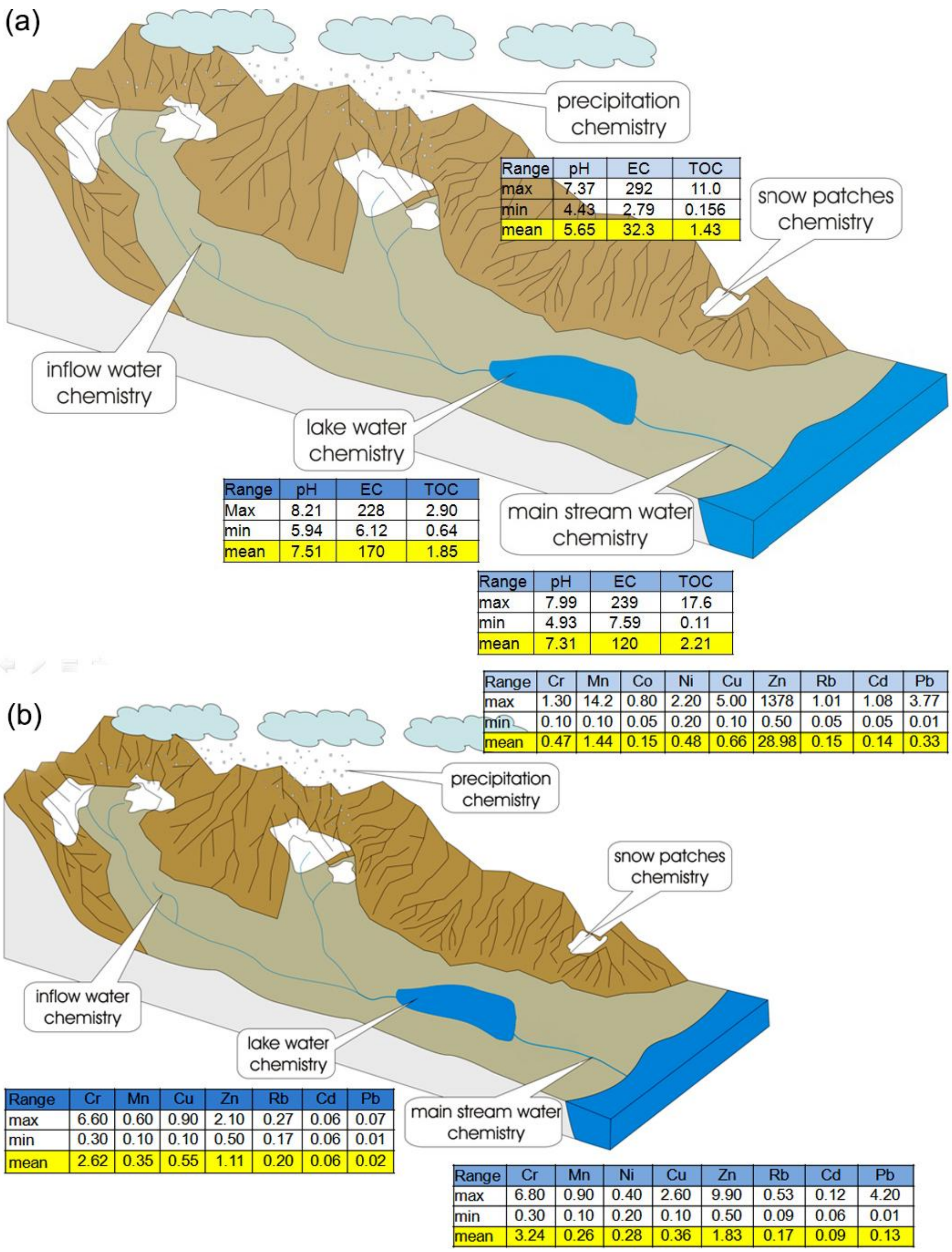
Supplementary file for: Kozak K., Kozioł K., Luks B., Chmiel S., Ruman M., Marć M., Namieśnik J. & Polkowska Ż. 2015. The role of atmospheric precipitation in introducing contaminants to the surface waters of the Fuglebekken catchment, Spitsbergen. *Polar Research 34.* Correspondence: Żaneta Polkowska, Department of Analytical Chemistry, The Chemistry Faculty, Gdansk University of Technology, 11/12 Narutowicza St., Gdansk PL-80-233, Poland. E-mail: zanpolko@pg.gda.pl




(a)

| Range | pH | EC | TOC |
|---|---|---|---|
| max | 7.37 | 292 | 11.0 |
| min | 4.43 | 2.79 | 0.156 |
| mean | 5.65 | 32.3 | 1.43 |

| Range | pH | EC | TOC |
|---|---|---|---|
| Max | 8.21 | 228 | 2.90 |
| min | 5.94 | 6.12 | 0.64 |
| mean | 7.51 | 170 | 1.85 |

| Range | pH | EC | TOC |
|---|---|---|---|
| max | 7.99 | 239 | 17.6 |
| min | 4.93 | 7.59 | 0.11 |
| mean | 7.31 | 120 | 2.21 |

