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Baseline

Distributions and potential sources of polychlorinated biphenyls and polycyclic aromatic hydrocarbons in the glacimarine sediments of Arctic Svalbard

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ABSTRACT

Distribution and sources of polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in the glacimarine sediments (35 sites) of Svalbard were investigated. PCBs (32 congeners), traditional PAHs (15 homologs), emerging PAHs (11 homologs), and alkylated PAHs (16 homologs) were widely distributed in the Svalbard sediments (ranges: below method detection limit to 20, 21 to 3600, 1.0 to 1400, and 31 to 15,000 ng g^{-1} dry weight, respectively). Compositional analysis indicated that PCBs mainly originated from combustion sources, with PAHs being strongly influenced by local sources. Positive matrix factorization analysis showed that PAHs were associated with vehicle and petroleum combustion, coal, and coal combustion. Coal-derived PAHs contributed significantly to the sediments of Van Mijenfjorden. Remnants of coal mining activity trapped in the permafrost appear to enter the coastal environments as ground ice melts. Consequently, PAHs are currently emerging as the most significant contributors to potential risks in the Svalbard ecosystems.

Svalbard archipelago, located at the gateway to the Arctic Ocean, has permafrost covering 60% of its terrestrial area, as well as a large number of glacial fjords (Hanssen-Bauer et al., 2019). The environment in the Arctic region is characterized by low mean annual temperatures (−12 to 5.2 °C), low precipitation, and drought (Killingtveit et al., 2003; Førland et al., 2011). The Arctic region is generally considered less polluted due to its remoteness from pollution sources and limited anthropogenic activity (Armitage et al., 2011; Macdonald et al., 2007). However, toxic substances generated by anthropogenic activity in the northern hemisphere are introduced to the Arctic region through long-range transport via the oceanic current and the atmosphere (Wania and Mackay, 1993). Gradually increasing local human activity has also been considered as a source of pollution in recent years (Steenhuisen and van den Heuvel-Greve, 2021). Consequently, environmental pollution in the Arctic region is gradually increasing, which could adversely affect the ecosystem (Hop et al., 2002; Rose et al., 2004; Sagerup et al., 2009). Pollutants introduced into the Arctic region are more conserved and accumulative than in other environments due to the low temperatures (Wong et al., 2021).

At present, the Arctic region is subjected to remarkable environmental changes related to global climate changes (Ademollo et al., 2021; Bogdal et al., 2009). For example, permafrost cover gradually decreases, and glacial variability increases. Seasonal permafrost thawing increases the mobilization and downstream transport of organic matter and pollutants trapped in soils, transporting them to the marine environment (AMAP, 2017). These changes trigger the remobilization of persistent toxic substances (PTSs) in permafrost; consequently, research in this region increasingly focuses on the behavior and fate of PTSs (Bogdal et al., 2009; Carlsson et al., 2012). In recent decades, most mines in Svalbard have been closed, and projects for regeneration are underway (Viken, 2006). However, the effects of the coal industry are still visible. In addition, the number of tourists is gradually increasing, and its environmental impact is a concern. Despite these concerns and increasing interest, few studies have investigated the contamination and ecological risks of PTSs in the Svalbard fjords.

PTSs originate from various anthropogenic activities, including the

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combustion of fossil fuels, transportation, and industrial and domestic products. These compounds are toxic to aquatic organisms and humans, causing carcinogenicity, genotoxicity, and growth inhibition (Brienza et al., 2016). PTSs include polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). They are persistent in the environment, can be transported over long distances, and become widely distributed in multiple environmental media (Ademollo et al., 2021; Pouch et al., 2017). Previous studies identified PTSs in polar regions, thousands of kilometers away from source regions, following long-range transportation via the atmosphere, oceans, sea ice drift, and rivers (Ubl et al., 2017). PTSs accumulate in and adversely affect marine and terrestrial ecosystems in polar regions. Due to their significant environmental risks, PCBs and PAHs are currently managed as priority pollutants (Neff, 1979; Renner, 1997).

In the past, PCBs were widely used for insulating oil and electronic devices. Since the 1970s, they have been banned in most countries due to their persistence, toxicity, and bioaccumulation potential. PCBs were designated as persistent organic pollutants (POPs) by the 2001 Stockholm Convention (Breivik et al., 2007; Muir et al., 2003). PAHs (traditional 16 PAHs; t-PAHs) are managed as priority pollutants by the US Environmental Protection Agency (US EPA), due to their great toxic potential (Neff, 1979; Tam et al., 2001). In addition to 16 t-PAHs, other emerging PAHs (e-PAHs) have been reported to have similar toxicity and environmental distributions (Cha et al., 2021; Kim et al., 2019; Lee et al., 2020). Alkylated PAHs (alkyl-PAHs) are detected in high concentrations in specific environments, such as areas contaminated with oil or coal. They are used as tracers for oil contamination (Buell et al., 2021; Mu et al., 2014; Turcotte et al., 2011). Yet, baseline data on the distribution, behavior, fate, and potential risk of these PTSs in the Arctic ecosystems remain limited. Here, we investigated the distributions and sources of PCBs and PAHs in the glacimarine sediments of Svalbard. In addition, the potential ecological risk of PTSs contamination in the sediments was evaluated.

This study used previously collected and archived samples to analyze PTSs. Glacimarine sediments ($n = 35$, See Table S1 of the Supplementary Materials) were collected using a box-corer from Hornsund ($n = 18$) with RV Helmer Hanssen during the Poland-Norway Svalbard cruise in September 2015 (Fig. 1). Additional sediment samples were collected using a single-corer from Krossfjorden ($n = 3$) with MS Teisten in July 2016 and using a box-corer from Isfjorden ($n = 2$), Van Mijenfjorden ($n = 4$), Van Keulenfjorden ($n = 2$), Hambergbukta ($n = 3$), and Hornsund ($n = 3$) with RV Helmer Hanssen during the 3rd Korea-Norway Svalbard cruise in July 2019. Sediment samples were stored at −20 °C and were freeze-dried. After drying, all sediment samples were sieved (2-mm mesh) to eliminate impurities, and were stored until analysis.

PTSs were analyzed for all the collected sediments (Table S2). Target PTSs included 32 PCBs (obtained from Wellington Laboratories, Guelph, ON, Canada), 15 t-PAHs (obtained from ChemService, West Chester, PA, USA), 11 e-PAHs (obtained from Sigma-Aldrich, Saint Louis, MO, USA), and 20 alkyl-PAHs (obtained from Wellington Laboratories). PTSs were analyzed using slightly modified methods of previous studies (Hong et al., 2022; Kim et al., 2021). In brief, 10 g of sediments were extracted using an accelerated solvent extractor (ASE; Dionex ASE 350, Thermo Scientific, Salt Lake, UT, USA) with dichloromethane (DCM, Burdick & Jackson, Muskegon, MI, USA). For the ASE, a stainless cell (34 mL) was used, and the extraction time was set to 10 min at 120 °C. The extracts were collected in 60-mL glass vials and were concentrated by N_2 gas flow (TurboVap LV, Biotage, Uppsala, Sweden). To eliminate sulfur in

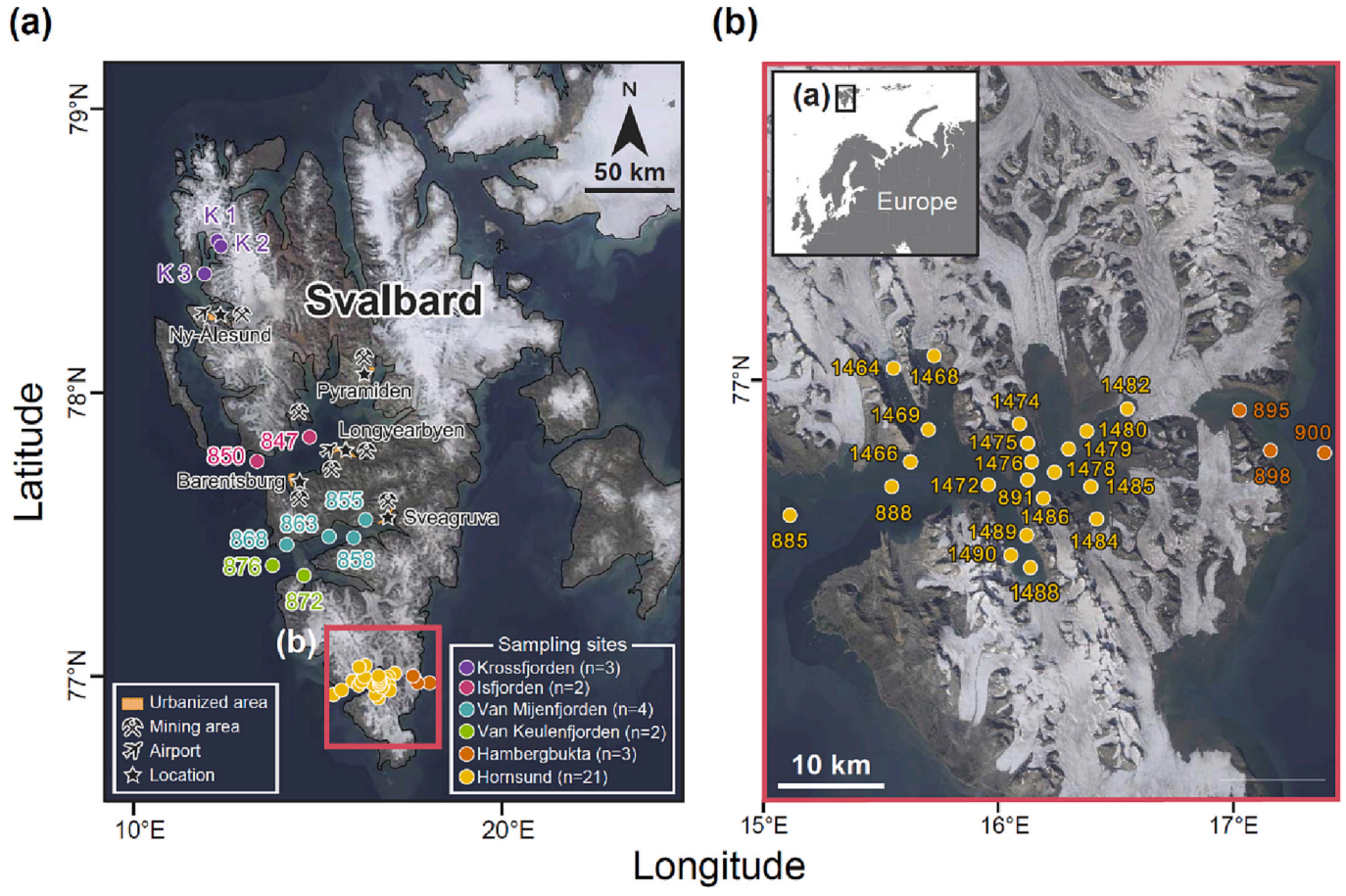

Fig. 1. Map showing the sampling sites in (a) Arctic Svalbard and (b) zoomed map of sampling sites in Hambergbukta and Hornsund. Glacimarine sediments were collected between September 2015 and August 2019. Previously collected and archived samples were used to analyze PTSs.

the extracts, activated copper powder (Merck, Darmstadt, Germany) was added. The extracts were separated and cleaned up using open column chromatography filled with 8 g activated silica gel (70–230 mesh, Merck). The first fraction (F1) was eluted with 30 mL hexane, and was collected to analyze PCBs. The second fraction (F2) was collected to analyze t-PAHs, e-PAHs, and alkyl-PAHs by eluting 60 mL hexane:DCM (8:2, *v/v*). Instrumental analyses were performed using an Agilent 7890B gas chromatograph coupled with a 5977B mass spectrometer detector (Agilent Technologies, Santa Clara, CA, USA). Isomers of alkyl-PAHs with the same molar mass have very similar fragmentation patterns. Because standard materials for individual alkyl-PAHs are unavailable, the total concentration for each methyl substituent of PAHs (total 16 alkyl-PAHs) was semi-quantitated using 20 model compounds (Table S2, Hong et al., 2012).

Mass-labeled surrogate standards were spiked to all samples before extraction for quality control. A procedural blank was included per batch. The analysis was performed under the same conditions for the blank to evaluate contamination during the experiment. To compensate for the sensitivity of the instrument, 100 ng of internal standard (2-fluorobiphenyl, ChemService) was added before instrumental analysis. The method detection limits for each compound, surrogate recoveries, and target ions are summarized in Table S2. Details on instrumental conditions are presented in Table S3.

Principal component analysis (PCA) was performed using SPSS 24.0 (SPSS Inc., Chicago, IL, USA) to estimate PCB sources. The Bartlett's and Kaiser-Meyer-Olkin (KMO) test was performed to assess the compatibility of sampling adequacy for the statistical analysis. Since the KMO index was more than the guideline of 0.6 (0.64), the PCA was appropriate for the dataset.

The EPA positive matrix factorization (PMF) model (version 5.0) was used to identify the major sources of PAHs. The PMF model suggests the composition of the potential origin of PAHs, allowing the quantitative contribution to the origin of PAHs to be determined (Hong et al., 2022; Kim et al., 2021). First, the number of factors judged as pollution sources presented in the model was determined. When there were three factors, the Q_{True}/Q_{Exp} value was 0.12; thus, three factors for the PAH sources were selected and used for the analysis. Then, to determine the composition and contribution of each factor, the Q value was selected based on Eq. (1).

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} f_{jk}}{u_{ij}} \right]^2 \quad (1)$$

where u_{ij} is the uncertainty of x_{ij}, x_{ij} is the concentration of species j in sample i, and p is the number of factors. Factor k is the relative contribution of g_{ik}, and f_{kj} is the profile of each source. Based on PMF user guidelines, uncertainties (U_{nc}) were calculated using Eqs. (2) and (3).

$$U_{nc} = \frac{5}{6} \times MDL \quad (2)$$

$$U_{nc} = \sqrt{(Error\ fraction \times concentration)^2 + (0.5 \times MDL)^2} \quad (3)$$

Eqs. (2) and (3) were used when the concentration of compounds was below or above the MDL, respectively. *Error fraction* was calculated using the standard deviation of the compound. For the PMF model run, datasets for 15 PAHs (t-PAHs without naphthalene) × 36 sites were used as input data. Every base model was run 100 times. The coefficient between the predicted concentration and estimated concentration was 0.99 (r^2) in the linear regression, indicating that the results of the PMF model were satisfactory.

