Supporting information for:

Seabird-transported contaminants are reflected in the Arctic tundra, but not in its soil-dwelling springtails (Collembola)

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Supporting information includes 5 bodies of text, 4 figures and 3 tables, on a total of 18 pages.

Content:

S1. Determination of lipid-soluble contaminants

Solvents applied during the extraction and clean-up prior to analysis of POPs were of SupraSolv® grade, purchased from Merck, Darmstadt, Germany.

Lipid-associated contaminants were extracted from substrate samples using Soxhlet extraction. Borosilicate fibre glass extraction thimbles (603 g, 25 mm x 100 mm) were burned at 450°C for 8 hours. Approximately 10 g of substrate homogenates were weighed into the thimbles, ~20 g material for Ny-Ålesund samples, and spiked with 21-211 ng internal standard containing ^{13}C labelled PCBs, OCPs, and PBDEs. The thimbles were covered with cotton, prewashed with dichloromethane (DCM). Round bottomed flasks were filled with 210 mL of toluene, and the extraction was run for 17–24 hours per sample, with four cycles per hour. Sulphur was removed from the soil/moss to avoid analytical disturbance by adding 1 g activated (acid-washed) granulated copper to the solvent. Extracts were concentrated using TurboVap® 500 Evaporation System (Caliper Life Sciences, Mountain View, USA), before transferred to glass centrifuge tubes, using n-hexane and DCM to dissolve sample material from the glass walls, ensuring transfer of the complete sample. Samples were then re-concentrated with RapidVap® Vacuum Dry Evaporation System (Labconco, Kansas City, USA) until almost dry, and supplemented with a few drops of isooctane. The first clean-up step was performed with multi-bed solid phase extraction (SPE) cartridges (Supelclean™ EZ-POP NP, 54341-U, Supelco, Sigma-Aldrich, Bellefonte, US) in a SPE station. The samples were added to cartridges using isooctane and acetonitrile to dissolve sample material from the glass walls, and each cartridge was added 5 mL acetonitrile. This was repeated 3 times. The contaminant extracts were re-concentrated using RapidVap® to 0.1 mL, added n-hexane to 0.7 mL and mixed using a vortex mixer. As extracts contained more matrix than preferable, sampled were split into two sub-samples and diluted with n-hexane to a total of 0.7 mL. The second clean-up step was carried out with Zymark RapidTrace SPE Workstation (Caliper Life Sciences, Mountain View, USA). SilactSPE™ columns (Affinisep, Paris, France) were loaded with 1.0 g Florisil® (0.15–0.25 mm), between two glass fibre fritz. The samples were automatically loaded into a separate SPE column and eluted with 6 mL 10% DCM/hexane (mobile phase). Sub-samples were merged and concentrated to 0.2 mL with RapidVap®. Samples were transferred to gas-chromatograph (GC) vials with a micro-volume insert using isooctane and concentrated to 50 µL using a N_2 evaporator (N_2 purity 99.995%, quality 5.0, Yara Praxair AS, Porsgrunn, Norway). Samples were added a recovery standard (20 µL of ^{13}C PCB 159, 213 pg/µL), before mixed with a vortex mixer and stored at 4°C until analysis.

Springtail samples were homogenized using a mortar and pestle, before extracted for lipid-soluble contaminants using cold column extraction. Homogenates were weighed (1.99 g–3.59 g) and added sodium sulfate (Na_2SO_4) until all had a similar dry consistency (1:10), before further homogenised with a metal spatula, and left at -20°C overnight to dry. Samples were acclimatized to room temperature before re-homogenised with a spatula. Homogenates were transferred to glass columns and spiked with 200 µL of the internal standard containing ^{13}C labelled PCBs, OCPs, and PBDEs. Cyclohexane:acetone (50 mL, 3:1) were added to the column, which was closed when the solvents had permeated the whole sample, and opened after 30 min letting the solvent run through. This was repeated 2 times. Extracts were concentrated to 1–2 mL, using TurboVap®. The concentrated extracts were transferred to pre-weighed glass containers, using n-hexane and DCM to dissolve sample material from the glass walls. Extracts with solvents were re-concentrated using RapidVap® until only remaining matrix, and lipid content was determined gravimetrically. The clean-up steps were completed in the same manner as described for substrate samples.

Separation and detection of PCBs in substrate and springtails were conducted with a gas chromatograph-mass spectrometer (GC-MS) quadrupole instrument (Agilent, Santa Clara, CA, USA, GC 7890, MSD 5975C), in electron ionization mode, and in single ion monitoring mode. For separation of compounds, a 1 µL aliquot of the sample was injected in splitless mode (250°C, non-tapered liner), with helium as the carrier gas at a flow rate of 1.5 mL/min. The following temperature program was applied: 70°C for 2 min, followed by an increase of 15°C/min until reaching 180°C, an increase of 5°C/min to 280°C, before holding 280°C constant for 5 min. Analyses were conducted on a DB-5 MS column (length 30 m, 0.25 µm film thickness, 0.25 mm inner diameter). The MS transfer line temperature held at 300°C and ion source temperature was set to 230°C. The analysis of OCPs was performed in negative chemical ionization mode, with helium as carrier gas at a flow rate of 1.0 mL/min. Sample aliquots of 2 µl were injected in splitless mode at 220°C (glass wool liner). Temperatures were programmed as: 80°C was held for 2 min, followed by an increase of 20°C/min until reaching 100°C, held for 5 min, before an increase of 20°C/min to 170°C, held for 3 min, before a final increase of 20°C/min to 300°C, held for 2 min. Analyses were performed on an Agilent Ultra2 column (length 25 m, 0.11 µm film thickness, 0.20 mm inner diameter). The MS transfer line temperature held at 300°C and ion source temperature was set to 160°C. PBDEs were analysed in electron ionization mode and single ion monitoring mode with a Waters Quattro Micro GC-MS (Waters Corp., MA, USA). Helium was applied as carrier gas (flow rate of 1.6 mL/min), with a 5 µl sample injection volume in splitless mode at 300°C. The temperature program used for these contaminants was: 85°C initially held for 1 min, then an increase of 21°C/min to 210°C, followed by 9°C/min increase until a final 310°C, kept for 5 min. Analyses were conducted with a Restek 1614 column (length 15 m, 0.25 µm film thickness, 0.25 mm inner diameter), with a 5 m x 0.32 mmID pre-column and a pressfit inbetween.