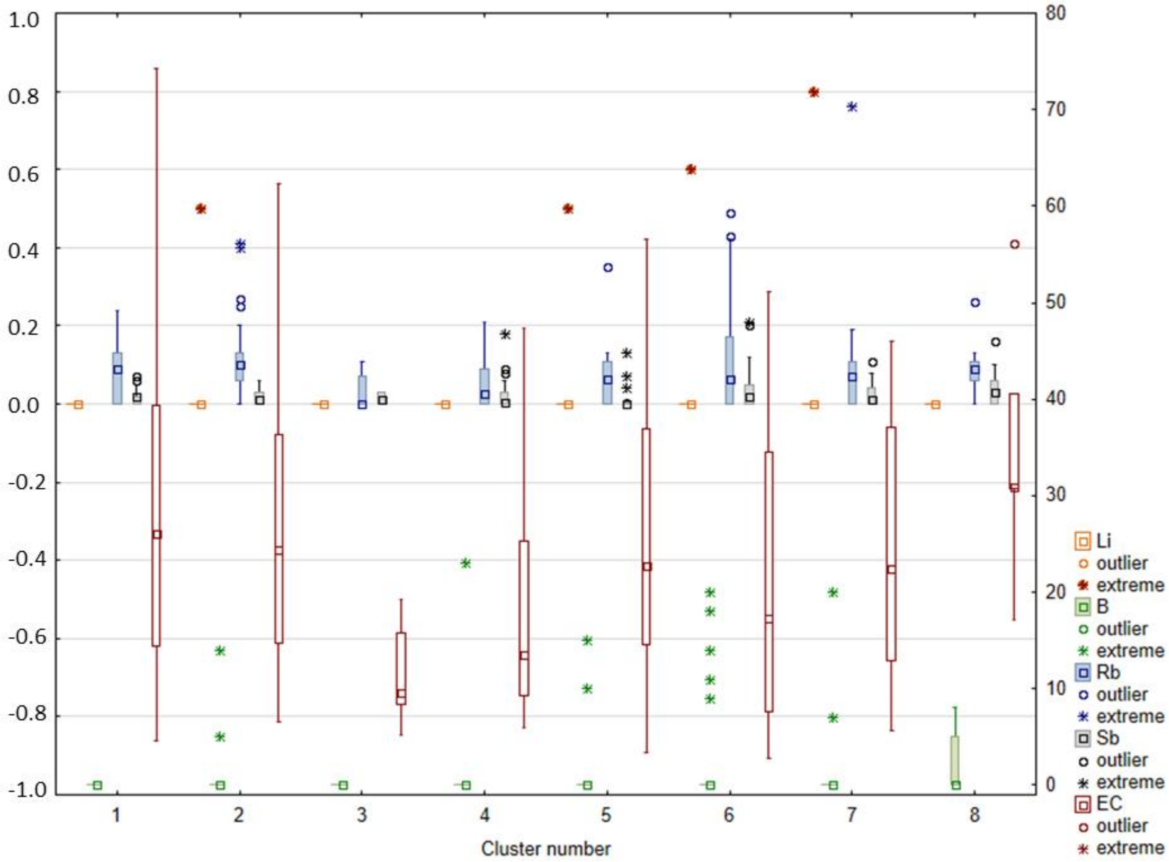
(b)

| Range | Cr | Mn | Co | Ni | Cu | Zn | Rb | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|
| max | 1.30 | 14.2 | 0.80 | 2.20 | 5.00 | 1378 | 1.01 | 1.08 | 3.77 |
| min | 0.10 | 0.10 | 0.05 | 0.20 | 0.10 | 0.50 | 0.05 | 0.05 | 0.01 |
| mean | 0.47 | 1.44 | 0.15 | 0.48 | 0.66 | 28.98 | 0.15 | 0.14 | 0.33 |