Hazard quotient (HQ) values of PCBs and PAHs in sediments were calculated for the ecological risk assessment. HQ was evaluated by comparing the predicted no-effect concentration (PNEC) and measured environmental concentrations (MEC) (Pintado-Herrera et al., 2017). Half maximal effective concentration (EC50) of each PTS is required to calculate the PNEC; however, the experimental data for all target compounds were limited. Thus, based on the 96-h acute toxicity of green algae, the EC50 values of the target compounds were calculated using the ecological structure-activity relationships (ECOSAR) model. PNEC values were estimated by dividing ECOSAR-calculated toxicity values (EC50) by an assessment factor of 1000. HQ was calculated based on Eq. (4).

$$\text{HQ (total hazard quotient)} = \frac{MEC}{PNEC} \div 1000 \quad (4)$$

PCB concentrations in the glacimarine sediments of Svalbard ranged from below the detection limit to 20 ng g^{-1} dry weight (dw) (mean: 3.1 ng g^{-1} dw; Fig. 2a). The mean concentration of PCBs was higher in Van Mijenforden (6.1 ng g^{-1} dw) compared to the other Svalbard fjords, with the greatest concentration being recorded at Site 855 (20 ng g^{-1} dw). Relatively higher concentrations of PCBs were also found at two of the 21 sites in Hornsund (Site 1472: 19 ng g^{-1} dw; Site 891: 18 ng g^{-1} dw) compared to all other sites. The PCB concentrations in the sediments detected in this study were similar to that previously recorded at Ny-Ålesund (mean: 2.3 ng g^{-1} dw) and lower compared to that at Guba Pechenga (mean: 13 ng g^{-1} dw) in the polar regions (Table 1). PCB concentrations in the glacimarine sediments of Svalbard did not exceed the interim sediment quality guidelines (ISQG: 20.4 ng g^{-1} dw) of the Canadian Council of Ministers of the Environment (CCME) (CCME, 2002) and the effect-range low (ERL: 20.4 ng g^{-1} dw) of the National Oceanic and Atmospheric Administration (NOAA) (Long et al., 1995). Although the ecological risk of PCBs in the studied fjords was negligible, continued monitoring is required in certain areas (e.g., Site 855 in Van Mijenfjorden; Site 1472 in Hornsund), which had concentrations similar to guideline values (Fig. 2a).

PCA was performed using the composition of PCBs detected in the Svalbard sediments and the composition of known sources, such as Aroclor, Sovol, ClophenA50, Keneclor, and combustion origin (Fig. S1). The results showed that these PCBs were mainly associated with combustion origin, which was low-chlorinated PCBs. Out of 32 PCB congeners, the 2,4′-dichlorobiphenyl (CB 8), 3,4,4′-trichlorobiphenyl (CB 37), 2,2′,5,5′-tetrachlorobiphenyl (CB 52), 2,2′,4,5′-tetrachlorobiphenyl (CB 49) were mainly detected (Table S4). Low-chlorinated PCBs (such as di- to tetra-CBs) were dominant, with 93% of the relative contributions. In contrast, high-chlorinated PCBs (such as penta- to deca-CBs) had relatively low contributions. Low-chlorinated PCBs are relatively volatile compared to high-chlorinated PCBs, and can travel through the atmosphere to remote areas (Kim et al., 2021; Meijer et al., 2002; Wania and Mackay, 1993). Previous studies showed that PCBs in the environmental samples of polar regions contained more low-chlorinated PCBs (AMAP, 2004; Evenset et al., 2007; Pouch et al., 2021). Thus, these compounds were detected far from the source of pollution, with the PCBs in the sediments of Svalbard likely being introduced by long-range transport via the atmosphere.

t-PAHs were detected in all sediments of Svalbard (Table 2, Fig. 2b, and Table S5). t-PAH concentrations ranged from 21 to 3600 ng g^{-1} dw (mean: 1200 ng g^{-1} dw), with the greatest concentration at Site 855 in Van Mijenfjorden (3600 ng g^{-1} dw), followed by Sites 1475 (2800 ng g^{-1} dw) and 1480 (2700 ng g^{-1} dw) in Hornsund. PAH concentrations in the sediments of Svalbard recorded here did not exceed existing sediment quality guidelines, such as ERL (4022 ng g^{-1} dw) (Long et al., 1995; Planas et al., 2006). Compositional patterns of t-PAHs revealed that 3–4 ring PAHs were dominant (mean: 69%) in Svalbard sediments. Phenanthrene (Phe) was the most dominant PAH (mean: 410 ng g^{-1} dw), followed by chrysene (Chr) (mean: 150 ng g^{-1} dw) and benzo[*b*] fluoranthene (BbF) (mean: 120 ng g^{-1} dw). PAHs with 2–4 rings belong to the group of petrogenic PAHs, representing contamination of petroleum sources, and include naphthalene (Na), Phe, and Chr (Manzetti, 2013). A previous analysis of coal samples from the abandoned Ny-Ålesund mine showed a significant peak of Phe, which is an indicator of

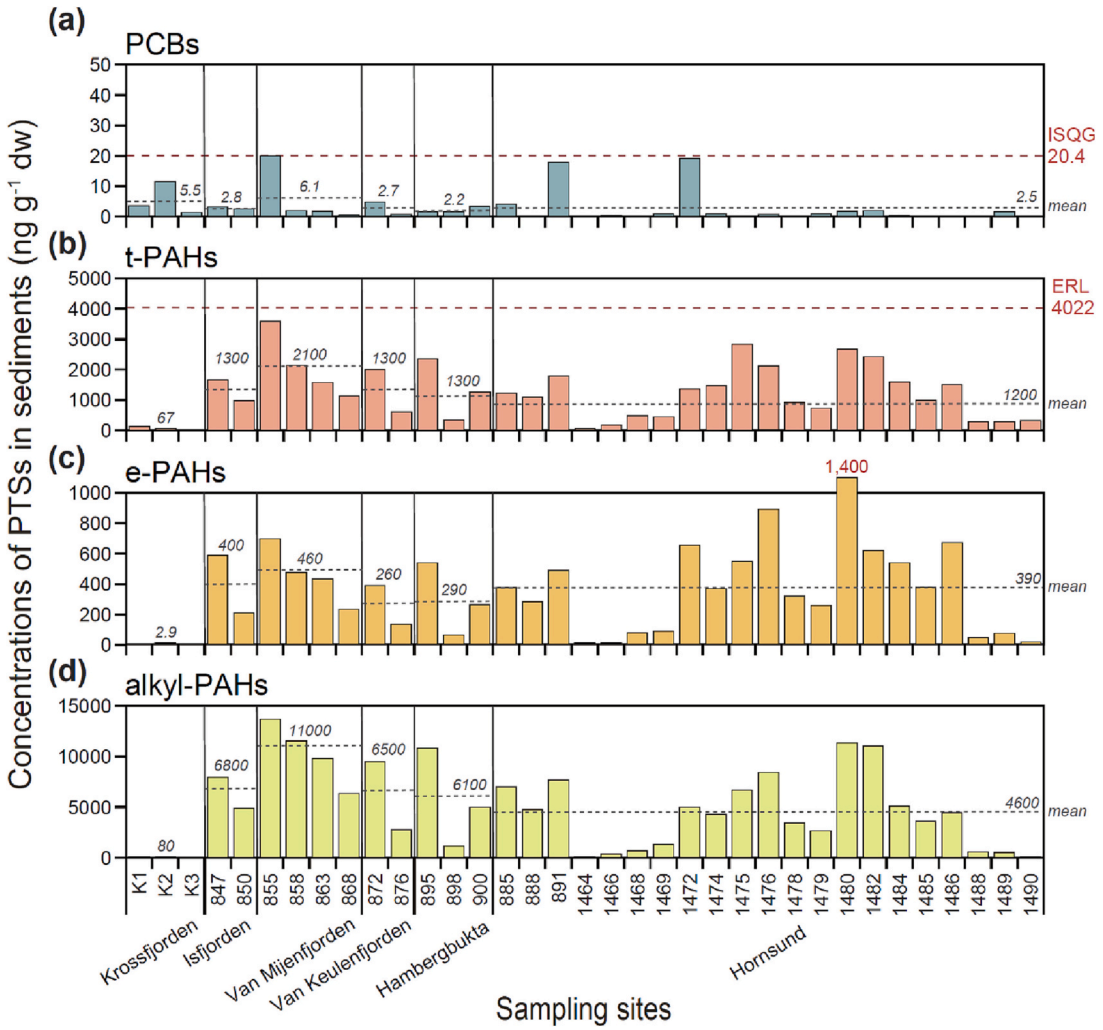

Fig. 2. Concentrations of (a) PCBs, (b) traditional PAHs (t-PAHs), (c) emerging PAHs (e-PAHs), and (d) alkyl-PAHs in the glacimarine sediments of Svalbard. The dotted line represents the regional mean concentration of PTSs. ISQG: interim sediment quality guideline (CCME, 2002); ERL: effects range low (Long et al., 1995).

Table 1
Concentrations of PCBs in the sediments of Arctic regions obtained from this study and previous studies.

Study area		# of sites	# of targets	Concentration (ng g^{-1} dw)			Reference
Country	Region			Min	Max	Mean	
Russia	Guba Pechenga	7	11	1.1	38	13	Savinov et al. (2003)
Norway	Hornsund	5	7	0.1	1.5		Pouch et al. (2017)
	Hornsund	21	32	0.0	19	2.5	This study
	Isfjorden	2	32	2.5	3.2	2.8	This study
	Krossfjorden	3	32	1.4	12	5.5	This study
	Ny-Ålesund	8	9	0.2	18		Jiao et al. (2009)
	Ny-Ålesund	1	7	0.002	0.1	0.01	Szczybelski et al. (2016)
	Ny-Ålesund	8	29	3.1	8.3	5.0	Zhang et al. (2014)
	Ny-Ålesund/Adventdalen	63	7	1.3	8.1	3.7	Aslam et al. (2019)
	Hambergbukta	3	32	1.6	3.3	2.2	This study
	Van Mijenfjorden	4	32	0.6	20	6.1	This study
	Van Keulenfjordne	1	32	0.7	4.8	2.7	This study
	Western Barents Sea	4	7	0.7	3.5		Zaborska et al. (2011)

PAHs contamination by coal (Steenhuisen and van den Heuvel-Greve, 2021). Although most mines in Svalbard (Ny-Ålesund, Pyramiden, Grumantbyen, and most recently Svea) have stopped operations, two mines located in Longyearbyen and Barentsburg are still operational (Fig. 1). PAHs detected in the Svalbard sediments of our study show that coal mines might be the origin of some contamination. LMW-PAHs with high atmospheric mobility might also have been transported from their sources via medium or long-range atmospheric mechanisms (Balmer et al., 2019; Chung et al., 2007).

Concentrations of e-PAHs in the Svalbard sediments ranged from 1.0 to 1400 ng g^{-1} dw (mean: 340 ng g^{-1} dw) (Fig. 2c and Table S6). The greatest concentration was found at Site 1480 of Hornsund (1400 ng g^{-1} dw), followed by Site 1476 (900 ng g^{-1} dw) and Site 855 in Van Mijenfjorden (700 ng g^{-1} dw). Spatial distributions of e-PAHs in the

Table 2
Concentrations of PAHs in the sediments of Arctic regions obtained from this study and previous studies.

Study area		# of sites	# of targets	Concentration (ng g^{-1} dw)			Reference
Country	Region			Min	Max	Mean	
Canada	Baffin Bay	11	66	340	2700		Foster et al. (2015)
	Canadian Arctic Archipelago	113	23	7.8	250	57	Corminboeuf et al. (2021)
	Gulf of St. Lawrence	45	23	71	5700	325	Corminboeuf et al. (2022)
Norway	Forlandsundet/Isfjorden	2	18	3400	9900		Morgunova et al. (2019)
	Hornsund	5	12	37	2000		Pouch et al. (2017)
	Hornsund	14	8	<LOD[a]	3100		Kosek et al. (2018)
	Hornsund	21	26	52	4100	1600	This study
	Isfjorden	2	26	1200	2300	1700	This study
	Kongsfjorden	3	13	12	2300	140	Szczybelski et al. (2016)
	Krossfjorden	3	26	24	130	70	This study
	North area	87	20	9.5	1800	300	Boitsov et al. (2013)
	Norwegian coast	8	22	82	3100		Eide et al. (2011)
	Ny-Ålesund	8	15	11	1100		Jiao et al. (2009)
	Southern and central	20	20	20	1400	460	Boitsov et al. (2009)
	Hambergbukta	3	26	390	2900	1600	This study
	Van Keulenfjordne	1	26	700	2400	1600	This study
	Van Mijenfjorden	4	26	1400	4300	2600	This study
	Western Barents Sea	4	12	35	130		Zaborska et al. (2011)
Norway-Russia	Kola-Kanin Monocline	3	18	170	300		Morgunova et al. (2019)
	Shtokman gas-condensate field	4	18	900	2200		Morgunova et al. (2019)
Russia	East Siberian	3	18	80	170		Lakhmanov et al. (2022)
	Guba Pechenga	7	18	430	3300	1500	Savinov et al. (2003)
	Kara Sea	4	18	30	71		Lakhmanov et al. (2022)
	Laptev Sea	17	18	38	220		Lakhmanov et al. (2022)
Russia-USA (Alaska)	Bering-Chukchi-Canadian Basin	14	16	28	170	77	Chen et al. (2018)
	Northern Bering-Chukchi Sea	34	27	50	600	290	Lin et al. (2020)

[a] Below limit of detection.

Svalbard sediments were similar to those of t-PAHs ($r = 0.83$, $p < 0.01$). The compositional patterns of t-PAHs with a predominance of 3–4 rings were also found in e-PAHs (3 ring e-PAHs: 30%, 4 ring e-PAHs: 56%). e-PAHs and t-PAHs have chemically similar structures; thus, their sources might be similar, as they tend to form as by-products (Kim et al., 2021). Consequently, their fate in the environment is similar, as demonstrated by several previous studies (Hong et al., 2022). Concentrations of t-PAHs and e-PAHs in the sediments of Isfjorden, Van Mijenfjorden, and Van Keulenfjorden tended to decrease from inside to outside of the fjord (Fig. 2c). Previous studies reported that high concentrations of PAHs were detected in inside the fjord, due to coal mining activity (Eide et al., 2011; Jiao et al., 2009). Coal-derived PAHs appear to enter the coastal environments seasonally, as part of ice-melt water associated with climate change. Our data supported this observation, as high concentrations of PAHs were detected along the inner fjord sites adjacent to terrestrial areas in Svalbard (Pouch et al., 2021). Some e-PAHs (such as 11H-benzo[*a*]fluorine and 11H-benzo[*b*]fluorine) had similar distributions to Phe, which is a well-known indicator of coal origin. Thus, these compounds could be used as potential indicators of coal contamination in the Arctic region. The toxic potential of e-PAHs is as high as that of t-PAHs (Kim et al., 2021). The current study was the first to report the distribution and contamination levels of these e-PAHs in the Arctic regions. In addition to traditional PTSs, monitoring and risk assessment of emerging PTSs should continue in the future.

To improve our understanding of the sources of PAHs in the glacimarine sediments of Svalbard, diagnostic analyses were performed at the site- and compound-specific levels (An et al., 2020; Katsoyiannis et al., 2011) (Fig. S2). The sources of PAHs in sediments were estimated using anthracene (Ant), Phe, fluoranthene (Fl), pyrene (Py), indeno [*1,2,3-cd*]pyrene (IcdP), and benzo[*g,h,i*]perylene (BghiP) (Fig. S2). The values of Ant / (Ant + Phe), Fl / (Fl + Py), and IcdP / (IcdP + BghiP) had ranges of 0.009 to 0.088, 0.08 to 0.61, and 0.018 to 0.67, respectively. Diagnostic analysis showed that coal and petroleum are the main sources of PAHs in Svalbard fjords, with contamination from petroleum combustion requiring action. In some fjords in Svalbard (Isfjorden, Van Mijenfjorden, and Van Keulenfjorden), where coal mines are located, PAHs of petroleum and petroleum combustion origin dominated (Szczybelski et al., 2016). Petroleum-derived PAHs emitted from coal mines accumulated in the local environment. A study conducted in Longyearbyen in 2020 obtained similar results, with PAHs from coal combustion dominating sites near coal mines (Drotikova et al., 2020).