S2. Determination of PFASs

Substrate and springtails were analysed for PFASs following a method developed by Powley et al. (2005) with modifications [1]. Solvents applied during the extraction and clean-up were of LiChrosolv® grade, purchased from Merck, Darmstadt, Germany.

Substrate homogenates (5.0–5.8 g) and springtail homogenates (0.5–2.4 g) were placed in 50 mL polypropylene (PP)-centrifuge tubes before spiked with 20 µL of internal standard (0.5 ng/µL ^{13}C PFAS mix). One mL of 200 mM sodium hydroxide (NaOH) in methanol was added, and the samples were left resting for 30 min. They were then added 100 µL of 2 M hydrogen chloride (HCl) in methanol, and additionally 9 mL of methanol before mixed using a vortex mixer. PFASs were extracted by ultrasonic treatment (Branson 5510, Branson Ultrasonics Corp., Conneticut, USA), three treatments of 10 min with 15 sec of mixing using a vortex mixer in between. The samples were centrifuged at 2000 rpm for 5 min, and the supernatants were transferred to new 15 mL PP-tubes, before concentrated to 2 mL (1 mL for springtails) using RapidVap®. Approximately 1 mL (0.8 mL for springtails) of the extracts were transferred to 1.5 mL Eppendorf tubes containing 25 mg Envi-Carb graphitized carbon adsorbent and 50 µL fresh anhydrous glacial acetic acid before mixed using a vortex mixer. The tubes were centrifuged at 10,000 rpm for 10 min, and 0.5 mL of the supernatant were transferred to a 1.5 mL glass vial, before added 20 µL of recovery standard (0.25 ng/µL 3,7-dimethyl PFOA; branched PFDcA in methanol) and mixed using a vortex mixer. An aliquot of 50 µL (100 µL for springtails) of the extract was transferred to a liquid chromatography (LC) vial with a micro-volume insert and diluted 1:1 with 2 mM aqueous ammonium acetate (NH_4OAc, ≥99%). Samples were stored at 4°C until analysis. PFASs in substrate and springtails were analysed and quantified according to the procedure described in detail in Hanssen et al., 2013 [2].

S3. Determination of Hg

Substrate samples were air-dried at room temperature for 3 days prior to extraction of Hg, while no pre-treatment was conducted for springtail samples, before analysed for Total Hg by the Norwegian Institute for Air Research (NILU, Kjeller, Norway). Approximately 0.5 g substrate and 0.25-0.68 g springtails were weighed accurately on a Mettler PG503 balance and added 5 mL nitric acid (HNO_3, s.p.) and 3 mL deionized water (MilliQ). The samples were extracted according to a 65 min. temperature programme, with stepwise heating to 250°C and a hold tima at this temperature for 30 min. After cooling, the samples were quantitatively transferred to polyethylene tubes, diluted with deionoized water to a total volume of 50 mL, and topped with 250 µl hydrochloric acid (HCl, s.p.). Blank samples and certified reference material (CRM) were prepared and analysed in every run. Prior to analysis, internal standards (^{115}In) were added to all samples. Control samples traceable to National Institute of Standards and Technology (NIST) were used to verify all calibration curves. Hg measurements were performed using an inductively coupled plasma mass spectrometer (ICP-MS) from Agilent, USA (Agilent, 7700x).

S4. Quality assurance

Quantification of organic compounds was performed with the internal-standard method with isotope-labelled OCs, PBDEs, and PFASs. Control parameters included internal standards, recovery standards, solvent blanks, and standard reference materials (SRMs) or reference samples, to ensure accurate and reliable measurements. For substrate samples, the SRMs in the POPs analyses consisted of 0.5 g sediment (SRM 1944 – New York/New Jersey Waterway Sediment (NIST)). For springtail samples, the SRMs containing 0.5 g fish tissue (Contaminated Fish, Reference Material, EDF-2525, Cerilliant CIL, Inc. Texas, USA) were added Na_2SO_4 in a ratio of 1:20. The PFAS analysis included SRMs of UNEP ILS (Sediment sample, Jar n° 072, 2016) for substrate and reference samples of Pike-perch sample (QM 03-2, Quasimeme; #7 and #18) for springtails. The analysis of PFASs in the samples was carried out twice to test for precision, as we expected low levels.

The recovery efficiency for chlorinated and brominated compounds ranged from 30–98% for substrate, springtails, blank and reference samples. The PFAS compounds were not included in statistical analyses, but reported, with recoveries ranging between 19–48% for substrate, and 26% for PFDoDA reported in springtails. Solvent blanks and SRMs had higher recovery for PFASs (50–70% for SRMs), indicating that the low recovery results were linked to difficulties with the matrix. For chlorinated and brominated compounds, the limit of detection (LOD) was defined as 3 times the method noise for each compound as average of all samples of the same kind. When contamination was registered in the blank samples, the LOD was adjusted to the threefold of the found concentration. LODs for PFASs were set to 0.05 ng/g or 0.10 ng/g dry weight (d.w.) for substrate samples, and wet weight (w.w.) for springtail samples. Limit of quantification (LOQ) was set as 3 × LOD for PFASs, PCBs, PBDEs, DDTs. Some OCPs had a lower LOQ, set to 1.6–2.6 × LOD.

S5. Stable isotope analysis

Samples (1.5 mg of substrate or springtails in Sn capsules) were combusted with O_2 and Cr_2O_3 at 1700ºC in a Eurovector EA3028 element analyser. NO_x was reduced to N_2 in a Cu oven at 650ºC. H_2O was removed in a chemical trap of $Mg(ClO_4)_2$ before separation of N_2 and CO_2 on a 2 m Poraplot Q GC column. N_2 and CO_2 are directly injected on-line to a Horizon Isotope Ratio Mass Spectrometer (IRMS) from Nu-Instruments, for determination of $\delta^{13}C$ and $\delta^{15}N$. Isotopic composition was expressed as parts per mille differences by comparison with international standards; atmospheric N_2 for nitrogen (IAEA-N-1 and IAEA-N-2), and Vienna PeeDee Belemnite (VDPB) for carbon (USGS-24 standard). The ratios of stable isotope were expressed as equation 1 and 2 for $\delta^{15}N$ and $\delta^{13}C$, respectively:

$$\delta^{15}N = ((R_{sample}/R_{standard})-1) \times 1000 \qquad (1),$$

where R is the ratio of $^{15}N/^{14}N$, and

$$\delta^{13}C = ((R_{sample}/R_{standard})-1) \times 1000 \qquad (2),$$

where R is the ratio of $^{13}C/^{12}C$, respectively.