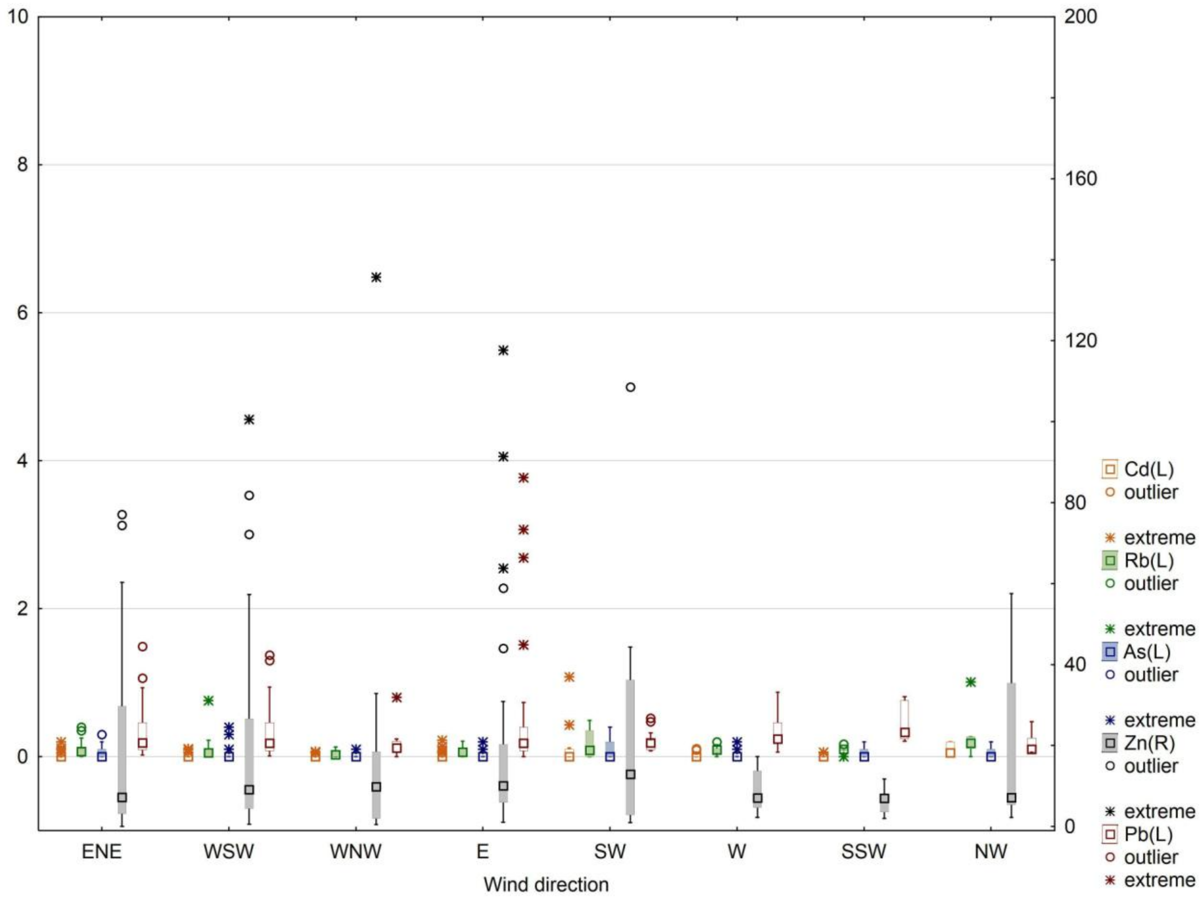
| Range | Cr | Mn | Cu | Zn | Rb | Cd | Pb |
|---|---|---|---|---|---|---|---|
| max | 6.60 | 0.60 | 0.90 | 2.10 | 0.27 | 0.06 | 0.07 |
| min | 0.30 | 0.10 | 0.10 | 0.50 | 0.17 | 0.06 | 0.01 |
| mean | 2.62 | 0.35 | 0.55 | 1.11 | 0.20 | 0.06 | 0.02 |

| Range | Cr | Mn | Ni | Cu | Zn | Rb | Cd | Pb |
|---|---|---|---|---|---|---|---|---|
| max | 6.80 | 0.90 | 0.40 | 2.60 | 9.90 | 0.53 | 0.12 | 4.20 |
| min | 0.30 | 0.10 | 0.20 | 0.10 | 0.50 | 0.09 | 0.06 | 0.01 |
| mean | 3.24 | 0.26 | 0.28 | 0.36 | 1.83 | 0.17 | 0.09 | 0.13 |

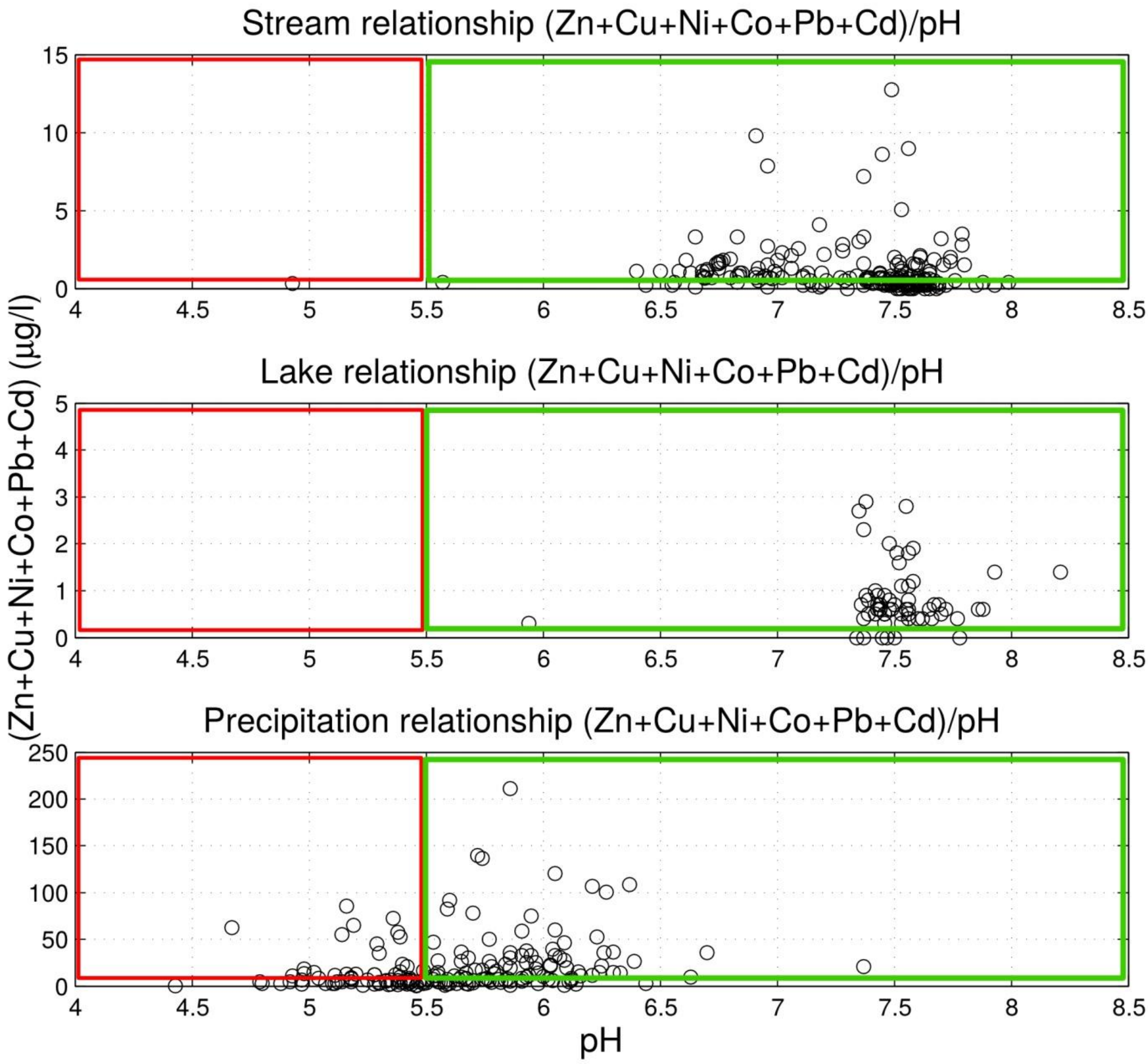
**Supplementary Fig. S1**. A comparison of the chemical composition of waters in the stream, lake and bulk precipitation: (a) pH, electrical conductivity and total organic carbon (TOC) levels; (b) the concentrations of selected heavy metals.