The PMF model was used to identify the sources of PAHs and to quantify how sources contributed to the glacimarine sediments of Svalbard. The main components of Factor 1 included benzo[*a*]anthracene (BaA), Fl, and Phe. The high proportion of 3–4 ring PAHs was attributed to vehicle and petroleum combustion (Fig. 3a and Table S7). Factor 2 showed that 2–4 ring PAHs were prevalent, with Phe being abundant, which might be associated with coal. BghiP and IcdP were the main components in Factor 3. A large proportion of high molecular weight PAHs likely originated from coal combustion. PAHs in the sediments of the outer sites of Van Keluenfjorden, Hambergbukta, and Hornsund were associated with vehicle and petroleum combustion (Factor 1). PAHs in the inner sites of Krossfjorden and Hornsund were considered to be associated with coal (Factor 2). (Fig. 3b). Coal combustion (Factor 3) was identified as the major source of PAHs in the sediments in Isfjorden and Van Mijenfjorden (Fig. 3b), where the coal mining industry has developed (Senger et al., 2019). PMF modeling showed that coal sources for sedimentary PAHs were dominant in Svalbard fjords, with these results being consistent with the diagnostic ratio analysis. However, PAHs at some sites in the Hornsund region were dominated by vehicle and petroleum combustion sources (Fig. 3b). This region is located about 100 km from the nearest coal mine, Svaegruva (Van Mijenfjorden); thus, it is hard to specify the source of petroleum pollution in the region (Kozak et al., 2017). Some PAHs were derived from mines, but these sources were local, rather than regional. Previous studies showed that mines in Longyearbyen had a low impact on Hornsund (Kozak et al., 2017). Furthermore, snow pollution from coal dust emissions of mines (such as Pyramiden and Sveagruva) was also limited to the nearby area (Aamaas et al., 2011; Jiao et al., 2014; Rose et al., 2004). Hornsund is less explored than other regions in Svalbard. Thus, oil spills due to accidents from tourism cruises and ship emissions are unlikely the main sources of PAH pollution (Bystrowska, 2019; Pouch et al., 2021). PAHs released from northern Europe could reach the Arctic via northern air masses. PAHs tend to enter the aquatic

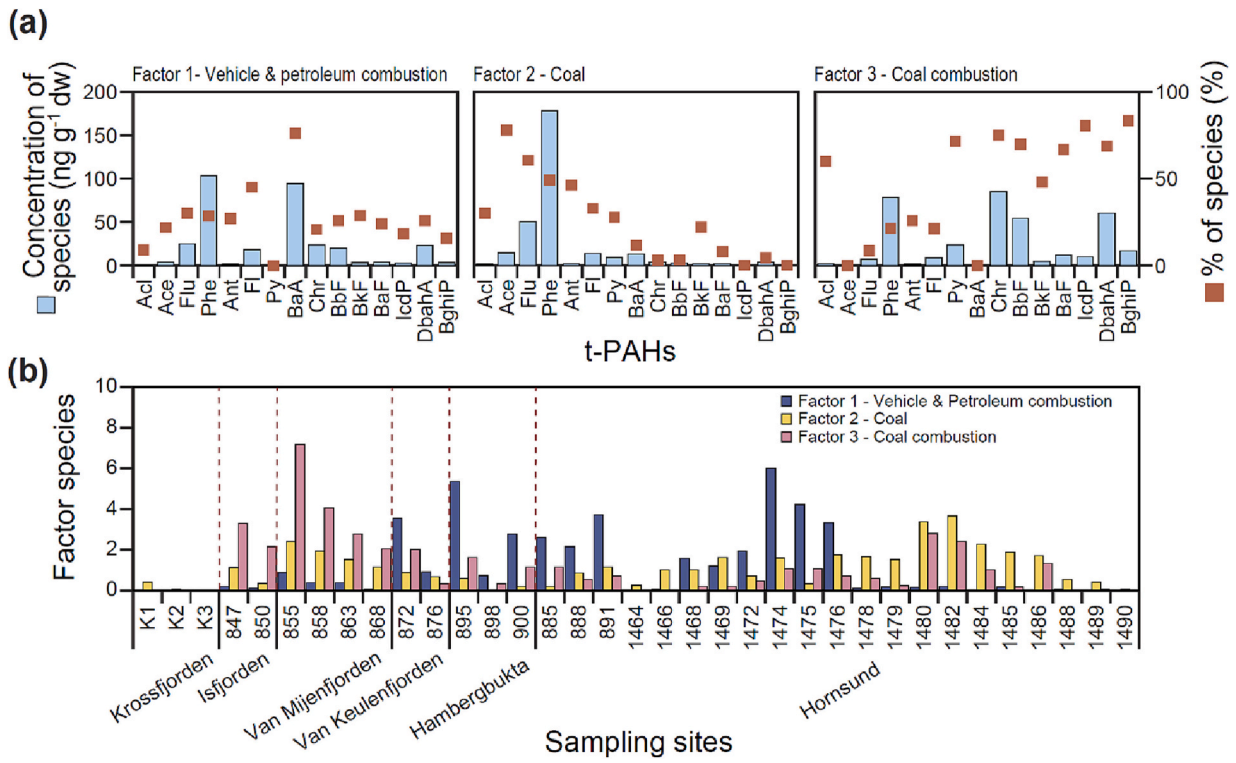

Fig. 3. Results of the positive matrix factorization (PMF) model estimating the sources of PAHs in the glacimarine sediments of Svalbard. (a) Source factors (Factor 1: vehicle & petroleum combustion, Factor 2: coal, and Factor 3: coal combustion) in the PMF model, and (b) contributions of each PAH source.

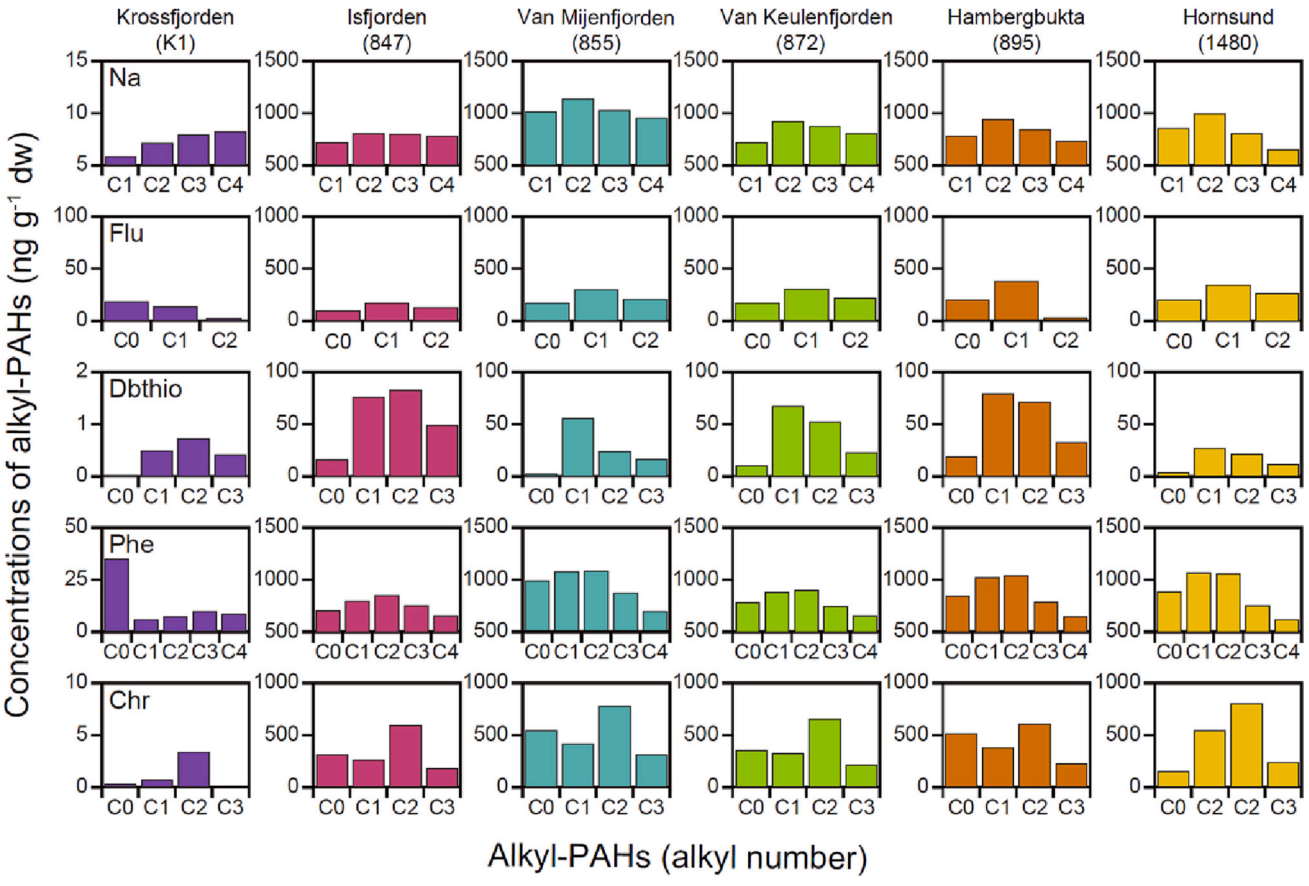

Fig. 4. Relative composition of alkyl-PAHs in the glacimarine sediments of selected sites in Svalbard.

environment from the atmosphere (Horwell et al., 2013; Kozak et al., 2017; Pawlak et al., 2019). Thus, PAHs in Hornsund were likely introduced through long-range transport, rather than local sources.

To identify the effects of coal on PAH distributions, alkyl-PAHs, which are used as indicators of coal-derived PAHs, were analyzed in the glacimarine sediments of Svalbard (Fig. 2d and Table S8). Alkyl-PAH concentrations in the sediments of Svalbard ranged from 31 to 15,000 ng g^{-1} dw (mean: 5300 ng g^{-1} dw). Sites in Van Mijenfjorden had the highest alkyl-PAH concentrations, particularly at Sites 855 (15,000 ng g^{-1} dw) and 858 (12,300 ng g^{-1} dw) (Fig. 2d). The mine in Van Mijenfjorden appears to release PAHs into the surrounding environment (Curran et al., 2000; French, 1998; Johnson and Bustin, 2006). Site 855 in Van Mijenfjorden is located near the Sveagruva coal mine, resulting in high concentrations of PAHs (Kozak et al., 2017). Bell-shaped distribution patterns of alkyl-PAHs were obtained at most sites in Svalbard, except for Krossfjorden (Fig. 4). There was clear evidence for coal- and oil-derived PAHs (Hong et al., 2015). In general, the PAHs of petroleum origin showed a "bell-shaped" C0 − C4 distribution, with a decreasing pattern of C0 > C1 > C2 > C3 > C4 as the methyl group increased, indicative of combustible origin (Hong et al., 2012; Sauer et al., 1998). Alkyl homologs of alkyl-PAHs are distributed depending on the degree of alkylation through weathering. The pattern of alkyl-PAHs detected in this study indicated that the degree of weathering was relatively low, with contributions of C0- and C1-PAHs. The composition of alkyl-PAHs detected in this study was compared to that of coal in previous reports (Stout and Emsbo-Mattingly, 2008) (Fig. 5). By identifying the type of coal using C2-dibenzothiophene (C2-Dbthio)/C3-Dbthio and C2-Phe/C3-Phe double ratios, Krossfjorden was shown to be similar to lignites. Most areas, including Van Mijenfjorden, had PAHs derived from bituminous coal, with Hornsund being slightly distinct. Bituminous coal contains up to hundreds and, in exceptional cases, thousands of mg kg^{-1} of PAHs. Nevertheless, knowledge of the distribution and impact of coal-derived PAHs in polar regions remains limited (Ahrens and Morrisey, 2005). Coal residues in the vicinity of coal mines and abandoned mines likely represent a significant source of PAHs in Svalbard. The flow of these residues into coastal environments might gradually increase due to the melting of permafrost (McGovern et al., 2022).

PNEC predicted using ECOSAR was used to evaluate the potential ecological risk of PCBs, t-PAHs, e-PAHs, and alkyl-PAHs in the glacimarine sediments of Svalbard (Fig. 6 and Table S9). t-PAHs explained 61% of total HQ on average, followed by e-PAHs (21%), alkyl-PAHs (13%), and PCBs (5%) (Fig. 6, Tables S10–S13). Site 1480 of Hornsund and Site 855 of Van Mijenfjorden had relatively high HQ values. Despite Hornsund being far from major pollution sources, Hornsund sediments contained high PTS concentrations with high HQ. Thus, studies are required to determine the sources of PTSs in Hornsund. Hornsund is strongly affected by melting permafrost, with previous studies showing that it contains high concentrations of PTSs (Pouch et al., 2021; Zaborska et al., 2011). Thus, these high PTS concentrations might be associated with the remobilization of PTSs trapped in permafrost. The high Phe concentrations in this region might be of coal origin. Van Mijenfjorden had the highest sediment HQ values out of all our study sites. Coal-derived PAHs were major contributors (Fig. 6). Out of the PTSs analyzed in this study, t-PAHs represented major potential ecological risks in the sediments of Svalbard. Of note, HQ values decreased from the inside to outside areas of the fjord, indicating that toxic substances with high ecological risk are introduced within the fjord (e.g., coal mines).

This study investigated the contamination status of PTSs in the glacimarine sediments of Svalbard. High concentrations of PAHs were detected in sediment, despite it being in a remote region far from pollution sources associated with anthropogenic activities. Large proportions of sedimentary PAHs originated from coal mining, which could adversely affect the coastal ecosystem of this region. The accelerated melting of permafrost due to climate change means that the inflow of coal-derived PTSs to the coastal ecosystem is gradually increasing. Therefore, it is necessary to continue investigating the distribution, sources, fate, and potential risk of coal-derived PTSs in the Svalbard ecosystems.

