expected (2004/2006)
DDT, HCH Timeseries

(a) alpha_HCH

(b) gamma_HCH

(c) op_DDT

(d) pp_DDT

(e) op_DDD

(f) pp_DDD

(g) op_DDE

(h) pp_DDE
Influence of Asian and Western United States Urban Areas and Fires on the Atmospheric Transport of Polycyclic Aromatic Hydrocarbons, Polychlorinated Biphenyls, and Fluorotelomer Alcohols in the Western United States

ES&T in press.

(A) $\Sigma$gas (red, triangles) and $\Sigma$particulate-phase PAH (black, circles). (B) $\Sigma$PCB (black, circles) and $\Sigma$FTOH (red, circles). (C) levoglucosan (red, triangles) and retene (black, circles). (D) 1,3,5-triphenylbenzene (black, circles). [MBO from 2004 to 2006, Spring (Sp), Summer (Su), Fall (F), Winter (W)]. Recovery-corrected FTOH concentrations were only measured in the spring 2006 samples (7).
Retene, levoglucosan and PCBs are elevated in air masses influenced by regional fire events, suggesting revolatilisation from soil and vegetation, there are indications of high elevations of correlation with pesticides as well.
First observation of biomass burning influence on PCBs concentrations in a remote region

Biomass burning emissions have a high influence of Arctic PCBs concentrations

Emission factors for the sum of PCBs of 130 and 66 \( \mu \text{g/kg} \) biomass could be derived for the 2004 and 2006 episode, controled lab and field experiments would be needed to improve emission factors.

Global warming will lead to more burning and enhanced inflow into the Arctic region, which again could mitigate the efficiency of international agreements on the reduction of POPs.
Record high peaks in PCB concentrations in the Arctic atmosphere due to long-range transport of biomass burning emissions

Eckhardt S., Breivik K., Manø S. and Stohl A.

Atmospheric Chemistry and Physics

Volume: 7 Issue: 17 Pages: 4527-4536 Published: 2007