S6. Exclusion of PFAS:

Besides PFOS, only few individual PFAS compounds were above the detection limit in several springtail and substrate samples (Table S2 and S3). This demonstrates either the low presence of PFASs compared to other organohalogen compounds occurring in terrestrial ecosystems, and/or reflects challenges in the chemical analyses. PFASs had low methodological recovery of internal standards of mainly the long-chained perfluorinated carboxylic acids (PFCAs) with a chain length of 10 carbons and longer (average 24% for substrate, and 38% for springtails). Thus, some uncertainty is linked to the analysis of these substances in substrate samples and we refer to the Supporting Information for illustration of PFASs relative concentrations (Figure S4). The good fit with standard reference materials and very limited contributions by method blanks indicated that the laboratory procedures were satisfactory. The low recovery of PFASs internal standards indicated therefore that both matrices require further optimizing of the extraction techniques prior to analysis and our data have to be considered semiquantitative for PFAS compounds.

S7. Principal component analyses:

All compounds in the PCA on contaminant concentrations in springtails (Figure S2) were negatively correlated or uncorrelated with $\delta^{15}N$ and with *Lipid.* Of the total variation, 10% was conditioned by the covariate *Lipid*, which was therefore included as a covariate in the final RDA. Increasing concentrations with decreasing δ^{15}N explained 31% of the constrained variation in contamination in *H. viatica* (RDA, permutation test,p=0.003). Thus, in springtails, the concentrations of several chlorinated and brominated compounds, e.g. HCB, chlordanes, high-chlorinated PCBs, BDEs, and *p,p'*-DDE decreased with increasing seabird influence. These surprising findings suggest complex dynamics within soil systems, such as bioavailability, and should be further studied.

The concentrations of *p,p'*-DDE in substrate (Figure S1), representing also α-HCH, PCB-52, BDE-206, BDE-209, *trans* chlordane and γ-HCH, was positively associated with α-HCH, BDE-209 and *p,p'*-DDE in *H. viatica* (Figure S2). The trans-nonachlor concentrations in substrate (*t-NC (substrate)*), representing the clustering of *cis*-chlordane, HCB, *trans*-nonachlor, *cis*-nonachlor and PCB-180 and was positively correlated with all chlordanes, low-chlorinated PCBs and HCHs in *H. viatica*. This vector is positioned along PC1, and thereby accounts for the most variation. Although this could indicate bioaccumulation of contaminants in springtails to a certain degree, the last substrate representative (*PCB-153 (substrate)*) representing the concentrations of high-chlorinated PCBs was negative correlated or uncorrelated with all compounds detected in *H. viatica.* These unclear findings can possibly reflect the variation in bioavailability between sites.