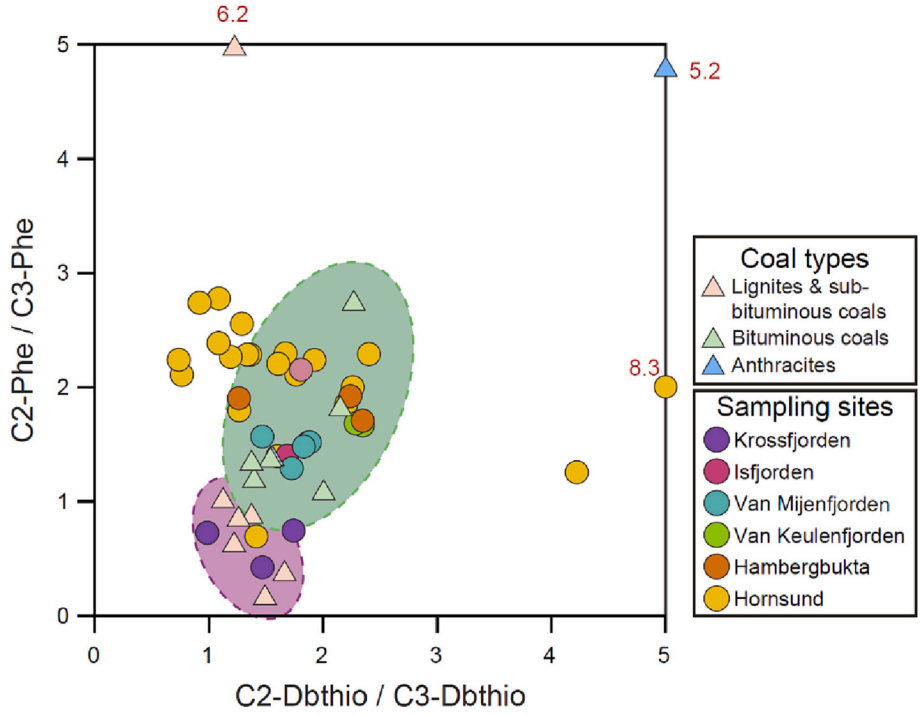

Fig. 5. Diagnostic double ratios (C2-Phe/C3-Phe and C2-Dbthio/C3-Dbthio) in the glacimarine sediments of Svalbard obtained from this study, and coal samples reported by previous studies (Hindersmann and Achten, 2018; Pies et al., 2008; Yunker et al., 2002).

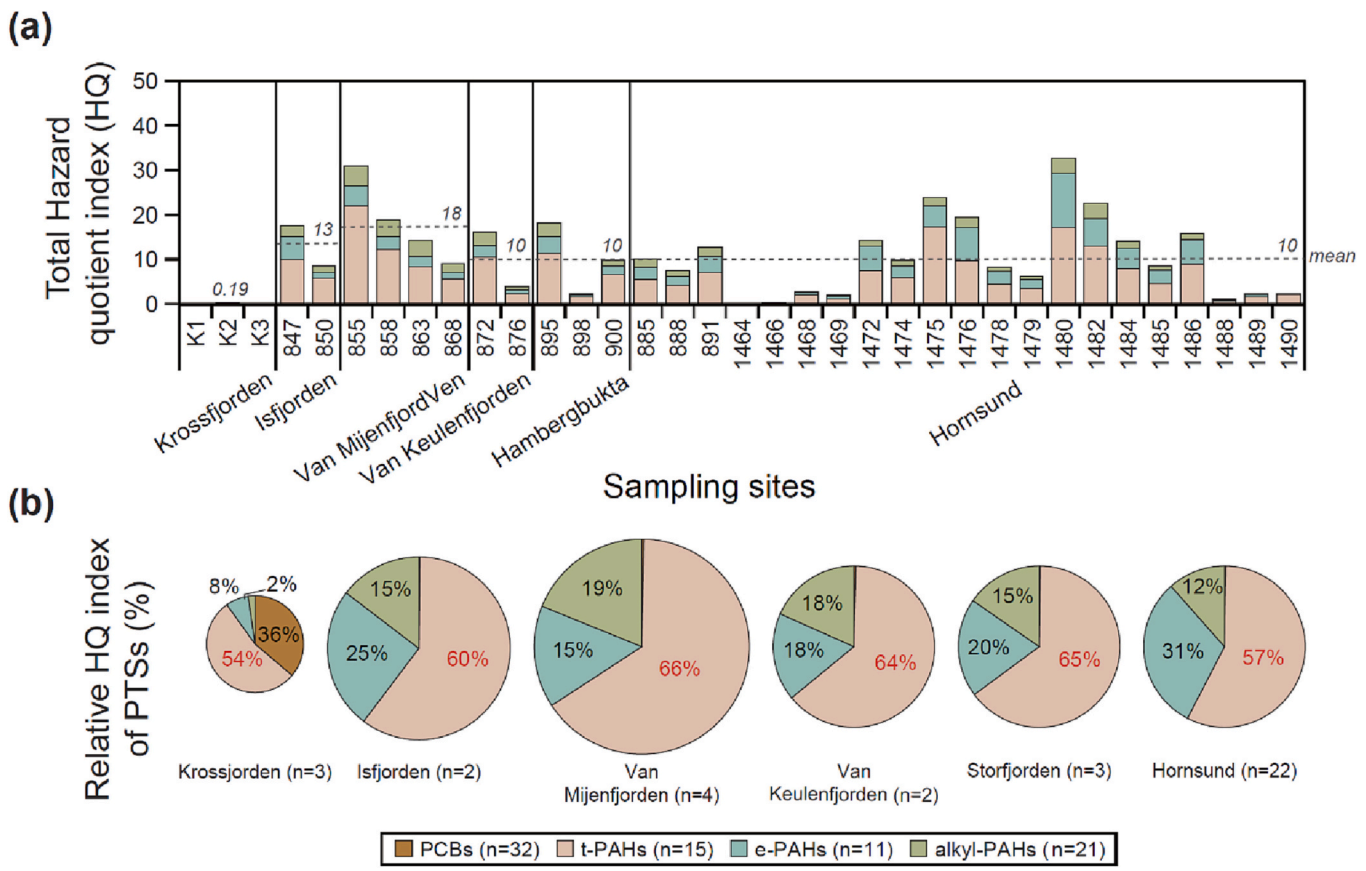

Fig. 6. (a) Hazard quotient (HQ) values for PTSs in the glacimarine sediments of Svalbard. HQ values of each compound group were calculated and summed using the ECOSAR model and measured concentrations. (b) Relative contribution of PTSs to total HQ.

CRediT authorship contribution statement

Juhee Lee: Conceptualization, Investigation, Formal analysis, Data curation, Visualization, Writing – original draft. **Youngnam Kim:** Conceptualization, Investigation, Formal analysis, Data curation, Visualization, Writing – original draft. **Jihyun Cha:** Investigation, Formal analysis, Data curation. **Dahae Kim:** Investigation, Formal analysis, Data curation. **Kwangchul Jang:** Investigation, Data curation, Writing – review & editing. **Jung-Hyun Kim:** Conceptualization, Investigation, Data curation, Writing – review & editing. **Seung-Il Nam:** Conceptualization, Investigation, Data curation, Project administration. **Seongjin Hong:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2023.114740.

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Supplementary materials for

Distributions and potential sources of polychlorinated biphenyls and polycyclic aromatic hydrocarbons in the glacimarine sediments of Arctic Svalbard

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Supplementary Tables

Table S1. Information on the sampling sites considered in this study.

Sampling site	Short name of the sampling site	Location	Latitude (°N)	Longitude (°E)	Sampling date (mm/yyyy)	Sample depth (cm)	Water depth (m)
Koller #1_1B	K1	Krossfjorden	79.287	12.046	07/2016	0-2	21
Mayerbukta #1_1B	K2	Krossfjorden	79.266	12.160	07/2016	0-2	7
Julibreen #1_1B	K3	Krossfjorden	79.123	11.846	07/2016	0-2	23
HH19 BOX 847	847	Isfjorden	78.334	15.331	07/2019	0-1	257
HH19 BOX 850	850	Isfjorden	78.153	13.741	07/2019	0-1	425
HH19 BOX 855	855	van Mijenfjorden	77.856	16.658	07/2019	0-1	33
HH19 BOX 858	858	van Mijenfjorden	77.826	16.548	07/2019	0-1	68
HH19 BOX 863	863	van Mijenfjorden	77.786	16.006	07/2019	0-1	78
HH19 BOX 868	868	van Mijenfjorden	77.734	14.873	07/2019	0-1	107
HH19 BOX 872	872	van Keulenfjorden	77.567	15.287	07/2019	0-1	98
HH19 BOX 876	876	van Keulenfjorden	77.609	14.579	07/2019	0-1	128
HH19 BOX 895	895	Hambergbukta	77.045	17.163	07/2019	0-1	101
HH19 BOX 898	898	Hambergbukta	76.997	17.354	07/2019	0-1	114
HH19 BOX 900	900	Hambergbukta	76.982	17.829	07/2019	0-1	126
HH19 BOX 885	885	Hornsund	76.937	15.390	07/2019	0-1	161
HH19 BOX 888	888	Hornsund	76.988	15.820	07/2019	0-1	203
HH19 BOX 891	891	Hornsund	76.989	16.305	07/2019	0-1	115
HH15-1464-BC	1464	Hornsund	77.153	16.325	09/2015	0-5	156
HH15-1466-BC	1466	Hornsund	77.007	16.489	09/2015	0-5	119
HH15-1468-BC	1468	Hornsund	77.161	16.561	09/2015	0-5	78
HH15-1469-BC	1469	Hornsund	77.066	16.616	09/2015	0-5	45
HH15-1472-BC	1472	Hornsund	77.649	16.321	09/2015	0-5	83
HH15-1474-BC	1474	Hornsund	77.055	16.465	09/2015	0-5	44
HH15-1475-BC	1475	Hornsund	77.035	16.507	09/2015	0-5	50
HH15-1476-BC	1476	Hornsund	77.009	16.527	09/2015	0-5	84
HH15-1478-BC	1478	Hornsund	77.653	16.679	09/2015	0-5	120
HH15-1479-BC	1479	Hornsund	77.026	16.760	09/2015	0-5	138
HH15-1480-BC	1480	Hornsund	77.056	16.846	09/2015	0-5	87
HH15-1482-BC	1482	Hornsund	77.092	17.089	09/2015	0-5	71
HH15-1484-BC	1484	Hornsund	77.596	16.973	09/2015	0-5	65
HH15-1485-BC	1485	Hornsund	77.642	16.868	09/2015	0-5	71
HH15-1486-BC	1486	Hornsund	77.632	16.594	09/2015	0-5	37
HH15-1488-BC	1488	Hornsund	77.522	16.550	09/2015	0-5	89
HH15-1489-BC	1489	Hornsund	77.572	16.455	09/2015	0-5	140
HH15-1490-BC	1490	Hornsund	77.564	16.391	09/2015	0-5	64

Table S2. Target compounds, abbreviations, and target ions in the instrumental analysis and method detection limits and recoveries of surrogate standards.

Target compounds	Abbreviation	Quantification ion	Confirmation ion	Method detection limit (ng g^{-1} dw)
Polychlorinated biphenyls (PCBs)				
2,4'-Dichlorobiphenyl	CB8	222	224	0.03
2,4,4'-Trichlorobiphenyl	CB28	256	258	0.03
2,2',5,5'-Tetrachlorobiphenyl	CB52	292	290	0.02
2,2',4,5'-Tetrachlorobiphenyl	CB49	292	290	0.02
2,2',3,5'-Tetrachlorobiphenyl	CB44	292	290	0.03
3,4,4'-Trichlorobiphenyl	CB37	256	258	0.02
2,4,4',5-Tetrachlorobiphenyl	CB74	292	290	0.02
2,3',4',5-Tetrachlorobiphenyl	CB70	292	290	0.01
2,3',4,4'-Tetrachlorobiphenyl	CB66	292	290	0.03
2,3,4,4'-Tetrachlorobiphenyl	CB60	292	290	0.03
2,2',4,5,5'-Pentachlorobiphenyl	CB101	326	324	0.02
2,2',4,4',5-Pentachlorobiphenyl	CB99	326	328	0.02
2,2',3,4,5'-Pentachlorobiphenyl	CB87	292	290	0.02
3,3',4,4'-Tetrachlorobiphenyl	CB77	326	256	0.01
2,2',3,3',4-Pentachlorobiphenyl	CB82	338	340	0.03
2,3',4,4',5-Pentachlorobiphenyl	CB118	326	328	0.03
2,3,4,4',5-Pentachlorobiphenyl	CB114	326	328	0.02
2,2',4,4',5,5'-Hexachlorobiphenyl	CB153	360	362	0.02
2,3,3',4,4'-Pentachlorobiphenyl	CB105	326	324	0.02
2,2',3,3',5,6,6'-Heptachlorobiphenyl	CB179	396	398	0.03
2,2',3,4,4',5'-Hexachlorobiphenyl	CB138	360	362	0.02
2,3,3',4,4',6-Hexachlorobiphenyl	CB158	326	328	0.03
3,3',4,4',5-Pentachlorobiphenyl	CB126	360	362	0.02
2,3,4,4',5,6-Hexachlorobiphenyl	CB166	394	396	0.02
2,2',3,4',5,5',6-Heptachlorobiphenyl	CB187	394	396	0.02
2,2',3,4,4',5',6-Heptachlorobiphenyl	CB183	360	362	0.02
2,2',3,3',4,4'-Hexachlorobiphenyl	CB128	440	442	0.02
2,3,3',4,4',5-Hexachlorobiphenyl	CB156	360	362	0.02
2,2',3,4,4',5,5'-Heptachlorobiphenyl	CB180	394	396	0.03
3,3',4,4',5,5'-Hexachlorobiphenyl	CB169	360	362	0.03
2,2',3,3',4,4',5-Heptachlorobiphenyl	CB170	394	396	0.03
2,3,3',4,4',5,5'-Heptachlorobiphenyl	CB189	476	478	0.03
Traditional Polycyclic aromatic hydrocarbons (t-PAHs)				
Acenaphthylene	Acl	152	151	3.51
Acenaphthene	Ace	153	154	4.23
Fluorene	Flu	166	165	4.41
Phenanthrene	Phe	178	176	4.38
Anthracene	Ant	178	176	5.27
Fluoranthene	Fl	202	200	3.37
Pyrene	Py	202	200	2.83
Benzo[*a*]anthracene	BaA	228	226	2.11
Chrysene	Chr	228	226	2.59
Benzo[*b*]fluoranthene	BbF	252	253	1.82
Benzo[*k*]fluoranthene	BkF	252	253	0.55
Benzo[*a*]pyrene	BaP	252	253	2.76
Indeno[*1,2,3-cd*]pyrene	IcdP	276	138	4.04
Dibenz[*a,h*]anthracene	DbahA	278	276	3.73
Benzo[*g,h,i*]perylene	BghiP	276	138	5.41
Emerging PAHs (e-PAHs)				