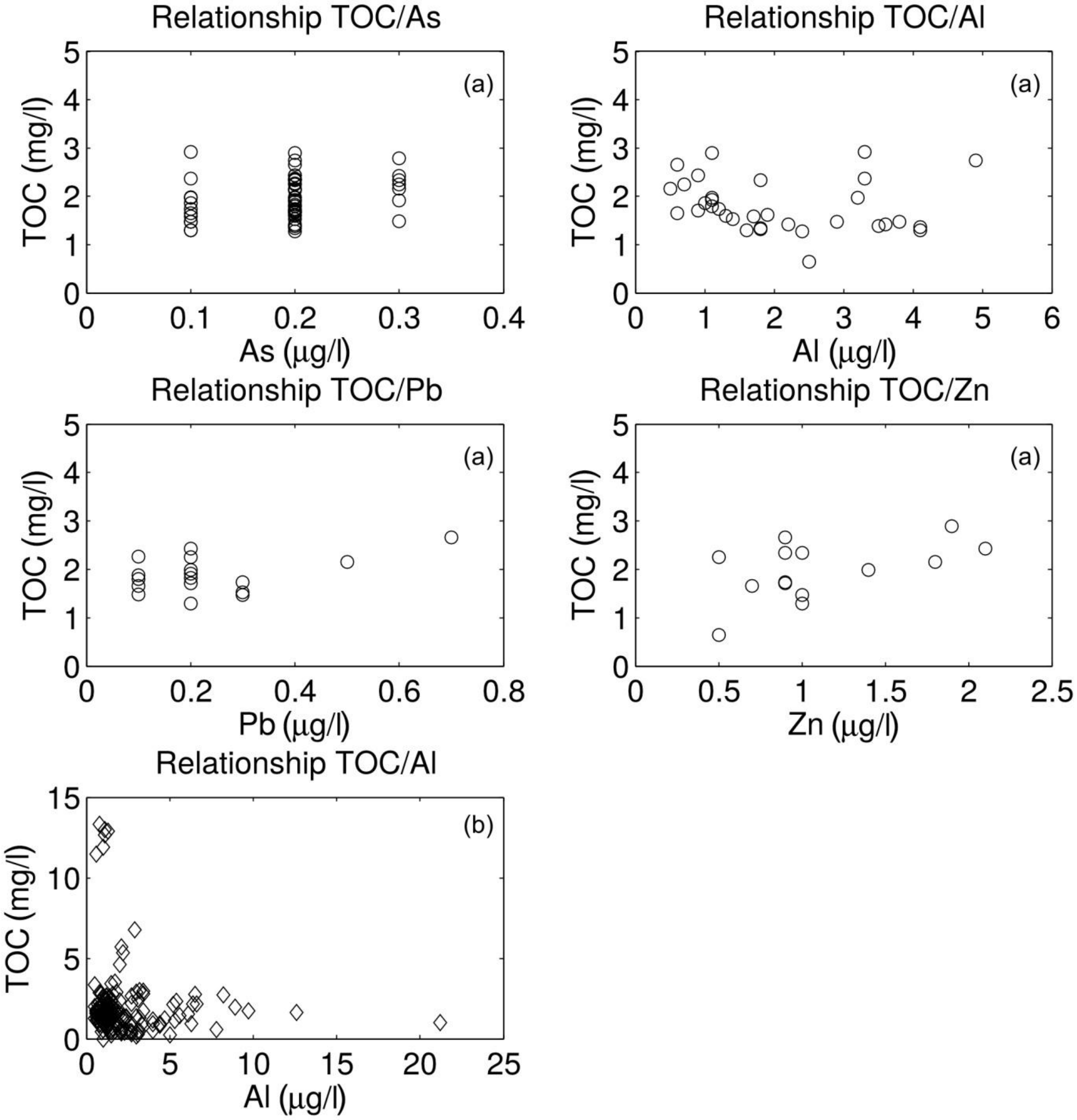

**Supplementary Fig. S2.** Box and whisker plot (marking all quartiles and the extent of non-outliers) of the concentrations of the five variables in the discriminant analysis model based on trajectory cluster classification. Li, Rb and Sb are presented on the left axis, while B and electrical conductivity (EC) are measured on the right axis.