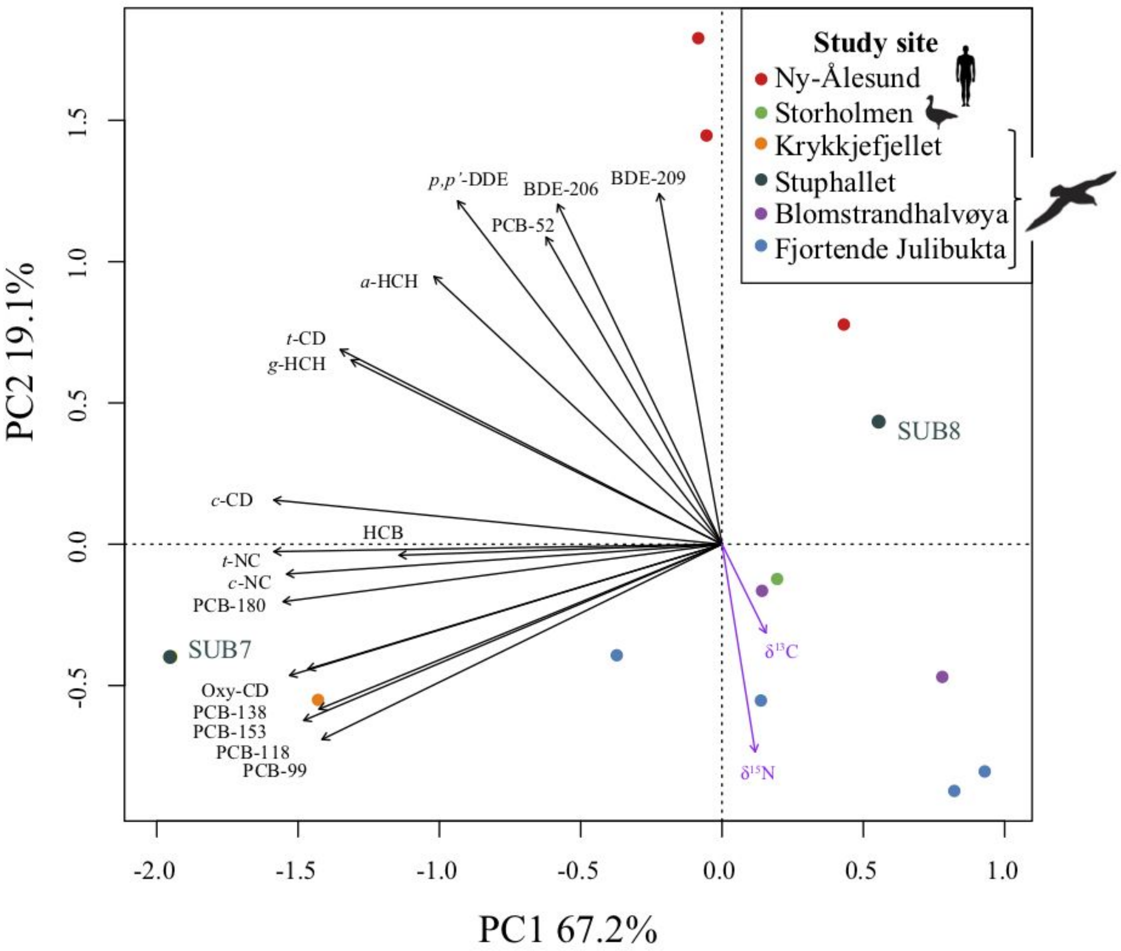

Figure S1. Principal component analyses (PCA) triplot of intercorrelations between logarithmically transformed contaminant concentrations in substrate (pg/g d.w.). Response loadings (contaminants) are projected onto the plot as black arrows, and passive explanatory variables of stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) (purple arrows) did not influence the scores of samples or loadings of responses. The extracted variance (% of total variance) per principal component is given on each axis. Abbreviations: Oxy-CD=oxychlordane, t-CD=*trans* chlordane, c-CD=*cis* chlordane, t-NC=*trans* nonachlor, c-NC=*cis* nonachlor, HCB=hexachlorobenzene, HCH=hexachlorocyclohexane, BDE=congener of polybrominated diphenyl ether, PCB=polychlorinated biphenyl, DDE=dichlorodiphenyldichoroethylene. Symbols indicate the *a priori* ranking of study sites: human-affected (low seabird influence); terrestrial birds (medium seabird influence) and high seabird influence.

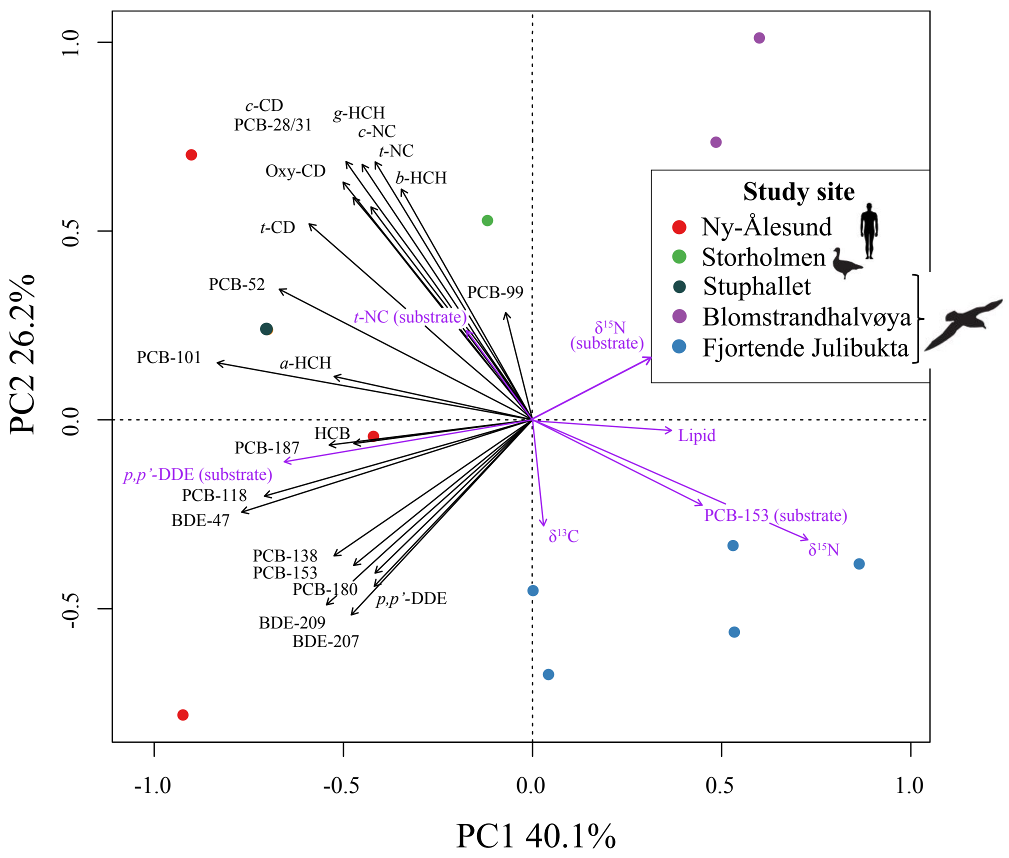

Figure S2. Principal component analyses (PCA) triplot of intercorrelations between logarithmically transformed contaminant concentrations in *Hypogastrura viatica* (pg/g w.w.). Response loadings (contaminants) are projected onto the plot as black arrows, and the passive explanatory variables (purple arrows) did not influence the scores of samples or response loadings. Passive variables include stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) in springtails and $\delta^{15}N$ in substrate. The logarithmically transformed concentrations of PCB-153, *t*-NC and *p,p*'-DDE in substrate represent clusters in the substrate PCA (Figure S1). The extracted variance (% of total variance) per principal component is given on each axis. Abbreviations: Oxy-CD=oxychlordane, t-CD=*trans* chlordane, c-CD=*cis* chlordane, t-NC=*trans* nonachlor, c-NC=*cis* nonachlor, HCB=hexachlorobenzene, HCH=hexachlorocyclohexane, BDE=congener of polybrominated diphenyl ether, PCB=polychlorinated biphenyl, DDE= dichlorodiphenyldichloroethylene. Symbols indicate the *a priori* seabird influence ranking of study sites: human-affected (low); terrestrial birds (medium) and high seabird influence.