Benzo[*b*]naphtho[*2,3-d*]furan	BBNF	218	189	2.36
11H-benzo[a]fluorene	11BaF	216	215	2.00
11H-Benzo[*b*]fluorene	11BbF	216	215	3.49
Benzo[*b*]naphtho[*2,1-d*]thiophene	BBNT	234	235	1.11
3-Methylchrysene	3MC	242	241	1.50
5-Methylbenzo[*a*]anthracene	5MBA	242	241	1.35
4,5-Methanochrysene	4,5MC	239	240	3.10
1-Methylchrysene	1MC	242	241	1.45
7-Methylbenz[a]anthracene	7MbA	242	241	1.98
7,12-Dimethylbenz[a]anthracene	7,12DbA	256	241	1.07
10-Methylbenzo[a]pyrene	10MbA	266	256	2.83
Alkylated PAHs (alkyl-PAHs)				
1-Methylnaphthalene	1-Na	142	141	
2-Methylnaphthalene	2-Na	142	141	
1,3-Dimethylnaphthalene	1,3-Na	156	141	
1,4,5-Trimethylnaphthalene	1,4,5-Na	170	155	
1,2,5,6-Tetramethylnaphthalene	1,2,5,6-Na	184	169	
1-Methylfluorene	1-Flu	180	165	
9-Methylfluorene	9-Flu	180	165	
Dibenzothiophene	Dbthio	184	185	
2-Methyldibenzothiophene	2-Dbthio	198	197	
2,4-Dimethyldibenzothiophene	2,4-Dbthio	212	197	
2,4,7-Trimethyldibenzothiophene	2,4,7-Dbthio	226	211	
3-Methylphenanthrene	3-Phe	192	191	
2-Methylphenanthrene	2-Phe	192	191	
1,6-Dimethylphenanthrene	1,6-Phe	206	191	
1,2-Dimethylphenanthrene	1,2-Phe	206	191	
1,2,9-Trimethylphenanthrene	1,2,9-Phe	220	-	
1,2,6,9-Tetramethylphenanthrene	1,2,6,9-Phe	234	219	
3-Methylchrysene	3-Chr	242	239	
6-Ethylchrysene	6-Ethyl-Chr	256	241	
1,3,6-Trimethylchrysene	1,3,6-Chr	252	264	
Internal standard				
2-Fluorobiphenyl	IS	172	171	
Surrogate standards		**Quantification ion**	**Confirmation ion**	**Surrogate recovery (%, mean ± SD)**
Polychlorinated biphenyl (PCBs)				
^{13}C-labeled CB 28		268	270	106 ± 7
^{13}C-labeled CB 52		304	302	99 ± 6
^{13}C-labeled CB 101		326	328	102 ± 6
^{13}C-labeled CB 153		372	374	109 ± 7
^{13}C-labeled CB 138		360	362	110 ± 6
^{13}C-labeled CB 180		406	408	114 ± 7
^{13}C-labeled CB 209		510	512	115 ± 8
Polycyclic aromatic hydrocarbons (PAHs)				
Acenaphthene-d10	Ace-d10	164	162	87 ± 11
Phenanthrene-d10	Phe-d10	188	189	82 ± 12
Chrysene-d12	Chr-d12	240	236	100 ± 20
Perylene-d12	Pery-d12	264	270	110 ± 18

Table S3. Instrumental conditions of gas chromatograph equipped with a mass selective detector for analyses of persistent toxic substances.

Instrument	**Agilent 7890B GC / 5977B MSD**	
Column	DB-5ms (30 m × 250 μm × 0.25 μm)	
Gas flow	1 mL He/min	
Injection mode	Splitless	
Injection volume	1 μL	
Oven temperature program	PCBs	60 °C (hold 1 min) → 5 °C min^{-1} to 140 °C (hold 1 min) → 30 °C min^{-1} to 200 °C (hold 1 min) → 4 °C min^{-1} to 250 °C (hold 5 min) → 10 °C min^{-1} to 300 °C (hold 1 min)
	t-PAHs and e-PAHs	60 °C (hold 2 min) → 6 °C min^{-1} to 300 °C (hold 13 min)
	Alkyl-PAHs	60 °C (hold 2 min) → 6 °C min^{-1} to 162 °C (hold 0 min) 2 °C min^{-1} to 168 °C (hold 0 min) 6 °C min^{-1} to 300 °C (hold 13 min)

Table S4. Concentrations of polychlorinated biphenyls (PCBs) in the glacimarine sediments of Svalbard.

Region	Sampling site	Concentrations of PCBs (ng g^{-1} dw)										
		CB 8	CB 28	CB 37	CB 52	CB 49	CB 44	CB 74	CB 70	CB 66	CB 60	CB 77
Krossfjorden	K1	0.3	0.4	0.4	-	0.8	0.4	-	-	-	-	-
	K2	-	-	-	-	0.2	-	-	-	-	-	-
	K3	0.7	-	0.4	0.5	-	-	-	-	-	-	-
Isfjorden	847	0.5	-	-	-	2.1	0.3	-	-	-	0.4	-
	850	0.3	0.3	1.0	-	0.5	-	-	-	-	0.3	-
Van Mijenfjorden	855	0.5	0.3	16.2	-	2.1	-	-	-	-	0.3	-
	858	0.4	-	-	-	1.5	-	-	-	-	-	-
	863	0.3	0.6	0.3	-	0.4	-	-	-	-	0.2	-
	868	0.3	-	-	-	0.2	-	-	-	-	-	-
Van Keulenfjorden	872	0.4	0.5	0.5	-	2.5	0.6	-	-	-	-	-
	876	0.3	-	-	-	0.3	-	-	-	-	-	-
Hambergbukta	895	0.3	-	1.3	-	-	-	-	-	-	-	-
	898	0.6	-	-	-	0.4	0.3	-	-	-	0.3	-
	900	0.7	0.3	0.9	-	-	-	-	-	-	0.2	-
Hornsund	885	0.4	0.6	1.2	-	0.7	-	-	-	-	0.2	-
	888	0.3	-	-	-	-	-	-	-	-	-	-
	891	0.9	1.8	5.3	0.9	2.3	1.0	0.8	2.0	1.0	1.9	-
	1464	0.2	-	-	-	-	-	-	-	-	-	-
	1466	0.4	-	-	-	-	-	-	-	-	-	-
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	0.5	-	-	-	0.5	-	-	-	-	-	-
	1472	0.2	-	-	18.6	0.3	-	-	-	-	-	-
	1474	0.3	-	0.4	-	0.2	-	-	-	-	-	-
	1475	0.2	-	-	-	-	-	-	-	-	-	-
	1476	0.4	-	-	-	0.3	-	-	-	-	-	-
	1478	0.3	-	-	-	-	-	-	-	-	-	-
	1479	-	-	-	0.4	0.3	0.2	-	-	-	-	-
	1480	0.3	0.4	0.3	-	0.4	0.4	-	-	-	-	-
	1482	0.4	-	0.4	-	1.1	-	-	-	-	-	-
	1484	0.3	-	-	-	-	-	-	-	-	-	-
	1485	-	-	-	-	0.2	-	-	-	-	-	-
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	0.7	-	0.4	0.5	-	-	-	-	-	-	-
	1490	-	-	-	-	-	-	-	-	-	-	-

- : Below detection limits.

Table S4. (Continued).

Region	Sampling site	Concentrations of PCBs (ng g^{-1} dw)										
		CB 101	CB 99	CB 87	CB 82	CB 118	CB 114	CB 105	CB 126	CB 153	CB 138	CB 158
Krossfjorden	K1	-	-	-	-	-	-	-	-	-	-	-
	K2	-	-	-	-	-	-	-	-	-	-	-
	K3	-	-	-	-	-	-	-	-	-	-	-
Isfjorden	847	-	-	-	-	-	-	-	-	-	-	-
	850	-	-	-	-	-	-	-	-	-	-	-
Van Mijenfjorden	855	-	-	-	-	-	0.3	-	-	-	-	-
	858	-	-	-	-	-	-	-	-	-	-	-
	863	-	-	-	-	-	-	-	-	-	-	-
	868	-	-	-	-	-	-	-	-	-	-	-
Van Keulenfjorden	872	-	-	-	-	-	-	-	-	0.3	-	-
	876	-	-	-	-	-	-	-	-	-	-	-
Hambergbukta	895	-	-	-	-	-	-	-	-	-	-	-
	898	-	-	-	-	-	-	-	-	-	-	-
	900	0.2	-	-	-	-	-	-	1.1	-	-	-
Hornsund	885	-	-	-	-	-	-	-	-	1.0	-	-
	888	-	-	-	-	-	-	-	-	-	-	-
	891	-	-	-	-	-	-	-	-	-	-	-
	1464	-	-	-	-	-	-	-	-	-	-	-
	1466	-	-	-	-	-	-	-	-	-	-	-
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	-	-	-	-	-	-	-	-	-	-	-
	1472	-	-	-	-	-	-	-	-	-	-	-
	1474	-	-	-	-	-	-	-	-	-	-	-
	1475	-	-	-	-	-	-	-	-	-	-	-
	1476	-	-	-	-	-	-	-	-	-	-	-
	1478	-	-	-	-	-	-	-	-	-	-	-
	1479	-	-	-	-	-	-	-	-	-	-	-
	1480	-	-	-	-	-	-	-	-	-	-	-
	1482	-	-	-	-	-	-	-	-	-	-	-
	1484	-	-	-	-	-	-	-	-	-	-	-
	1485	-	-	-	-	-	-	-	-	-	-	-
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	-	-	-	-	-	-	-	-	-	-	-
	1490	-	-	-	-	-	-	-	-	-	-	-

- : Below detection limits.

Table S4. (Continued).

Region	Sampling site	Concentrations of PCBs (ng g^{-1} dw)										
		CB 166	CB 128	CB 156	CB 169	CB 179	CB 187	CB 183	CB 180	CB 170	CB 189	PCBs
Krossfjorden	K1	-	-	-	-	-	-	-	-	-	-	2.2
	K2	-	-	-	-	-	-	-	-	-	-	0.2
	K3	-	-	-	-	-	-	-	-	-	-	1.6
Isfjorden	847	-	-	-	-	-	-	-	-	-	-	3.2
	850	-	-	-	-	-	-	-	-	-	-	2.5
Van Mijenfjorden	855	-	0.3	-	-	-	-	-	-	-	-	20
	858	-	-	-	-	-	-	-	-	-	-	1.9
	863	-	-	-	-	-	-	-	-	-	-	1.9
	868	-	-	-	-	-	-	-	-	-	-	0.6
Van Keulenfjorden	872	-	-	-	-	-	-	-	-	-	-	4.8
	876	-	-	-	-	-	-	-	-	-	-	0.7
Hambergbukta	895	-	-	-	-	-	-	-	-	-	-	1.6
	898	-	-	-	-	-	-	-	-	-	-	1.6
	900	-	-	-	-	-	-	-	-	-	-	3.3
Hornsund	885	-	-	-	-	-	-	-	-	-	-	4.1
	888	-	-	-	-	-	-	-	-	-	-	0.3
	891	-	-	-	-	-	-	-	-	-	-	18
	1464	-	-	-	-	-	-	-	-	-	-	0.2
	1466	-	-	-	-	-	-	-	-	-	-	0.4
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	-	-	-	-	-	-	-	-	-	-	1.0
	1472	-	-	-	-	-	-	-	-	-	-	19
	1474	-	-	-	-	-	-	-	-	-	-	0.9
	1475	-	-	-	-	-	-	-	-	-	-	0.2
	1476	-	-	-	-	-	-	-	-	-	-	0.7
	1478	-	-	-	-	-	-	-	-	-	-	0.3
	1479	-	-	-	-	-	-	-	-	-	-	0.9
	1480	-	-	-	-	-	-	-	-	-	-	1.8
	1482	-	-	-	-	-	-	-	-	-	-	1.9
	1484	-	-	-	-	-	-	-	-	-	-	0.3
	1485	-	-	-	-	-	-	-	-	-	-	0.2
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	-	-	-	-	-	-	-	-	-	-	1.6
	1490	-	-	-	-	-	-	-	-	-	-	-

- : Below detection limits.

Table S5. Concentrations of traditional polycyclic aromatic hydrocarbons (t-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling site	Concentrations of t-PAHs (ng g^{-1} dw)															
		Acl	**Ace**	**Flu**	**Phe**	**Ant**	**Fl**	**Py**	**BaA**	**Chr**	**BbF**	**BkF**	**BaP**	**IcdP**	**DbahA**	**BghiP**	**t-PAHs**
Krossfjorden	K1	0.8	6.0	36	71	1.3	10	6.3	0.9	0.6	-	0.4	0.8	-	-	0.5	130
	K2	0.1	0.3	2.9	12	-	6.3	5.6	0.5	3.9	0.1	0.8	12	-	-	-	45
	K3	-	0.1	4.9	7.3	-	2.8	3.3	0.8	-	-	0.5	1.0	-	-	0.3	21
Isfjorden	847	8.4	31	96	450	4.9	77	87	35	310	160	22	46	55	55	230	1700
	850	5.2	4.5	70	250	7.0	50	52	16	180	110	14	23	40	29	120	970
Van Mijenfjorden	855	19	49	170	1100	19.0	120	180	110	540	340	48	130	110	120	530	3600
	858	16	43	130	670	13.0	71	110	61	330	190	20	72	58	69	290	2100
	863	13	21	88	540	12.0	55	95	55	220	130	16	58	35	38	200	1600
	868	6.8	13	72	410	7.6	41	61	21	200	90	10	27	23	28	130	1100
Van Keulenfjorden	872	9.4	50	170	630	9.4	60	100	27	350	190	18	38	44	52	250	2000
	876	3.3	21	68	230	3.8	25	29	4.9	94	42	4.0	7.4	10	10	44	600
Hambergbukta	895	7.5	45	200	770	8.7	59	110	15	510	230	20	36	41	54	250	2400
	898	0.9	8.9	27	92	0.9	11	17	5.9	69	34	4.7	12	8.6	7.0	32	330
	900	2.9	20	98	390	8.8	38	54	15	260	130	13	24	31	33	140	1300
Hornsund	885	4.8	4.8	120	450	9.0	37	58	14	240	100	10	17	22	26	110	1200
	888	4.3	38	120	410	4.2	34	46	8.2	210	89	8.5	13	17	20	79	1100
	891	4.2	54	190	660	7.2	42	71	12	370	150	12	20	28	37	120	1800
	1464	-	1.6	9.0	24	0.3	3.6	3.1	0.3	2.9	-	0.8	0.2	-	-	0.4	46
	1466	1.3	8.2	34	94	1.5	8.9	7.3	0.7	9.8	2.5	1.3	0.5	-	-	2.2	170
	1468	-	7.8	33	190	1.9	17	24	1.9	80	60	11	11	11	0.6	38	490
	1469	1.4	11	46	200	1.9	20	26	2.2	67	32	2.8	6.9	0.3	-	19	440
	1472	7.9	72	110	480	9.4	53	85	9.1	75	140	39	35	52	65	140	1400
	1474	1.8	34	100	550	6.8	47	74	4.5	290	170	16	35	25	24	88	1500
	1475	5.6	48	100	600	11.0	73	110	24	160	190	100	1200	44	53	110	2800
	1476	9.3	120	180	780	18.0	77	130	37	140	200	52	64	59	75	170	2100
	1478	5.3	38	84	370	4.1	19	55	4.0	56	91	30	28	29	44	69	930
	1479	6.4	40	84	300	5.3	22	37	1.3	28	46	13	15	22	32	72	720
	1480	11	130	200	860	15	78	150	20	150	280	64	72	150	190	310	2700
	1482	10	120	200	900	25	13	150	15	157	230	65	81	110	140	200	2400
	1484	4.9	82	120	610	10	43	75	28	110	180	34	30	53	96	114	1600
	1485	6.3	66	110	390	6.7	30	46	13	46	74.0	14	18	27	48	91	990
	1486	5.5	43	95	560	7.3	50	89	5.2	93	160	30	38	69	99	160	1500
	1488	4.9	15	44	130	2.3	14	22	1.3	5.6	11	3.2	3.7	6.4	6.5	11	280
	1489	3.9	5.7	25	100	2.7	11	21	2.2	9.3	20	5.2	5.9	21	17	30	280
	1490	4.4	8.8	37	73	1.1	21	15	14	4.2	23	14	17	46	13	25	320

- : Below detection limits.