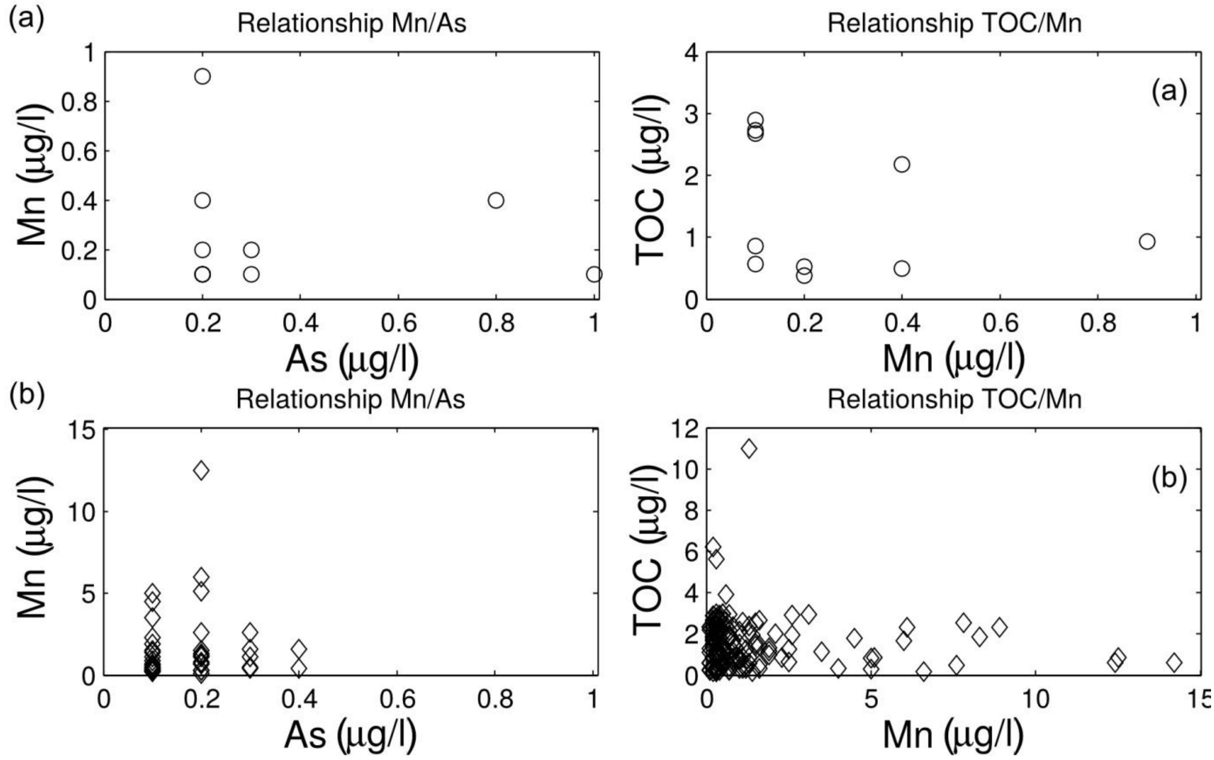

**Supplementary Fig. S3.** Box and whisker plot of the concentrations of the five variables in the discriminant analysis model based on wind direction classification, marking all quartiles and the extent of non-outliers. Please note that Zn concentrations are plotted on the right Y axis.




**Supplementary Fig. S4.** The relationship between metal concentration and pH in the surface waters and atmospheric precipitation.




**Supplementary Fig. S5.** The occurrence of relationships between chosen elements and the total organic carbon (TOC) in the samples collected from (a) the Fuglebekken lake and (b) the Fuglebekken stream.




**Supplementary Fig. S6.** Relationships between the concentrations of Mn and As or total organic carbon (TOC) and Mn, as detected in (a) the Fuglebekken stream samples and (b) the precipitation samples.

**Supplementary Table S1.** Validation parameters, technical specifications and reagents used in the applied analytical procedures.

| Analytical techniques | Measure-ment range | Limit of detection | Limit of quantification | Coefficient of variance (%) | Measurement information | Reagents/ standards |
|---|---|---|---|---|---|---|
| Total organic carbon (mg/l) | 0.15-100 | 0.030 | 0.10 | 0.1-5.0 | Total organic carbon analyser TOC-VCSH/CSN, method of catalytic combustion (oxidation) with the use of nondispersive infrared detector<br>(Shimadzu, Kyoto, Japan) | Potassium biphthalate, $C_6H_4(COOH)$ FW204.23, purity 99.9%<br>(Kanto Chemical Co., Tokyo, Japan) |
| Metals (μg/l) | 0.005-1000 | 0.002 | 0.005 | 0.5-1.5 | Elan DRC, gas fed to the atomizer Ar: 0.98 l/min, plasma gas Ar: 15 l/min<br>(PerkinElmer, Waltham, MA, USA) | Inductively coupled plasma mass spectrometry standards, mix 10 ppm<br>(Inorganic Ventures, Christians-burg, VA, USA) |
| Bi, U | 0.01-1000 | 0.003 | 0.01 | | | |
| Cs, Pb | | | | | | |
| Ag, Ba, Cd, Co, Cu, Mo, Rb, Tl | 0.05-1000 | 0.02 | 0.05 | | | |
| As, Cr, Mn, Sr, Ni | 0.10-1000 | 0.03 | 0.10 | | | |
| Al, Li, Zn | 0.5-1000 | 0.2 | 0.5 | | | |
| B | 5-1000 | 2 | 5 | | | |