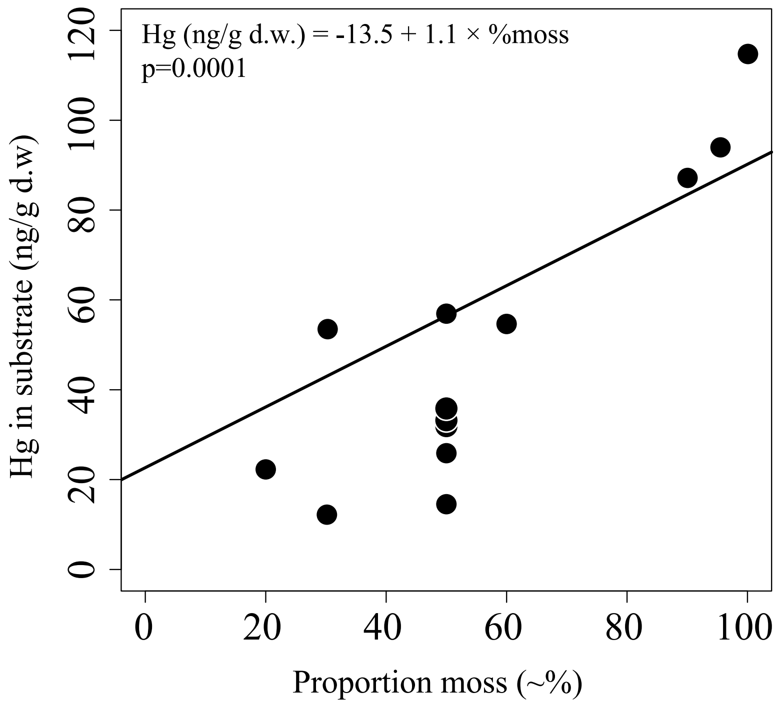

Figure S3. Linear relationship between approximate proportion of moss in substrate sample materials and the concentrations of Hg (ng/g d.w.) in substrate.

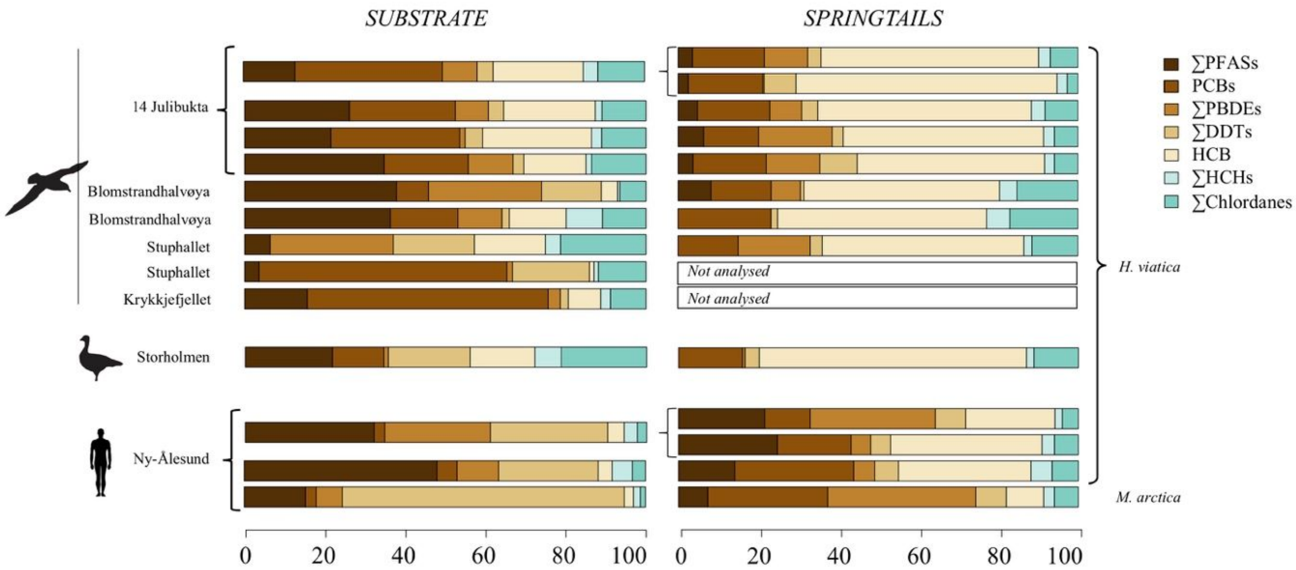

Figure S4. Relative proportions of organic contaminant groups to the sum (∑) of all groups in substrates (left panel) and springtails (right panel). Samples of substrates are presented horizontal to their respective springtail sample. Note that springtails from Storholmen was not analysed for per- and polyfluoroalkyl substances (PFASs) due to insufficient sample material. In Fjortende Julibtukta and Ny-Ålesund, two springtail samples were collected along with one substrate sample, indicated on the figure. Abbreviations: PCBs=polychlorinated biphenyls, PBDEs=polybrominated diphenyl ethers, DDT=dichlorodiphenyltrichloroethane and its metabolites, HCB=hexachlorobenzene, HCH=hexachlorocyclohexanes, Chlordanes=chlordane and its metabolites.

Table S1: Overview and descriptions of samples.

	Location	Springtail sample-ID	Springtail Species	Substrate sample-ID	Substrate content	Distance from seabird colony	Site description
	Ny-Ålesund	MA1	*M. arctica*	SUB1	60% moss, 40% soil (with cyanobacteria layer)	50-200 m from research settlement	Wet area, pond by the beach
	Ny-Ålesund	HV2	*H. viatica*	SUB2/3	20% moss, 80% soil (with cyanobacteria layer)	50-200 m from research settlement	Wet area, pond by the beach
	Ny-Ålesund	HV3	*H. viatica*			50-200 m from research settlement	Wet area, pond by the beach
	Ny-Ålesund	HV4	*H. viatica*	SUB4	50% moss, 50% soil	50-200 m from research settlement	Wet area, pond by the beach
	Storholmen	HV5	*H. viatica*	SUB5	100% moss	Centre of Storholmen island	Flat ground, wet area
	Krykkjefjellet	MA6	*M. Arctica*	SUB6	90% moss, 10% soil	0-2 m from seabird colony	In the slope
	Stuphallet	MA7	*M. Arctica*	SUB7	50% moss, 50% soil	0-2 m from seabird colony	In the slope
	Stuphallet	HV8	*H. viatica*	SUB8	50% moss, 50% soil	250 m from seabird colony	Bottom of the slope, wet area
	Blomstrandøya	HV9	*H. viatica*	SUB9	95% moss, 5% soil (with cyanobacteria layer)	150 m from seabird colony	In the slope
	Blomstrandøya	HV10	*H. viatica*	SUB10	50% moss, 50% soil (with cyanobacteria layer)	400 m from seabird colony	Bottom of the slope, wet area
	Fjortende Julibukta	HV11	*H. viatica*	SUB11	30% moss, 70% soil	130-150 m from seabird colony	Bottom of the slope, wet area
	Fjortende Julibukta	HV12	*H. viatica*	SUB12	30% moss, 70% soil	130-150 m from seabird colony	Bottom of the slope, wet area
	Fjortende Julibukta	HV13	*H. viatica*	SUB13/14	50% moss, 50% soil	130-150 m from seabird colony	Bottom of the slope, wet area
	Fjortende Julibukta	HV14	*H. viatica*		50% moss, 50% soil	130-150 m from seabird colony	Bottom of the slope, wet area
	Fjortende Julibukta	HV15	*H. viatica*	SUB15	50% moss, 50% soil	130-150 m from seabird colony	Bottom of the slope, wet area

Substrate sample SUB13/14 is parallel to springtail samples HV13 and HV14. Substrate sample SUB2/3 is parallel to springtail sa mples HV2 and HV3. Distance from bird cliffs are approximate and retrieved using TopoSvalbard (toposvalbard.npolar.no)

Table S2. Raw data of contaminant concentrations in substrate (soil/moss).