Table S6. Concentrations of emerging polycyclic aromatic hydrocarbons (e-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling	Concentrations of e-PAHs (ng g^{-1} dw)											
	Site	BBNF	11BaF	11BbF	BBNT	3MC	5MBA	4,5MC+1MC	7MbA	7,12DbA	20MC	10MbA	11 e-PAHs
Krossfjorden	K1	-	-	0.4	0.2	-	-	0.2	-	0.1	-	-	1.0
	K2	-	-	0.7	-	0.2	0.4	3.8	-	0.2	-	-	5.3
	K3	-	-	-	0.4	-	0.3	1.4	0.20	0.2	-	-	2.5
Isfjorden	847	26	65	36	35	180	35	15	1.4	39	5.4	150	580
	850	10	42	29	17	27	16	11	0.9	20	3.6	30	210
Van Mijenfjorden	855	67	134	82	12	130	71	33	19	72	7.1	70	700
	858	47	94	56	36	62	45	19	0.6	50	5.9	57	470
	863	61	95	43	22	74	35	14	4.7	44	8.1	28	430
	868	21	45	23	16	33	24	10	1.3	26	3.2	29	230
Van Keulenfjorden	872	17	83	56	28	57	34	14	0.7	32	9.6	56	390
	876	4.4	20	13	6.1	57	6.6	2	0.3	7.8	1.6	12	130
Hambergbukta	895	6.5	110	80	59	64	49	20	3.5	46	14	85	540
	898	1.7	13	9.3	3.1	10	3.7	1	1.7	4.8	1.4	9.4	59
	900	6.5	59	42	6.0	33	26	10	0.4	27	5.4	44	260
Hornsund	885	4.3	51	37	25	160	21	8.5	3	20	5.9	37	370
	888	3	42	28	19	130	14	5.7	0.4	12	3.5	23	280
	891	2.7	64	48	16	260	23	10	0.7	15	8.7	40	490
	1464	-	-	0.5	-	1.1	-	3.6	-	0.2	-	-	5.4
	1466	-	0.8	1.7	0.5	5.2	-	0.4	-	0.2	-	-	8.8
	1468	-	9.8	11	1.7	40	6.4	2.0	0.1	0.2	0.3	4.1	76
	1469	-	9.7	10	3.4	44	8	2.9	-	1.6	0.9	4.5	85
	1472	3.2	48	49	27	210	64	22	100	20	36	73	660
	1474	0.8	44	45	9.5	190	32	13	0.2	4.7	3.9	24	370
	1475	1.9	52	66	20	82	33	26	130	8.3	19	110	550
	1476	2.4	64	81	29	340	32	32	140	20	9.1	140	890
	1478	1.2	8	40	7.0	150	7.7	14	3.6	15	-	69	320
	1479	1.2	7	23	14	86	23	7.9	42	8.4	-	43	260
	1480	5.3	78	95	72	450	140	49	240	51	49	210	1400
	1482	6.9	16	120	16	93	37	51	0.5	49	-	230	620
	1484	0.6	37	48	16	88	110	23	110	12	24	73	540
	1485	0.9	31	28	15	140	40	10	56	9.2	-	48	380
	1486	3.4	38	45	28	250	76	19	99	17	20	76	670
	1488	-	1.9	5.2	2.3	15	1.6	1.7	7.1	1.3	-	5.8	42
	1489	0.4	2.4	6.2	4.5	25	4.7	2	11	2.1	3.1	8.6	70
	1490	1.2	-	1.8	0.6	-	-	1.4	4.1	1.4	0.7	3.7	15

- : Below detection limits.

Table S7. Positive factorization model factor scores and factor contributions using traditional polycyclic aromatic hydrocarbons in the glacimarine sediments of Svalbard.

Region	Sampling site	Factor scores			Factor contributions (%)		
		Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Krossfjorden	K1	0.22	1.1	3.3	4.6	25	71
	K2	0.12	0.34	2.2	4.7	13	82
	K3	0.87	2.4	7.2	8.3	23	69
Isfjorden	847	0.38	1.9	4.0	6.0	31	64
	850	0.38	1.5	2.8	8.2	33	59
Van Mijenfjorden	855	0.07	1.2	2.0	2.1	36	62
	858	3.6	0.87	2.0	55	14	31
	863	0.91	0.68	0.32	48	36	17
	868	2.6	0.20	1.2	66	5.1	29
Van Keulenfjorden	872	2.2	0.84	0.5	61	24	15
	876	3.7	1.2	0.71	67	21	13
Hambergbukta	895	5.4	0.61	1.6	71	8.0	21
	898	0.73	0.01	0.32	69	0.0	31
	900	2.8	0.19	1.2	67	4.7	28
Hornsund	885	0.05	0.41	0.00	11	89	0.1
	888	0.01	0.05	0.00	10	89	1.5
	891	0.04	0.43	0.01	9.1	90	1.1
	1464	0.03	0.06	0.01	33	53	14
	1466	0.01	0.05	0.00	9.6	85	5.6
	1468	0.01	0.05	0.00	9.6	86	4.8
	1469	0.02	0.17	0.01	10	86	4.0
	1472	0.04	0.31	0.00	12	88	0.6
	1474	0.03	0.27	0.02	8.2	87	5.1
	1475	0.07	1.0	0.02	6.7	92	1.5
	1476	1.6	1.0	0.20	56	36	7.2
	1478	1.2	1.6	0.20	40	53	6.6
	1479	1.9	0.71	0.45	62	23	15
	1480	6.0	1.6	1.1	69	19	12
	1482	4.2	0.33	1.1	75	5.8	19
	1484	3.3	1.8	0.70	58	30	12
	1485	0.13	1.7	0.61	5.3	69	25
	1486	0.17	1.5	0.23	9.0	79	12
	1488	0.16	3.4	2.8	2.5	54	44
	1489	0.20	3.7	2.4	3.2	58	38
	1490	0.01	2.3	1.0	0.1	69	31

Table S8. Concentrations of alkylated polycyclic aromatic hydrocarbons (alkyl-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling site	Concentrations of alkyl-PAHs (ng g^{-1} dw)									
		C1-Na	C2-Na	C3-Na	C4-Na	C1-Flu	C2-Flu	Dbthio	C1-Dbthio	C2-Dbthio	C3-Dbthio
Krossfjorden	K1	1.8	4.9	6.7	7.3	13	2.1	-	0.51	0.74	0.42
	K2	-	3.6	6.2	5.7	8.5	2.0	-	-	1.5	1.5
	K3	-	0.55	2.5	3.3	2.6	0.20	-	-	0.91	0.61
Isfjorden	847	480	690	660	620	170	130	15	76	82	49
	850	300	460	400	320	140	110	8.4	40	39	21
Van Mijenfjorden	855	1100	1400	1200	1000	300	210	1.7	55	23	16
	858	1000	1400	1300	1100	210	150	18	95	74	40
	863	700	980	1000	1100	150	120	11	92	63	37
	868	410	600	560	520	110	83	5.7	50	48	26
Van Keulenfjorden	872	490	940	840	690	300	220	10	67	52	22
	876	170	260	220	170	88	60	2.1	19	17	7.5
Hambergbukta	895	630	990	760	510	380	25	19	79	71	32
	898	48	81	61	42	50	32	-	5.2	4.6	3.6
	900	260	360	260	190	210	150	-	13	9.5	4.1
Hornsund	885	450	730	540	320	250	190	11	50	47	21
	888	310	480	340	190	180	130	6.0	30	29	13
	891	610	830	490	230	330	240	2.1	19	13	5.6
	1464	0.12	3.2	11	6.3	8.2	2.4	-	-	2.5	0.63
	1466	24	38	31	20	25	9.4	-	2.0	2.6	1.6
	1468	3.3	18	14	9.5	47	20	-	1.6	2.6	2.3
	1469	5.9	67	84	54	73	39	-	4.2	4.1	2.3
	1472	440	560	340	160	160	120	-	11	8.7	5.4
	1474	180	330	220	98	180	120	-	5.0	3.7	3.4
	1475	62	230	250	150	230	200	-	11	8.0	6.6
	1476	570	910	570	250	290	220	0.11	13	8.3	6.1
	1478	16	150	170	110	140	100	-	4.7	3.8	5.0
	1479	81	230	170	86	95	71	-	6.3	6.1	4.5
	1480	800	1100	680	330	340	260	2.8	27	21	11
	1482	710	1100	810	480	410	290	-	19	7.7	9.8
	1484	110	290	190	68	200	150	-	4.0	3.9	4.1
	1485	270	360	190	79	130	92	-	5.0	4.6	3.5
	1486	120	180	170	120	130	110	-	9.9	7.5	4.5
	1488	36	53	36	21	29	14	-	1.5	2.3	1.8
	1489	3.5	12	11	8.3	20	14	-	0.24	0.43	0.17
	1490	0.53	3.7	5.1	4.6	6.8	1.6	-	0.70	1.5	1.0

- : Below detection limits.

Table S8. (Continued).

Region	Sampling site	Concentrations of alkyl-PAHs (ng g^{-1} dw)							
		C1-Phe	C2-Phe	C3-Phe	C4-Phe	C1-Chr	C2-Chr	C3-Chr	alkyl-PAHs
Krossfjorden	K1	5.4	7.1	9.7	8.5	0.72	3.3	-	120
	K2	4.6	8.5	12	8.3	2.9	7.6	-	90
	K3	0.61	2.3	5.7	4.6	-	1.9	-	31
Isfjorden	847	660	780	560	340	260	590	180	8400
	850	420	480	320	190	170	330	110	5100
Van Mijenfjorden	855	1300	1300	840	430	420	780	310	15000
	858	910	950	650	420	270	700	230	12000
	863	680	800	620	560	230	750	230	10000
	868	540	640	420	270	190	460	140	6800
Van Keulenfjorden	872	860	900	540	340	320	650	210	10000
	876	260	280	170	94	90	160	52	2900
Hambergbukta	895	1200	1200	640	330	380	600	220	12000
	898	120	120	64	33	59	90	29	1300
	900	540	530	320	140	220	340	130	5400
Hornsund	885	680	730	400	200	230	360	130	7400
	888	500	500	250	120	180	260	84	5200
	891	830	780	340	150	310	440	130	8400
	1464	12	14	11	5.1	4.6	7.3	-	140
	1466	36	32	23	12	11	18	1.2	460
	1468	120	60	22	13	74	55	5.4	960
	1469	170	150	73	32	71	87	20	1500
	1472	530	530	240	100	210	300	89	5400
	1474	560	460	200	81	280	320	81	5100
	1475	910	880	390	160	440	570	150	7200
	1476	970	900	390	150	360	500	140	9100
	1478	440	480	220	74	160	230	83	3700
	1479	320	340	150	51	97	130	59	2900
	1480	1300	1300	560	260	540	800	240	12000
	1482	1200	1200	590	200	400	510	210	12000
	1484	730	610	220	82	360	420	96	5700
	1485	420	420	160	59	160	210	72	3900
	1486	590	550	240	110	310	410	110	5000
	1488	62	66	37	15	18	25	25	700
	1489	77	68	34	17	41	51	10	630
	1490	6.7	8.7	13	9.7	8.1	19	2.7	180

- : Below detection limits.

Table S9. Predicted no-effect concentration (PNEC) of 95 PTSs using ecological structure-activity relationships (ECOSAR) model.

Compound	Organism	Endpoint	Duration	Value (mg L^{-1})	Assessment factor	PNEC (μg L^{-1})	K_{ow}
Polychlorinated biphenyls (PCBs)							
2,4'-Dichlorobiphenyl	Green Algae	EC50	96h	0.604	1000	0.604	5.09
2,4,4'-Trichlorobiphenyl	Green Algae	EC50	96h	0.25	1000	0.25	5.62
2,2',5,5'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.09
2,2',4,5'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.22
2,2',3,5'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	5.81
3,4,4'-Trichlorobiphenyl	Green Algae	EC50	96h	0.25	1000	0.25	5.9
2,4,4',5-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.67
2,3',4',5-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.23
2,3',4,4'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.31
2,3,4,4'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	5.84
2,2',4,5,5'-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	6.8
2,2',4,4',5-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	7.21
2,2',3,4,5'-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	6.85
3,3',4,4'-Tetrachlorobiphenyl	Green Algae	EC50	96h	0.101	1000	0.101	6.63
2,2',3,3',4-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	6.68
2,3',4,4',5-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	7.12
2,3,4,4',5-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	6.98
2,2',4,4',5,5'-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.75
2,3,3',4,4'-Pentachlorobiphenyl	Green Algae	EC50	96h	0.041	1000	0.041	6.79
2,2',3,3',5,6,6'-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
2,2',3,4,4',5'-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.44
2,3,3',4,4',6-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.62
3,3',4,4',5-Pentachlorobiphenyl	Green Algae	EC50	96h	0.41	1000	0.41	6.98
2,3,4,4',5,6-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.31
2,2',3,4',5,5',6-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
2,2',3,4,4',5',6-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
2,2',3,3',4,4'-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7..31
2,3,3',4,4',5-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.6
2,2',3,4,4',5,5'-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
3,3',4,4',5,5'-Hexachlorobiphenyl	Green Algae	EC50	96h	0.016	1000	0.016	7.41
2,2',3,3',4,4',5-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
2,3,3',4,4',5,5'-Heptachlorobiphenyl	Green Algae	EC50	96h	0.0063	1000	0.0063	8.27
Traditional Polycyclic aromatic hydrocarbons (t-PAHs)							
Acenaphthylene	Green Algae	EC50	96h	2.42	1000	2.42	3.94
Acenaphthene	Green Algae	EC50	96h	1.74	1000	1.74	3.92
Fluorene	Green Algae	EC50	96h	2.33	1000	2.33	4.18
Phenanthrene	Green Algae	EC50	96h	1.47	1000	1.47	4.46
Anthracene	Green Algae	EC50	96h	1.47	1000	1.47	4.45
Fluoranthene	Green Algae	EC50	96h	0.656	1000	0.656	5.16
Pyrene	Green Algae	EC50	96h	0.656	1000	0.656	4.88
Benzo[a]anthracene	Green Algae	EC50	96h	0.29	1000	0.29	5.76
Chrysene	Green Algae	EC50	96h	0.29	1000	0.29	5.81
Benzo[b]fluoranthene	Green Algae	EC50	96h	0.125	1000	0.125	5.78
Benzo[k]fluoranthene	Green Algae	EC50	96h	0.125	1000	0.125	6.11
Benzo[a]pyrene	Green Algae	EC50	96h	0.125	1000	0.125	6.13
Indeno[1,2,3-cd]pyrene	Green Algae	EC50	96h	0.054	1000	0.054	6.7
Dibenz[a,h]anthracene	Green Algae	EC50	96h	0.054	1000	0.054	6.54
Benzo[g,h,i]perylene	Green Algae	EC50	96h	0.054	1000	0.054	6.54
Emerging PAHs (e-PAHs)							
Benzo[b]naphtho[2,3-d]furan	Green Algae	EC50	96h	0.757	1000	0.757	4.89
11H-benzo[a]fluorene	Green Algae	EC50	96h	0.464	1000	0.464	5.4
11H-Benzo[b]fluorene	Green Algae	EC50	96h	0.464	1000	0.464	5.77
Benzo[b]naphtho[2,1-d]thiophene	Green Algae	EC50	96h	0.396	1000	0.396	5.19
3-Methylchrysene	Green Algae	EC50	96h	0.129	1000	0.129	6.07
5-Methylbenzo[a]anthracene	Green Algae	EC50	96h	0.129	1000	0.129	6.07
4,5-Methanochrysene	Green Algae	EC50	96h	0.202	1000	0.202	5.78
1-Methylchrysene	Green Algae	EC50	96h	0.129	1000	0.129	6.07
7-Methylbenz[a]anthracene	Green Algae	EC50	96h	0.129	1000	0.129	6.07
7,12-Dimethylbenz[a]anthracene	Green Algae	EC50	96h	0.057	1000	0.057	5.80