**Supplementary Table S2.** Reference materials.

| | |
|---|---|
| Reference material no. 409 | Simulated rainwater BCR-409, Institute for Reference Materials and Measurements, Geel, Belgium |
| Inorganic Ventures, Christiansburg, VA, USA Analytical reference material ANALITYK- CCS-4, CCS-6, CCS-1, IV-ICPMS-71A, Poland | 10 mg $L^{-1}$ concentration standards for: Ag, Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Cs, Mo, Ni, Pb, Sb, Se, Sr, V, Zn |
| Analytical reference material TM-DWS.2, Environment Canada, mixed standard | Al: 58.3 µg $L^{-1}$, Sb: 3.20 µg $L^{-1}$, As: 4.20 µg $L^{-1}$, Ba: 146 µg $L^{-1}$, Be: 13.4 µg $L^{-1}$, Bi: 14 µg $L^{-1}$, B: 81.0 µg $L^{-1}$, Cd: 4.20 µg $L^{-1}$, Cr: 44.4 µg $L^{-1}$, Co: 64.2 µg $L^{-1}$, Cu: 167 µg $L^{-1}$, Cs: 0.04 µg $L^{-1}$, Pb: 7.82 µg $L^{-1}$, Li: 20.1 µg $L^{-1}$, Mo: 66.7 µg $L^{-1}$, Ni: 82.3 µg $L^{-1}$, Rb: 0.42 µg $L^{-1}$, Se: 8.69 µg $L^{-1}$, Ag: 9.91 µg $L^{-1}$, Sr: 243 µg $L^{-1}$, Tl: 8.32 µg $L^{-1}$, Sn: 12.1 µg $L^{-1}$, U: 14.1 µg $L^{-1}$, V:44.3 µg $L^{-1}$, Zn: 379 µg $L^{-1}$ |

**Supplementary Table S3**. Minimum, maximum and mean concentrations of different compounds determined in surface waters and precipitation.

| Sample type | Determined parameter/ analyte | Li (μg·L$^{-1}$) | B (μg·L$^{-1}$) | Al (μg·L$^{-1}$) | V (μg·L$^{-1}$) | Cr (μg·L$^{-1}$) | Mn (μg·L$^{-1}$) | Co (μg·L$^{-1}$) | Ni (μg·L$^{-1}$) | Cu (μg·L$^{-1}$) | Zn (μg·L$^{-1}$) | As (μg·L$^{-1}$) | Se (μg·L$^{-1}$) | Rb (μg·L$^{-1}$) | Sr (μg·L$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atmos-pheric precipi-tation | Min. | 0.500 | 5.00 | 0.500 | 0.100 | 0,100 | 0.100 | 0.050 | 0.200 | 0.100 | 0.500 | 0.100 | 0.050 | 0.050 | 0.500 |
| | Max. | 0.800 | 23.0 | 13.7 | 0.400 | 1.30 | 14.2 | 0.800 | 2.20 | 5.00 | 1378 | 0.400 | 1.33 | 1.01 | 36.7 |
| | Mean | 0.600 | 11.5 | 1.63 | 0.218 | 0.465 | 1.44 | 0.150 | 0.476 | 0.664 | 28.9 | 0.175 | 0.279 | 0.146 | 3.87 |
| | Median | 0.600 | 10.0 | 1.00 | 0.200 | 0.400 | 0.500 | 0.075 | 0.300 | 0.400 | 9.75 | 0.200 | 0.220 | 0.100 | 2.00 |
| | N | 6 | 17 | 131 | 85 | 126 | 156 | 16 | 37 | 135 | 172 | 40 | 118 | 110 | 157 |
| Fugle-bekken stream | Min. | 0.500 | 5.00 | 0.500 | 0.200 | 0.300 | 0.100 | – | 0.200 | 0.100 | 0.500 | 0.100 | 0.050 | 0.090 | 11.7 |
| | Max. | 0.900 | 9.00 | 21.2 | 2.00 | 6.80 | 0.900 | – | 0.400 | 2.60 | 9.90 | 1.00 | 0.960 | 0.530 | 95.9 |
| | Mean | 0.861 | 7.80 | 2.18 | 1.13 | 3.24 | 0.260 | – | 0.283 | 0.361 | 1.83 | 0.184 | 0.259 | 0.168 | 50.7 |
| | Median | 0.700 | 9.00 | 1.40 | 1.10 | 3.45 | 0.15 | – | 0.250 | 0.300 | 1.00 | 0.200 | 0.250 | 0.160 | 55.6 |
| | N | 56 | 5 | 183 | 199 | 199 | 10 | – | 6 | 188 | 61 | 123 | 165 | 199 | 199 |
| Fugle-bekken lake | Min. | 1.00 | 7.00 | 0.500 | 1.00 | 0.300 | 0.100 | – | – | 0.100 | 0.500 | 0.100 | 0.080 | 0.170 | 58.4 |
| | Max. | 1.40 | 7.00 | 4.90 | 1.90 | 6.60 | 0.600 | – | – | 0.900 | 2.10 | 0.300 | 0.610 | 0.270 | 101 |
| | Mean | 1.18 | 7.00 | 2.06 | 1.47 | 2.63 | 0.350 | – | – | 0.549 | 1.11 | 0.191 | 0.349 | 0.202 | 73.3 |
| | Median | 1.20 | 7.00 | 1.80 | 1.40 | 0.800 | 0.350 | – | – | 0.600 | 0.950 | 0.200 | 0.365 | 0.200 | 72.8 |
| | N | 61 | 1 | 33 | 61 | 61 | 2 | – | – | 55 | 14 | 57 | 60 | 61 | 61 |