Study site	Ny-Ålesund			Storholmen	Krykkje-fjellet	Stuphallet		Blomstrandhalvøya		Fjortende Julibukta					
Substrate sample ID	**SUB1**	**SUB2/3**	**SUB4**	**SUB5**	**SUB6**	**SUB7**	**SUB8**	**SUB9**	**SUB10**	**SUB11**	**SUB12**	**SUB13/14**	**SUB15**	**LOD**	**LOQ**
Compounds															
pg/g d.w.														pg/g d.w.	
Hg	55020	22078	31796	115219	87244	36024	26146	93965	14895	12013	52633	34061	56152		
PFHxS	60.0	59.4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	50	150
PFNS	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	130	50	150
∑ PFOS	1724	1958	3810	<LOD	1164	539	<LOD	208	<LOD	144	<LOD	63.6	183	50	150
PFOA	105	<LOD	81.3	<LOD	351	161	98.7	203	567	158	297	92.2	184	50	150
PFNA	162	<LOD	<LOD	372	512	146	<LOD	253	523	61.7	145	63.0	<LOD	50	150
PFDA	<LOD	<LOD	<LOD	<LOD	184	120	<LOD	168	<LOD	<LOD	<LOD	<LOD	<LOD	50	150
PFUnDA	<LOD	<LOD	<LOD	<LOD	460	207	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	50	150
pg/g w.w.														pg/g w.w.	
PCB 28/31	<LOD	<LOD	<LOD	6.74	14.4	22.4	<LOD	7.25	<LOD	<LOD	<LOD	11.0	8.77	3.27	9.81
PCB 52	39.6	9.5	15.0	<LOD	20.1	32.9	<LOD	<LOD	26.9	<LOD	9.10	9.25	8.20	7.82	23.5
PCB 99	<LOD	4.3	4.54	<LOD	174	703	<LOD	4.37	8.64	6.64	10.5	14.8	16.4	3.16	9.48
PCB 101	<LOD	7.9	10.2	<LOD	57.0	435	<LOD	4.65	<LOD	<LOD	7.55	<LOD	5.37	3.67	11.0
PCB 105	<LOD	<LOD	<LOD	<LOD	102	624	<LOD	<LOD	<LOD	<LOD	<LOD	4.98	10.0	4.84	14.5
PCB 118	<LOD	6.0	6.46	8.32	247	1720	<LOD	8.59	5.90	10.3	13.8	18.7	26.7	4.39	13.2
PCB 138	16.8	11.7	10.3	14.5	819	2660	<LOD	14.8	7.29	17.3	27.8	29.2	54.0	3.50	10.5
PCB 153	39.1	15.2	<LOD	<LOD	1240	4460	<LOD	26.1	21.8	32.7	63.6	54.6	93.3	6.24	18.7
PCB 180	37.0	<LOD	8.40	7.03	587	2110	<LOD	11.1	11.1	14.8	18.3	<LOD	40.0	4.12	12.3
PCB 183	<LOD	<LOD	<LOD	<LOD	100	299	<LOD	<LOD	<LOD	<LOD	3.53	11.3	7.09	3.45	10.4
PCB 187	6.24	<LOD	<LOD	<LOD	167	251	<LOD	5.44	<LOD	5.53	7.50	8.01	13.1	4.00	12.0
PCB 194	<LOD	<LOD	<LOD	<LOD	106	280	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	6.72	20.1
PBDE 47	<LOD	<LOD	<LOD	<LOD	42.3	78.9	<LOD	<LOD	5.1	<LOD	<LOD	6.8	5.2	1.2	3.5
PBDE 99	<LOD	3.6	<LOD	<LOD	23.2	21.2	2.8	2.4	<LOD	<LOD	<LOD	3.6	3.5	1.2	3.6
PBDE 100	<LOD	<LOD	<LOD	3.2	7.0	7.4	<LOD	<LOD	13.4	<LOD	5.1	<LOD	<LOD	1.0	2.9
PBDE 153	<LOD	<LOD	<LOD	<LOD	5.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.1	3.2
PBDE 154	<LOD	<LOD	<LOD	<LOD	5.2	9.2	2.0	2.2	2.3	<LOD	<LOD	<LOD	<LOD	1.1	3.2
PBDE 183	<LOD	0.9	0.7	<LOD	<LOD	<LOD	<LOD	4.6	<LOD	<LOD	<LOD	<LOD	<LOD	3.7	11.0
PBDE 206	10.0	3.2	8.9	<LOD	5.6	8.6	3.4	4.3	3.6	0.9	1.7	2.7	2.0	1.3	4.0
PBDE 207	13.6	5.3	12.9	<LOD	4.8	9.3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.6	4.7
PBDE 209	321	99.5	520	<LOD	85.9	173	55.2	40.3	263	45.7	<LOD	37.7	56.1	26	79

Table S2 continued. Raw data of contaminant concentrations in substrate (soil/moss).