10-Methylbenzo[a]pyrene	Green Algae	EC50	96h	0.055	1000	0.055	6.66
Alkylated PAHs (alkyl PAHs)							
1-Methylnaphthalene	Green Algae	EC50	96h	3.2	1000	3.2	3.86
2-Methylnaphthalene	Green Algae	EC50	96h	3.2	1000	3.2	3.86
1,3-Dimethylnaphthalene	Green Algae	EC50	96h	1.47	1000	1.47	4.42
1,4,5-Trimethylnaphthalene	Green Algae	EC50	96h	0.67	1000	0.67	4.9
1,2,5,6-Tetramethylnaphthalene	Green Algae	EC50	96h	0.303	1000	0.303	5.36
1-Methylfluorene	Green Algae	EC50	96h	1.05	1000	1.05	4.97
9-Methylfluorene	Green Algae	EC50	96h	2.04	1000	2.04	4.15
1,7-Dimethylfluorene	Green Algae	EC50	96h	0.475	1000	0.475	5.11
Dibenzothiophene	Green Algae	EC50	96h	2.03	1000	2.03	4.38
2-Methyldibenzothiophene	Green Algae	EC50	96h	0.913	1000	0.913	4.71
2,4-Dimethyldibenzothiophene	Green Algae	EC50	96h	0.409	1000	0.409	5.26
2,4,7-Trimethyldibenzothiophene	Green Algae	EC50	96h	0.182	1000	0.182	5.81
3-Methylphenanthrene	Green Algae	EC50	96h	0.665	1000	0.665	4.86
2-Methylphenanthrene	Green Algae	EC50	96h	0.665	1000	0.665	4.86
1,6-Dimethylphenanthrene	Green Algae	EC50	96h	0.298	1000	0.298	5.44
1,2-Dimethylphenanthrene	Green Algae	EC50	96h	0.298	1000	0.298	5.44
1,2,9-Trimethylphenanthrene	Green Algae	EC50	96h	0.133	1000	0.133	5.99
1,2,6,9-Tetramethylphenanthrene	Green Algae	EC50	96h	0.059	1000	0.059	6.53
3-Methylchrysene	Green Algae	EC50	96h	0.129	1000	0.129	6.07
6-Ethylchrysene	Green Algae	EC50	96h	0.062	1000	0.062	6.56
1,3,6-Trimethylchrysene	Green Algae	EC50	96h	0.025	1000	0.025	7.16

Table S10. Hazard quotient (HQ) values of polychlorinated biphenyls (PCBs) in the glacimarine sediments of Svalbard.

Region	Sampling site	HQ of PCBs (ng g^{-1} dw)										
		CB 8	CB 28	CB 37	CB 52	CB 49	CB 44	CB 74	CB 70	CB 66	CB 60	CB 77
Krossfjorden	K1	0.4	8.0	9.6	-	-	1.2	-	-	-	-	-
	K2	1.1	-	59	-	-	-	-	-	-	1.7	3.1
	K3	0.9	1.1	6.2	-	-	-	-	-	-	-	-
Isfjorden	847	0.8	-	-	-	21	1.2	-	-	-	3.8	-
	850	0.5	1.4	1.0	-	5.4	-	-	-	-	2.5	-
Van Mijenfjorden	855	0.9	1.2	160	-	20	-	-	-	-	3.0	-
	858	0.7	-	-	-	15	-	-	-	-	-	-
	863	0.5	2.5	3.1	-	3.9	-	-	-	-	2.2	-
	868	0.5	-	-	-	2.4	-	-	-	-	-	-
Van Keulenfjorden	872	0.7	2.2	4.6	-	25	2.2	-	-	-	-	-
	876	0.6	0.1	-	-	2.9	-	-	-	-	-	-
Hambergbukta	895	0.5	-	13	-	-	-	-	-	-	-	-
	898	1.0	-	-	-	4.1	1.2	-	-	-	3.3	-
	900	1.1	1.3	8.6	-	-	-	-	-	-	1.8	-
Hornsund	885	0.7	2.4	11	-	7.0	-	-	-	-	2.0	-
	888	0.4	-	-	-	-	-	-	-	-	-	-
	891	1.5	7.0	52	9.2	23	4.0	7.5	20.2	10.3	19	-
	1464	0.4	-	-	-	-	-	-	-	-	-	-
	1466	0.6	-	-	-	-	-	-	-	-	-	-
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	0.9	-	-	-	4.5	-	-	-	-	-	-
	1472	0.4	-	-	180	3.4	-	-	-	-	-	-
	1474	0.5	-	3.5	-	2.3	-	-	-	-	-	-
	1475	0.3	-	-	-	-	-	-	-	-	-	-
	1476	0.6	-	-	-	3.2	-	-	-	-	-	-
	1478	0.5	-	-	-	-	-	-	-	-	-	-
	1479	-	-	-	3.7	2.8	0.9	-	-	-	-	-
	1480	0.4	1.6	3.3	-	4.4	1.5	-	-	-	-	-
	1482	0.7	-	4.1	-	11	-	-	-	-	-	-
	1484	0.5	-	-	-	-	-	-	-	-	-	-
	1485	-	-	-	-	2.4	-	-	-	-	-	-
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	1.2	-	3.8	4.7	-	-	-	-	-	-	-
	1490	-	-	-	-	-	-	-	-	-	-	-

- : Below detection limits.

Table S10. (Continued).

Region	Sampling site	HQ of PCBs (ng g^{-1} dw)										
		CB 101	CB 99	CB 87	CB 82	CB 118	CB 114	CB 105	CB 126	CB 153	CB 138	CB 158
Krossfjorden	K1	-	-	-	-	-	-	-	-	-	-	-
	K2	-	-	-	-	-	-	-	97	-	-	-
	K3	-	-	-	-	-	-	-	-	-	-	-
Isfjorden	847	-	-	-	-	-	-	-	-	-	-	-
	850	-	-	-	-	-	-	-	-	-	-	-
Van Mijenfjorden	855	-	-	-	-	-	7.3	-	-	-	-	-
	858	-	-	-	-	-	-	-	-	-	-	-
	863	-	-	-	-	-	-	-	-	-	-	-
	868	-	-	-	-	-	-	-	-	-	-	-
Van Keulenfjorden	872	-	-	-	-	-	-	-	-	46	-	-
	876	-	-	-	-	-	-	-	-	-	-	-
Hambergbukta	895	-	-	-	-	-	-	-	-	-	-	-
	898	-	-	-	-	-	-	-	-	-	-	-
	900	4.8	-	-	-	-	-	-	26	-	-	-
Hornsund	885	-	-	-	-	-	-	-	-	150	-	-
	888	-	-	-	-	-	-	-	-	-	-	-
	891	-	-	-	-	-	-	-	-	-	-	-
	1464	-	-	-	-	-	-	-	-	-	-	-
	1466	-	-	-	-	-	-	-	-	-	-	-
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	-	-	-	-	-	-	-	-	-	-	-
	1472	-	-	-	-	-	-	-	-	-	-	-
	1474	-	-	-	-	-	-	-	-	-	-	-
	1475	-	-	-	-	-	-	-	-	-	-	-
	1476	-	-	-	-	-	-	-	-	-	-	-
	1478	-	-	-	-	-	-	-	-	-	-	-
	1479	-	-	-	-	-	-	-	-	-	-	-
	1480	-	-	-	-	-	-	-	-	-	-	-
	1482	-	-	-	-	-	-	-	-	-	-	-
	1484	-	-	-	-	-	-	-	-	-	-	-
	1485	-	-	-	-	-	-	-	-	-	-	-
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	-	-	-	-	-	-	-	-	-	-	-
	1490	-	-	-	-	-	-	-	-	-	-	-

- : Below detection limits.

Table S10. (Continued).

Region	Sampling site	HQ of PCBs (ng g^{-1} dw)										
		CB 166	CB 128	CB 156	CB 169	CB 179	CB 187	CB 183	CB 180	CB 170	CB 189	HQ
Krossfjorden	K1	-	-	-	-	-	-	-	-	-	-	-
	K2	0.8	-	-	-	-	14	-	-	-	-	0.2
	K3	-	-	-	-	-	-	-	-	-	-	-
Isfjorden	847	-	-	-	-	-	-	-	-	-	-	-
	850	-	-	-	-	-	-	-	-	-	-	-
Van Mijenfjorden	855	-	17	-	-	-	-	-	-	-	-	0.2
	858	-	-	-	-	-	-	-	-	-	-	-
	863	-	-	-	-	-	-	-	-	-	-	-
	868	-	-	-	-	-	-	-	-	-	-	-
Van Keulenfjorden	872	-	-	-	-	-	-	-	-	-	-	0.1
	876	-	-	-	-	-	-	-	-	-	-	-
Hambergbukta	895	-	-	-	-	-	-	-	-	-	-	-
	898	-	-	-	-	-	-	-	-	-	-	-
	900	-	-	-	-	-	-	-	-	-	-	-
Hornsund	885	-	-	-	-	-	-	-	-	-	-	0.2
	888	-	-	-	-	-	-	-	-	-	-	-
	891	-	-	-	-	-	-	-	-	-	-	0.2
	1464	-	-	-	-	-	-	-	-	-	-	-
	1466	-	-	-	-	-	-	-	-	-	-	-
	1468	-	-	-	-	-	-	-	-	-	-	-
	1469	-	-	-	-	-	-	-	-	-	-	-
	1472	-	-	-	-	-	-	-	-	-	-	0.2
	1474	-	-	-	-	-	-	-	-	-	-	-
	1475	-	-	-	-	-	-	-	-	-	-	-
	1476	-	-	-	-	-	-	-	-	-	-	-
	1478	-	-	-	-	-	-	-	-	-	-	-
	1479	-	-	-	-	-	-	-	-	-	-	-
	1480	-	-	-	-	-	-	-	-	-	-	-
	1482	-	-	-	-	-	-	-	-	-	-	-
	1484	-	-	-	-	-	-	-	-	-	-	-
	1485	-	-	-	-	-	-	-	-	-	-	-
	1486	-	-	-	-	-	-	-	-	-	-	-
	1488	-	-	-	-	-	-	-	-	-	-	-
	1489	-	-	-	-	-	-	-	-	-	-	-
	1490	-	-	-	-	-	-	-	-	-	-	-

Table S11. Hazard quotient (HQ) values of polycyclic aromatic hydrocarbons (t-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling site	HQ of t-PAHs (ng g^{-1} dw)															
		Acl	**Ace**	**Flu**	**Phe**	**Ant**	**Fl**	**Py**	**BaA**	**Chr**	**BbF**	**BkF**	**BaP**	**IcdP**	**DbahA**	**BghiP**	**HQ**
Krossfjorden	K1	0.3	3.4	15	48	0.9	15	10	3.2	2.0	-	3.5	6.5	-	-	10	0.1
	K2	-	0.2	1.3	8.4	-	10	8.6	1.6	14	0.8	6.7	98	-	-	-	0.1
	K3	-	-	2.1	5.0	-	4.3	5.1	2.7	-	-	4.4	8.3	-	-	4.6	-
Isfjorden	847	3.5	18	41	310	3.3	120	130	120	1100	1300	180	370	1000	1000	4300	9.9
	850	2.1	2.6	30	170	4.8	76	79	55	620	880	110	180	740	540	2200	5.7
Van Mijenfjorden	855	7.9	28	73	750	13	180	270	380	1900	2700	380	1000	2000	2200	9800	22
	858	6.6	25	56	460	8.8	110	170	210	1100	1500	160	580	1100	1300	5400	12
	863	5.4	12	38	370	8.2	84	150	190	760	1000	130	460	650	700	3700	8.3
	868	2.8	7.5	31	280	5.2	63	93	72	690	720	80	220	430	520	2400	5.6
Van Keulenfjorden	872	3.9	29	73	430	6.4	91	150	93	1200	1500	140	300	820	960	4600	11
	876	1.4	12	29	160	2.6	38	44	17	320	340	32	59	190	190	820	2.2
Hambergbukta	895	3.1	26	86	520	5.9	90	170	52	1800	1800	160	290	760	1000	4600	11
	898	0.4	5.1	12	63	0.6	17	26	20	240	270	38	96	160	130	590	1.7
	900	1.2	11	42	270	6.0	58	82	52	900	1000	100	190	570	610	2600	6.5
Hornsund	885	2.0	2.8	52	310	6.1	56	88	48	830	800	80	140	410	480	2000	5.3
	888	1.8	22	52	280	2.9	52	70	28	720	710	68	100	320	370	1500	4.3
	891	1.7	31	82	450	4.9	64	110	41	1300	1200	96	160	520	690	2200	6.9
	1464	-	0.9	3.9	16	0.2	5.0	4.7	0.9	10	-	6.4	1.9	-	-	8.1	0.1
	1466	0.5	4.7	15	64	1.0	14	11	2.4	34	20	10	4.2	-	-	41	0.2
	1468	-	4.5	14	130	1.3	26	37	6.6	280	480	88	88	200	12	700	2.1
	1469	0.6	6.3	20	140	1.3	30	40	7.6	230	260	22	55	6.3	-	350	1.2
	1472	3.3	41	47	330	6.4	81	130	31	260	1100	310	280	960	1200	2500	7.3
	1474	0.8	20	43	370	4.6	72	110	16	1000	1400	130	280	460	440	1600	5.9
	1475	2.3	28	43	410	7.5	110	170	83	550	1500	830	9600	820	980	2100	17
	1476	3.8	69	77	530	12	120	190	130	480	1600	420	510	1100	1400	3100	9.7
	1478	2.2	22	36	250	2.8	29	84	14	190	730	240	220	540	820	1300	4.5
	1479	2.6	23	36	200	3.6	34	56	4.5	97	370	100	120	400	590	1300	3.4
	1480	4.3	74	86	590	10	120	230	69	520	2200	510	580	2800	3500	5700	17
	1482	4.1	68	86	610	17	20	230	52	540	1800	520	650	2000	2600	3700	13
	1484	2.0	47	52	420	6.8	66	110	97	380	1400	270	240	980	1800	2100	8.0
	1485	2.6	38	47	270	4.6	46	70	45	160	590	110	140	500	890	1700	4.6
	1486	2.3	25	41	380	5.0	76	140	18	320	1300	240	300	1300	1800	3000	8.9
	1488	2.0	8.6	19	88	1.6	21	34	4.5	19	88	26	30	120	120	200	0.8
	1489	1.6	3.3	11	68	1.8	17	32	7.6	32	160	42	47	390	320	560	1.7
	1490	1.8	5.1	16	50	0.7	32	23	48	14	180	110	140	850	240	460	2.2

- : Below detection limits.