**Supplementary Table S4.** Squares of (a) Mahalanobis distances and (b) their significance levels for wind direction classes in the discriminant analysis model devised based on all parameters.

| (a) | ENE | WSW | WNW | E | SW | W | SSW | NW |
|---|---|---|---|---|---|---|---|---|
| ENE | 0.00 | 1.65 | 2.57 | 1.82 | 9.30 | 3.90 | 2.52 | 10.35 |
| WSW | 1.65 | 0.00 | 1.72 | 2.04 | 8.20 | 2.48 | 3.71 | 10.51 |
| WNW | 2.57 | 1.72 | 0.00 | 2.72 | 9.03 | 3.25 | 3.83 | 9.78 |
| E | 1.82 | 2.04 | 2.72 | 0.00 | 8.23 | 3.88 | 3.16 | 8.79 |
| SW | 9.30 | 8.20 | 9.03 | 8.23 | 0.00 | 10.96 | 11.04 | 14.42 |
| W | 3.90 | 2.48 | 3.25 | 3.88 | 10.96 | 0.00 | 3.46 | 8.73 |
| SSW | 2.52 | 3.71 | 3.83 | 3.16 | 11.04 | 3.46 | 0.00 | 7.10 |
| NW | 10.35 | 10.51 | 9.78 | 8.79 | 14.42 | 8.73 | 7.10 | 0.00 |

| (b) | ENE | WSW | WNW | E | SW | W | SSW | NW |
|---|---|---|---|---|---|---|---|---|
| ENE | | 0.57 | 0.77 | 0.51 | 0.00 | 0.38 | 1.00 | 0.00 |
| WSW | 0.57 | | 0.98 | 0.59 | 0.00 | 0.91 | 0.96 | 0.01 |
| WNW | 0.77 | 0.98 | | 0.83 | 0.02 | 0.93 | 0.99 | 0.11 |
| E | 0.51 | 0.59 | 0.83 | | 0.00 | 0.53 | 0.99 | 0.04 |
| SW | 0.00 | 0.00 | 0.02 | 0.00 | | 0.00 | 0.14 | 0.00 |
| W | 0.38 | 0.91 | 0.93 | 0.53 | 0.00 | | 0.99 | 0.23 |
| SSW | 1.00 | 0.96 | 0.99 | 0.99 | 0.14 | 0.99 | | 0.83 |
| NW | 0.00 | 0.01 | 0.11 | 0.04 | 0.00 | 0.23 | 0.83 | |

**Supplementary Table S5.** Squares of Mahalanobis distances (a) and their significance levels (b) for air mass trajectory clusters in the discriminant analysis model devised based on all parameters.

| (a) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 3.62 | 6.52 | 3.24 | 4.89 | 7.20 | 3.89 | 7.81 |
| 2 | 3.62 | 0.00 | 3.06 | 3.04 | 2.35 | 3.72 | 2.80 | 6.64 |
| 3 | 6.52 | 3.06 | 0.00 | 2.86 | 2.72 | 2.46 | 2.35 | 5.62 |
| 4 | 3.24 | 3.04 | 2.86 | 0.00 | 3.30 | 4.03 | 3.17 | 6.40 |
| 5 | 4.89 | 2.35 | 2.72 | 3.30 | 0.00 | 3.04 | 3.46 | 5.26 |
| 6 | 7.20 | 3.72 | 2.46 | 4.03 | 3.04 | 0.00 | 2.28 | 4.20 |
| 7 | 3.89 | 2.80 | 2.35 | 3.17 | 3.46 | 2.28 | 0.00 | 4.45 |
| 8 | 7.81 | 6.64 | 5.62 | 6.40 | 5.26 | 4.20 | 4.45 | 0.00 |

| (b) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | | 0.09 | 0.58 | 0.16 | 0.11 | 0.00 | 0.18 | 0.03 |
| 2 | 0.09 | | 0.99 | 0.11 | 0.79 | 0.04 | 0.42 | 0.06 |
| 3 | 0.58 | 0.99 | | 0.99 | 1.00 | 1.00 | 1.00 | 0.91 |
| 4 | 0.16 | 0.11 | 0.99 | | 0.41 | 0.02 | 0.27 | 0.08 |
| 5 | 0.11 | 0.79 | 1.00 | 0.41 | | 0.56 | 0.54 | 0.47 |
| 6 | 0.00 | 0.04 | 1.00 | 0.02 | 0.56 | | 0.71 | 0.53 |
| 7 | 0.18 | 0.42 | 1.00 | 0.27 | 0.54 | 0.71 | | 0.57 |
| 8 | 0.03 | 0.06 | 0.91 | 0.08 | 0.47 | 0.53 | 0.57 | |