Study site	Ny-Ålesund			Storholmen	Krykkje-fjellet	Stuphallet		Blomstrandhalvøya		Fjortende Julibukta					
Substrate sample ID	**SUB1**	**SUB2/3**	**SUB4**	**SUB5**	**SUB6**	**SUB7**	**SUB8**	**SUB9**	**SUB10**	**SUB11**	**SUB12**	**SUB13/14**	**SUB15**	**LOD**	**LOQ**
Compounds															
pg/g w.w.														pg/g w.w.	
o,p'-DDT	<LOD	<LOD	<LOD	<LOD	<LOD	453	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	5.6	16.9
p,p'-DDT	107	<LOD	<LOD	<LOD	<LOD	1010	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	7.9	23.7
o,p'-DDD	<LOD	<LOD	<LOD	<LOD	14.7	62.9	4.65	<LOD	21.9	<LOD	<LOD	<LOD	<LOD	2.6	7.9
p,p'-DDD	<LOD	58.4	187	44.9	<LOD	593	37.2	<LOD	115	<LOD	<LOD	<LOD	<LOD	9.6	28.8
o,p'-DDE	<LOD	<LOD	<LOD	<LOD	<LOD	10	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.7	11.0
p,p'-DDE	3604	212	415	13.4	109	2088	<LOD	8.82	15.3	11.2	21.9	23.3	30.6	8.1	24.2
HCB	121	38	84.6	46.1	489	260	36.5	69.3	41.6	64.5	137	140	173	7.0	14.6
a-HCH	77.4	49.4	59	5.5	89	102	5	15.1	<LOD	3.7	8.2	6.3	12.1	0.4	1.2
b-HCH	n.d.	n.d.	n.d.	9.1	35.6	94.9	<LOD	21.3	<LOD	<LOD	<LOD	<LOD	11.5	0.6	1.9
c-HCH	11.9	5.2	8.3	4.1	22.2	42	2.8	7.8	5.5	2.1	4.6	4	4.6	1.7	5.1
Oxychlordane	34.3	28	34.1	40.1	311	1316	33.5	32.7	57.9	53.9	44.1	54.4	66	18.6	55.7
***Trans* chlordane**	4.1	1.2	1.6	1.9	15.4	92.7	1.6	1.2	0.9	0.5	0.9	1.2	1.9	0.3	0.9
***Cis* chlordane**	12.8	3.4	5.0	6.2	65	277	3.5	5.0	2.6	2.1	3.8	4	7.6	1.4	4.2
***Trans* nonachlor**	11.7	3.1	4.7	8.5	95	608	3.3	8.3	3.1	<LOD	4.3	4.8	8.7	2.6	7.0
***Cis* nonachlor**	5.1	<LOD	2.1	4.2	47.2	312	2.1	5.7	2.2	<LOD	2.4	2.8	5.2	1.2	2.8
Mirex	<LOD	<LOD	<LOD	<LOD	50.4	165	<LOD	<LOD	8.6	<LOD	5.7	<LOD	5.6	4.1	12.2

Abbreviations: LOD = limit of detection, LOQ=limit of quantificaiton, n.d. = not detected, d.w. = dry weight

Analyte abbreviations: Hg=mercury, PFHxS=perfluorohexane sulfonate, PFNS=perflurodecane sulfonate, PFOS=perfluorooctanesulfaonic acid, PFOA=perfluorooctanoic acid, PFNA=perfluorononanoic acid, PFDA=perfluorodecanoic acid , PFUnDA=perfluoroundecanoic acid, PCB=polychlorinated biphenyl, PBDE=polybrominated diphenyl ether, DDT=dichlorodiphenyltrichloroethane, DDD=dichlorodiphenyldichloroethane, DDE=dichlorodiphenyldichloroethylene, and HCB=hexachlorobenzene, HCH=hexachlorocyclohexane.

PFAS congeners below LOD in all substrate samples (pg/g d.w., given in brackets): PFBS (50), PFHpS (50), PFDcS (50), PFHxA (100), PFHpA (100), PFDoDA (100), PFTrDA (100), PFTeDA (100)
Other analytes below LOD in all substrate samples (pg/g w.w.., given in brackets): PBDE-28 (10.4), PBDE-138 (1.10), PBDE-196 (1.10) and PBDE-197 (1.00)

Table S3. Raw data of contaminant concentrations in springtails.

Study site	**Ny-Ålesund**				**Storholmen**	**Krykkje-fjellet**	**Stuphallet**		**Blomstrandhalvøya**		**Fjortende Julibukta**						
Springtail sample ID	**MA1**	**HV2**	**HV3**	**HV4**	**HV5**	**MA6**	**MA7**	**HV8**	**HV9**	**HV10**	**HV11**	**HV12**	**HV13**	**HV14**	**HV15**	**LOD**	**LOQ**
Compounds																	
pg/g d.w.																	
Hg	49752	12988	18228	11021	15577	88644	n.a.	19830	13747	13081	13012	10655	10616	9732	9309		
pg/g w.w.																pg/g w.w.	
∑PFOS	408	1085	1975	2634	n.a.	77.4	n.a.	n.a.	<LOD	<LOD	<LOD	115	<LOD	<LOD	<LOD	50	150
PFNA	<LOD	68.3	56	<LOD	n.a.	91.3	n.a.	n.a.	<LOD	94.3	<LOD	55.3	<LOD	50.6	<LOD	50	150
PFDA	<LOD	<LOD	<LOD	<LOD	n.a.	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	<LOD	60.1	<LOD	<LOD	50	150
PFUnDA	65.7	88.2	66.7	55.1	n.a.	15.7	n.a.	n.a.	<LOD	86.7	<LOD	52.6	<LOD	<LOD	<LOD	50	150
PFDoDA	<LOD	55.3	95.4	162	n.a.	86.7	n.a.	n.a.	<LOD	214	260	179	137	65.9	196	50	150
PCB 28/31	73.5	903	116	134	219	n.a.	n.a.	349	236	175	80.2	169	61.9	80.8	179	11.4	34.3
PCB 52	320	666	295	289	180	n.a.	n.a.	287	164	140	105	131	<LOD	149	153	71.5	214
PCB 99	89.2	137	242	137	101	n.a.	n.a.	85.1	57.5	54.4	223	64.1	60	121	73.7	26.7	80.2
PCB 101	153	242	222	222	84.5	n.a.	n.a.	143	63.0	75.4	106	64	38.1	<LOD	59.9	31.0	93.2
PCB 105	49.8	46.5	82.7	<LOD	<LOD	n.a.	n.a.	23.0	<LOD	<LOD	26.4	<LOD	26.2	49.8	<LOD	21.9	65.6
PCB 118	168	145	137	144	136	n.a.	n.a.	118	66.5	61.5	145	80.5	94.2	78.4	96.2	19.6	58.8
PCB 138	288	180	138	169	158	n.a.	n.a.	101	77.4	65.4	171	107	128	110	120	38.5	115
PCB 153	516	295	303	299	245	n.a.	n.a.	166	162	135	314	198	233	199	216	60.7	182
PCB 180	160	68.3	53.0	60.4	69.3	n.a.	n.a.	36.4	<LOD	<LOD	56.2	45.9	55.7	40.1	56.1	32.4	97.1
PCB 183	39.6	19.5	17.1	<LOD	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	15.9	<LOD	14.6	15.9	<LOD	13.7	41.1
PCB 187	79.1	36.7	23.7	47.3	<LOD	n.a.	n.a.	24.3	17.1	17.3	26.6	<LOD	23.1	<LOD	22.4	15.5	46.5
PBDE 47	133	109	111	110	32.3	n.a.	n.a.	38.4	<LOD	<LOD	28.3	36.6	34.6	<LOD	<LOD	7	22
PBDE 100	11.6	14.6	<LOD	24.7	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	19.9	<LOD	<LOD	<LOD	<LOD	10	31
PBDE 154	<LOD	<LOD	<LOD	<LOD	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	<LOD	14.9	3.3	<LOD	<LOD	10	29
PBDE 206	118	<LOD	<LOD	75.6	<LOD	n.a.	n.a.	76.8	<LOD	<LOD	<LOD	54.9	<LOD	<LOD	23.6	8	25
PBDE 207	99.4	14.3	11	107	21.9	n.a.	n.a.	75.6	<LOD	12.1	20.6	66.1	12.7	15.7	24.9	10	29
PBDE 209	2029	343	312	3820	<LOD	n.a.	n.a.	1411	<LOD	341	863	980	273	<LOD	541	201	603