Table S12. Hazard quotient (HQ) values of emerging polycyclic aromatic hydrocarbons (e-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling site	HQ of e-PAHs (ng g^{-1} dw)											
		BBNF	11BaF	11BbF	BBNT	3MC	5MBA	4,5MC+1MC	7MbA	7,12DbA	20MC	10MbA	HQ
Krossfjorden	K1	-	-	0.8	0.6	-	-	1.2	-	1.0	-	-	-
	K2	-	-	1.5	-	1.7	3.2	19	-	1.2	-	-	-
	K3	-	-	-	1.1	-	2.5	6.9	1.4	1.2	-	-	-
Isfjorden	847	34	140	78	88	1400	270	74	11	300	95	2700	5.2
	850	13	91	63	43	210	120	54	6.6	160	63	550	1.4
Van Mijenfjorden	855	89	290	180	30	1000	550	160	150	560	130	1300	4.4
	858	62	200	120	91	480	350	94	4.8	390	100	1000	2.9
	863	81	210	93	56	570	270	69	36	340	140	510	2.4
	868	28	97	50	40	260	190	50	10	200	56	530	1.5
Van Keulenfjorden	872	22	180	120	71	440	260	69	5.3	250	170	1000	2.6
	876	5.8	43	28	15	440	51	10	2.6	60	28	220	0.9
Hambergbukta	895	8.6	240	170	150	500	380	99	27	360	250	1500	3.7
	898	2.2	28	20	7.8	78	29	5.0	13	37	25	170	0.4
	900	8.6	130	91	15	260	200	50	2.9	210	95	800	1.9
Hornsund	885	5.7	110	80	63	1200	160	42	23	160	100	670	2.7
	888	4.0	91	60	48	1000	110	28	3.2	93	61	420	1.9
	891	3.6	140	100	40	2000	180	50	5.5	120	150	730	3.5
	1464	-	-	1.1	-	8.5	-	18	-	1.3	-	-	-
	1466	-	1.7	3.7	1.3	40	-	2.0	-	1.8	-	-	0.1
	1468	-	21	24	4.3	310	50	10	0.5	1.8	5.8	75	0.5
	1469	-	21	22	8.6	341	62	14		12	15	82	0.6
	1472	4.2	100	110	68	1600	500	110	800	160	630	1300	5.4
	1474	1.0	95	97	24	1500	250	64	1.4	36	68	440	2.5
	1475	2.5	110	140	51	640	260	130	990	64	330	2000	4.7
	1476	3.2	140	180	73	2600	250	160	1100	160	160	2500	7.4
	1478	1.6	17	86	18	1200	60	69	28	120	-	1300	2.8
	1479	1.6	15	50	35	670	180	39	330	65	-	780	2.2
	1480	7.0	170	210	180	3500	1100	240	1900	400	860	3800	12
	1482	9.1	34	260	40	720	290	250	3.6	380	-	4200	6.2
	1484	0.8	80	100	40	680	820	110	850	93	420	1300	4.5
	1485	1.2	67	60	38	1100	310	50	430	71	-	870	3.0
	1486	4.5	82	97	71	1900	590	94	770	130	350	1400	5.5
	1488		4.1	11	5.8	120	12	8.4	54	10	-	110	0.3
	1489	0.5	5.2	13	11	190	36	10	85	16	54	160	0.6
	1490	1.6	-	3.9	1.5	-	-	6.9	32	11	12	67	0.1

Table S13. Hazard quotient (HQ) values of alkyl polycyclic aromatic hydrocarbons (alkyl-PAHs) in the glacimarine sediments of Svalbard.

Region	Sampling site	HQ of alkyl-PAHs									
		C1-Na	C2-Na	C3-Na	C4-Na	C1-Flu	C2-Flu	Dbthio	C1-Dbthio	C2-Dbthio	C3-Dbthio
Krossfjorden	K1	0.56	3.3	10	24	8.4	4.4	-	0.56	1.8	2.3
	K2	-	2.5	9.3	19	5.5	4.2	-	-	3.7	8.2
	K3	-	0.37	3.7	11	1.7	0.42	-	-	2.2	3.4
Isfjorden	847	150	470	990	2000	110	270	7.4	83	200	270
	850	94	310	600	1100	91	230	4.1	44	95	120
Van Mijenfjorden	855	340	950	1800	3300	190	440	0.84	60	56	88
	858	310	950	1900	3600	140	320	8.9	100	180	220
	863	220	670	1500	3600	97	250	5.4	100	150	200
	868	130	410	840	1700	71	170	2.8	55	120	140
Van Keulenfjorden	872	150	640	1300	2300	190	460	4.9	73	130	120
	876	53	180	330	560	57	130	1.0	21	42	41
Hambergbukta	895	200	670	1100	1700	250	53	9.4	87	170	180
	898	15	55	91	140	32	67	-	5.7	11	20
	900	81	240	390	630	140	320	-	14	23	23
Hornsund	885	140	500	810	1100	160	400	5.4	55	110	120
	888	97	330	510	630	120	270	3.0	33	71	71
	891	190	560	730	760	210	510	1.0	21	32	31
	1464	0.04	2.2	16	21	5.3	5.1	-	-	6.1	3.5
	1466	7.5	26	46	66	16	20	-	2.20	6.4	8.8
	1468	1.0	12	21	31	30	42	-	1.8	6.4	12
	1469	1.8	46	130	180	47	82	-	4.6	10	12
	1472	140	380	510	530	100	250	-	12	21	30
	1474	56	220	330	320	120	250	-	5.5	9.1	19
	1475	19	160	370	500	150	420	-	12	20	36
	1476	180	620	850	830	190	460	0.05	14	20	34
	1478	5.0	100	250	360	91	210	-	5.2	9.3	27
	1479	25	160	250	280	61	150	-	6.9	15	25
	1480	250	750	1000	1110	220	550	1.4	30	51	60
	1482	220	750	1200	1600	270	610	-	21	19	54
	1484	34	200	280	220	130	320	-	4.4	9.5	23
	1485	84	240	280	260	84	190	-	5.5	11	19
	1486	38	120	250	400	84	230	-	11	18	25
	1488	11	36	54	69	19	29	-	1.6	5.6	9.9
	1489	1.1	8.2	16	27	13	29	-	0.26	1.1	0.93
	1490	0.17	2.5	7.6	15	4.4	3.4	-	0.77	3.7	5.5

- : Below detection limits.

Table S13. (Continued).

Region	Sampling site	HQ of alkyl-PAHs							
		C1-Phe	C2-Phe	C3-Phe	C4-Phe	C1-Chr	C2-Chr	C3-Chr	HQ
Krossfjorden	K1	8.1	24	73	140	5.6	53		0.36
	K2	6.9	29	90	140	22	120		0.46
	K3	0.9	7.7	43	78	-	31		0.18
Isfjorden	847	990	2600	4200	5800	2000	9500	7200	37
	850	630	1600	2400	3200	1300	5300	4400	22
Van Mijenfjorden	855	2000	4400	6300	7300	3300	13000	12000	55
	858	1400	3200	4900	7100	2100	11000	9200	47
	863	1000	2700	4700	9500	1800	12000	9200	48
	868	810	2100	3200	4600	1500	7400	5600	29
Van Keulenfjorden	872	1300	3000	4100	5800	2500	10000	8400	41
	876	390	940	1300	1600	700	2600	2100	11
Hambergbukta	895	1800	4000	4800	5600	2900	9700	8800	42
	898	180	400	480	560	460	1500	1200	5.1
	900	810	1800	2400	2400	1700	5500	5200	22
Hornsund	885	1000	2400	3000	3400	1800	5800	5200	26
	888	750	1700	1900	2000	1400	4200	3400	17
	891	1200	2600	2600	2500	2400	7100	5200	27
	1464	18	47	83	86	36	120	-	0.45
	1466	54	110	170	200	85	290	48	1.2
	1468	180	200	170	220	570	890	220	2.6
	1469	260	500	550	540	550	1400	800	5.1
	1472	800	1800	1800	1700	1600	4800	3600	18
	1474	840	1500	1500	1400	2200	5200	3200	17
	1475	1400	3000	2900	2700	3400	9200	6000	30
	1476	1500	3000	2900	2500	2800	8100	5600	30
	1478	660	1600	1700	1300	1200	3700	3300	15
	1479	480	1100	1100	860	750	2100	2400	9.8
	1480	2000	4400	4200	4400	4200	13000	9600	46
	1482	1800	4000	4400	3400	3100	8200	8400	38
	1484	1100	2000	1700	1400	2800	6800	3800	21
	1485	630	1400	1200	1000	1200	3400	2900	13
	1486	890	1800	1800	1900	2400	6600	4400	21
	1488	93	220	2800	250	140	400	1000	2.63
	1489	120	230	2600	290	320	820	400	2.53
	1490	10	29	98	160	63	310	110	0.82

- : Below detection limits.

Supplementary Figures

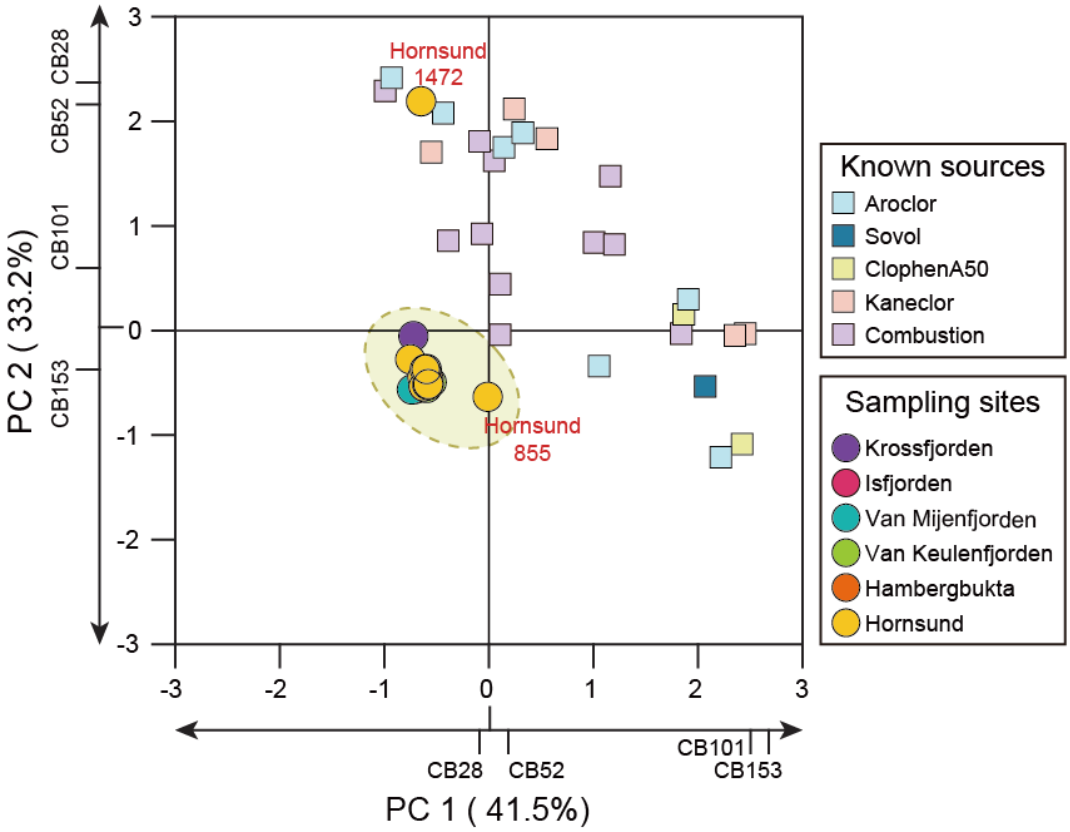

Fig. S1. Source identification of PCBs using principal component analysis (PCA) in the glacimarine sediments of Svalbard (Source profiles for PCA analysis from Ikonomou et al. (2002) and Pedersen et al. (2015)).

Ikonomou, M., Sather, P., Oh, J.-E., Choi, W.-Y., Chang, Y.-S., 2002. PCB levels and congener patterns from Korean municipal waste incinerator stack emissions. Chemosphere 49, 205-216.

Pedersen, K.B., Lejon, T., Jensen, P.E., Ottosen, L.M., 2015. Chemometric analysis for pollution source assessment of harbour sediments in Arctic locations. Water, Air, Soil Pollut. 226, 150.

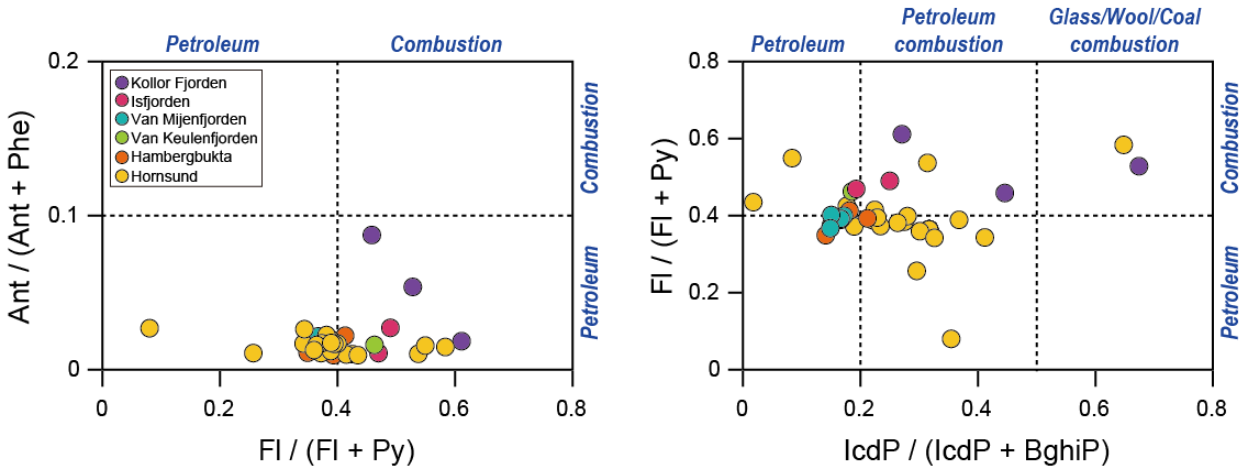

Fig. S2. Diagnostic double ratios of individual PAHs for estimation of potential sources in the glacimarine sediments of Svalbard.