**Supplementary Table S6.** The discriminant model for wind direction classes, with the variable number truncated to five (model parameters: Wilks's lambda = 0.61, approximate F (35.54) = 1.94, $p$ < 0.002).

| | Wilks's lambda | Partial Wilks's lambda | F to remove (7.13) | *p* | Tolerance |
|---|---|---|---|---|---|
| Zn | 0.66 | 0.92 | 1.53 | 0.16 | 0.99 |
| As | 0.65 | 0.93 | 1.39 | 0.22 | 0.59 |
| Rb | 0.71 | 0.86 | 3.06 | 0.01 | 0.61 |
| Cd | 0.69 | 0.88 | 2.42 | 0.02 | 0.99 |
| Pb | 0.65 | 0.93 | 1.37 | 0.23 | 0.98 |

**Supplementary Table S7.** The discriminant model for air mass trajectory clusters, with the variable number truncated to five (model parameters: Wilks's lambda = 0.70, approximate F (35.56) = 1.45, $p$< 0.048).

| | Wilks's lambda | Partial Wilks's lambda | F to remove (7.13) | *p* | Tolerance |
|---|---|---|---|---|---|
| Li | 0.75 | 0.93 | 1.52 | 0.17 | 0.22 |
| B | 0.73 | 0.96 | 0.86 | 0.54 | 0.30 |
| Rb | 0.76 | 0.92 | 1.69 | 0.12 | 0.42 |
| Sb | 0.76 | 0.92 | 1.74 | 0.10 | 0.76 |
| EC | 0.77 | 0.91 | 1.95 | 0.07 | 0.16 |

**Supplementary Table S8.** Metal concentrations in non-biological environmental samples collected in Svalbard.

| Non-biological sample type | Determined compounds/ compound groups | Identified content/scope | References |
|---|---|---|---|
| Air | Ni, Hg, Pb, Cd, Cu, Zn, Mn, As, Cr, Co, V | 0.005-1790 (pg $m^{-3}$) | Berg et al. 2004; Berg et al. 2008 |
| Seawater, groundwater, surface water (stream, river, lake, spring) | Cd, Zn, Cu, Pb, Cr, Mn, Fe, Co, Ni, Fe, Mg, Li, Na, Rb, Cs, Be, Ca, Sr, Ba, Si | 0.01-183 (μg $L^{-1}$) | Drbal et al. 1993; Headley 1996; Banks et al. 1998; Banks et al. 1999; Burzyk et al. 2004; Ahn et al. 2009 |
| | Li, Be, B, Al, V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Ag, Cd, Sn, Sb, Cs, Ba, Tl, Pb, Bi, U | 0.0001-95.9 (μg $L^{-1}$) | our research |
| Glacier ice (surface samples and ice cores) | Cd, Zn, Cu, Pb, Cr, Mn, Fe, Co, Ni, Mg | 0.0001-0.0255 (μg $L^{-1}$) | Drbal et al. 1993 |
| Snow | Ca, K, Mg, Na | 0.005-232.3 (mg $L^{-1}$) | de Caritat et al. 2005 |
| Precipitation | Cu, Zn, Pb, Fe, Ni, Mg | 0.01-12 (μg $L^{-1}$) | Headley et al. 1996 |
| | Li, Be, B, Al, V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Ag, Cd, Sn, Sb, Cs, Ba, Tl, Pb, Bi, U | 0.0001-1378 (μg $L^{-1}$) | our research |
| Waste rock pile | Fe, Al, Mn, Zn, Ni, Cu, Cr, As, Cd, Pb | 0.06-109000 (μg $L^{-1}$) | Søndergaard at al. 2008 |
| Sediment | Cd, Zn. Cu, Pb, Cr, Co, Ni, As, Hg, Sb, Sc, Ti, V, Mn | 0.031-46413.9 (μg $g^{-1}$) | Siegel et al. 2000; Burzyk et al. 2004; Evenset et al. 2007; Lu et al. 2013 |
| Peat profile | Cu, Zn, Pb, Fe, Ni, Mg | 3.2-1120 (μg $g^{-1}$) | Headley et al. 1996 |
| Rock pile | Al, Cr, Mn, Fe, Ni, Zn, As, Pb | 0.1-166888.3 (μg $g^{-1}$) | Elberling et al. 2007 |

| | | | |
|---|---|---|---|
| Coal | Al, Si, P, S, K, Ca, Ti, V, Mn, Fe, Ga, As, Se, Sr, Y, Zr, Nb, Cd, Sn, Sb, Ba, Pb, Ga | 0.03-15215 (µg $g^{-1}$) | Orheim et al. 2007; Lewińska-Preis et al. 2009 |
| Soil | Al, As, Sb, Se, Tl, Ba, Co, Cu, Ni, Pb, Cr, Mn, Fe, Be, Cd, Mg, Ti, Zr, Zn, Mo, Te, Sn, Li, B, V, Sr, Rb, Ce, U, Sc, La | 0.00006-679 (µg $g^{-1}$) | Plichta & Kuczyńsk 1991; Gulińska et al. 2003; Melke 2006; Luks & Głowacki 2007; Askaer et al. 2008 |

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