Table S3 continued. Raw data of contaminant concentrations in springtails.

  

Study site	Ny-Ålesund				Storholmen	Krykkje-fjellet	Stuphallet		Blomstrandhalvøya		Fjortende Julibukta						
Springtail sample ID	MA1	HV2	HV3	HV4	HV5	MA6	MA7	HV8	HV9	HV10	HV11	HV12	HV13	HV14	HV15	LOD	LOQ
Compounds pg/g w.w.																pg/g w.w.	
o,p'-DDT	75.5	205	209	340	27.6	n.a.	n.a.	27.6	<LOD	<LOD	<LOD	<LOD	18.1	<LOD	<LOD	18.0	54.1
p,p'-DDT	58.9	64.4	<LOD	<LOD	69.3	n.a.	n.a.	69.3	<LOD	<LOD	341	73.4	<LOD	<LOD	<LOD	26.5	79.5
o,p'-DDD	<LOD	27.6	<LOD	<LOD	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	12.0	35.9
p,p'-DDD	<LOD	<LOD	<LOD	462	38.9	n.a.	n.a.	38.9	15.7	<LOD	136	<LOD	49.3	102	72	15.1	45.3
o,p'-DDE	21.7	41.4	<LOD	<LOD	<LOD	n.a.	n.a.	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	14.0	42.1
p,p'-DDE	337	211	230	201	128	n.a.	n.a.	128	44.9	41.9	172	101	98	258	108	19.0	57.1
HCB	603	3052	3355	2953	5000	n.a.	n.a.	4478	1896	2353	3252	3139	2171	2960	2956	67.2	161
a-HCH	113	324	238	203	71.6	n.a.	n.a.	108	138	141	120	125	103	89.8	128	3.4	10.2
b-HCH	19.5	79.2	<LOD	<LOD	26.9	n.a.	n.a.	20.5	18.4	22.3	17.7	10.9	11.6	<LOD	<LOD	8.2	24.6
c-HCH	40.2	84	38.7	37.1	41.3	n.a.	n.a.	49.3	53.5	46.9	34	35.6	23	26.4	31	15.8	36.5
Oxychlordane	287	296	265	267	396	n.a.	n.a.	461	301	357	260	239	216	<LOD	242	202	364
***Trans* chlordane**	5.6	24.3	24.4	24.9	30.8	n.a.	n.a.	45.8	18	26.6	11.5	10.5	9	10.1	10.4	5.0	11.4
***Cis* chlordane**	23.6	110	99.4	99.4	128	n.a.	n.a.	201	109	138	54.1	48.4	42.8	41.8	49.2	15.3	26.9
***Trans* nonachlor**	44.8	106	88.4	88.4	167	n.a.	n.a.	194	121	133	51.6	46.7	44.2	46.9	47.3	30.3	73.0
***Cis* nonachlor**	25.9	65.9	50.7	50.7	110	n.a.	n.a.	119	69	78.2	30.2	23.3	23.1	21.9	24.8	13.9	31.8

Springtail sample-ID reflect species; MA=*M. arctica* , and HV=*H. viatica.* Abbreviations: LOD=limit of detection, LOQ=limit of quantification, n. a.=not analysed, d.w.=dry weight, w.w.=wet weight

Analyte abbreviations: Hg=mercury, PFOS=perfluorooctanesulfaonic acid , PFNA=perfluorononanoic acid , PFDA=perfluorodecanoic acid , PFUnDA=perfluoroundecanoic acid , PFDoDA=perfluorododecanoic acid, PCB=polychlorinated biphenyl, PBDE=polybrominated diphenyl ether, DDT=dichlorodiphenyltrichloroethane, DDD=dichlorodiphenyldichloroethane, DDE=dichlorodiphenyldichloroethylene, and HCB=hexachlorobenzene, HCH=hexachlorocyclohexane.

PFAS congeners below LOD in all springtail samples (pg/g w.w., given in brackets) (not analysed in HV5, MA7 and HV): PFBS, PFHxS (50), PFHpS, PFNS, PFDcS, PFHxA, PFHpA, PFOA, PFTrDA, PFTeDA (100).
Other analytes below LOD in all springtail samples (pg/g w.w., given in brackets) (not analysed in MA6 and MA7): PCB-194 (41.26), PBDE-28 (206), PBDE-138 (9.8), PBDE-153 (9.1), PBDE-183 (18.8), PBDE-196 (7.7), PBDE-197 (7.1), Mirex (78.1)

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