

Project Title: Long Term Environmental Monitoring of Fjord Ecosystems, Ny-Alesund

Dioxins/Furans (PCDD/Fs), DL-PCBs, and NDL-PCBs in the sediment

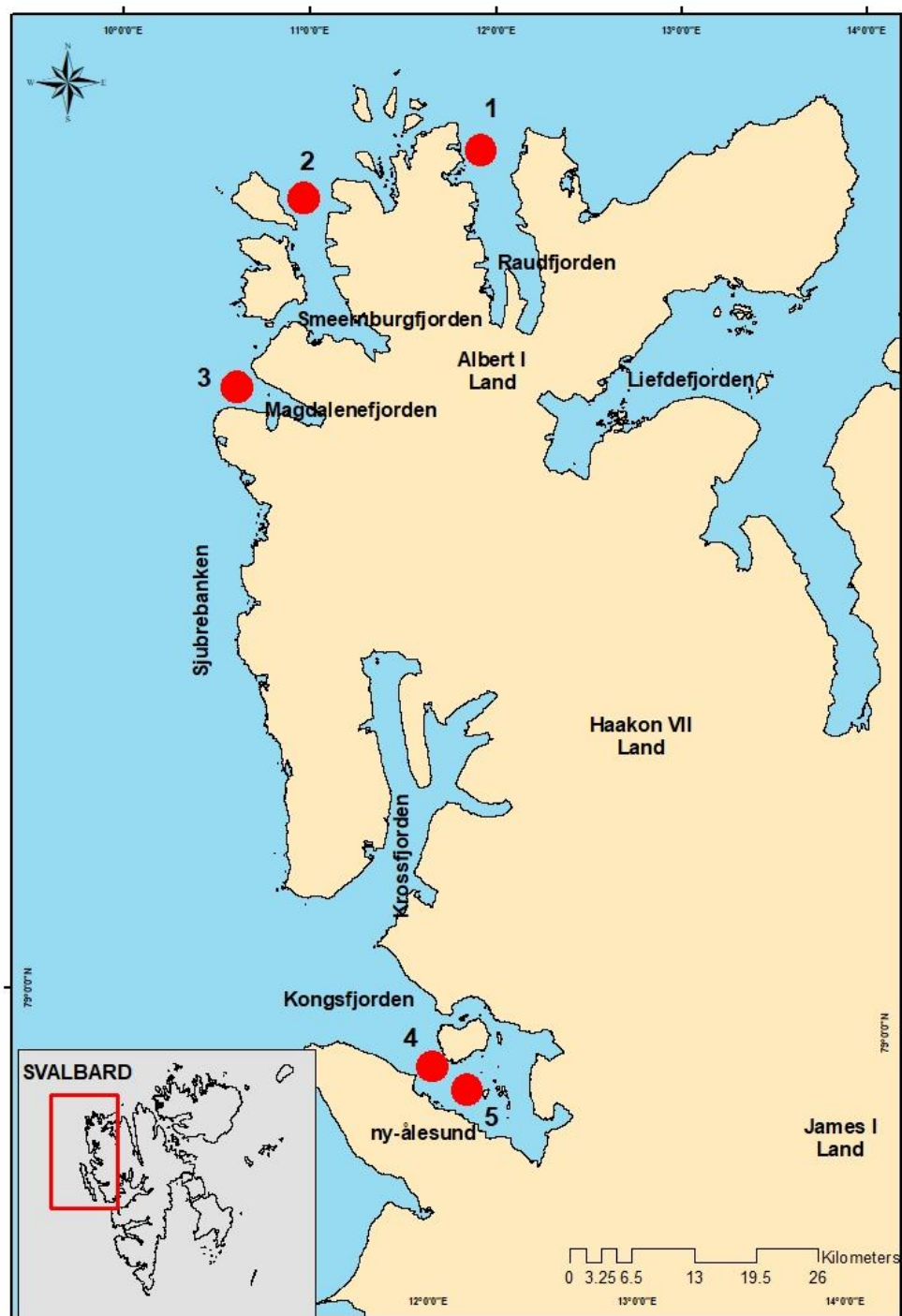


Figure 1 Study area showing sampling locations for Dioxin analysis– CLIONE 2019

Table 1 Concentration of PCDD/Fs (pg/g)in the sediment samples

Sl No	Compounds	RAUD	SMBG	MGDN	KONG-1	KONG-2
1	2378-TCDF	1.270	3.092	2.220	1.160	1.690
2	2378-TCDD	<0.037	1.070	<0.037	<0.037	<0.037
3	12378-PeCDF	1.840	1.830	1.760	2.190	1.770
4	23478-PeCDF	4.041	3.912	3.320	4.060	3.500
5	12378-PeCDD	<0.042	<0.042	<0.042	<0.042	<0.042
6	123478-HxCDF	<0.034	1.754	<0.034	<0.034	1.730
7	123678-HxCDF	1.890	<0.036	<0.036	2.500	<0.036
8	234678-HxCDF	<0.028	<0.028	<0.028	<0.028	0.976
9	123478-HxCDD	<0.040	<0.040	<0.040	<0.040	<0.040
10	123678-HxCDD	<0.033	<0.033	<0.033	<0.033	<0.033
11	123789-HxCDD	<0.044	<0.044	<0.044	3.230	<0.044
12	123789-HxCDF	<0.032	<0.032	<0.032	<0.032	2.300
13	1234678-HpCDF	0.700	0.668	<0.043	1.180	0.728
14	1234678-HpCDD	1.800	1.730	1.700	3.020	1.650
15	1234789-HpCDF	0.134	<0.031	0.033	<0.031	<0.031
16	OCDD	9.760	10.302	8.520	13.600	6.620
17	OCDF	1.370	1.310	0.715	2.580	0.729
Σ PCDD/Fs		22.805	25.668	18.268	33.520	21.693
Σ PCDD/Fs Pg TEQ/g		1.610	2.809	1.29	2.020	1.8

Table 2 Concentration of DL-PCBs (pg/g) in the sediment samples

Sl No	Compounds	RAUD	SMBG	MGDN	KONG-1	KONG-2
1	PCB 81	22.00	14.60	23.80	17.80	13.60
2	PCB 77	12.50	12.80	11	13.30	11.80
3	PCB 126	8.50	8.42	18.10	8.37	10.10
4	PCB 169	8.75	10.00	8.46	10.20	9.36

5	PCB 123	3.88	11.10	2.42	4.08	4.22
6	PCB 118	26.40	37.30	19.6	37.20	34.90
7	PCB 114	5.05	6.56	4.01	2.46	8.20
8	PCB 105	9.57	14.07	7.11	15.00	11.90
9	PCB 167	2.63	3.71	1.58	3.75	2.31
10	PCB 156	1.91	1.76	0.389	2.23	1.07
11	PCB 157	<0.177	<0.177	<0.177	<0.177	<0.177
12	PCB 189	0.76	0.47	0.19	0.29	0.32
Σ DL PCBs		101.95	120.79	96.66	114.68	107.78
ΣDL-PCBs Pg TEQ/g		1.12	1.15	2.07	1.15	1.29

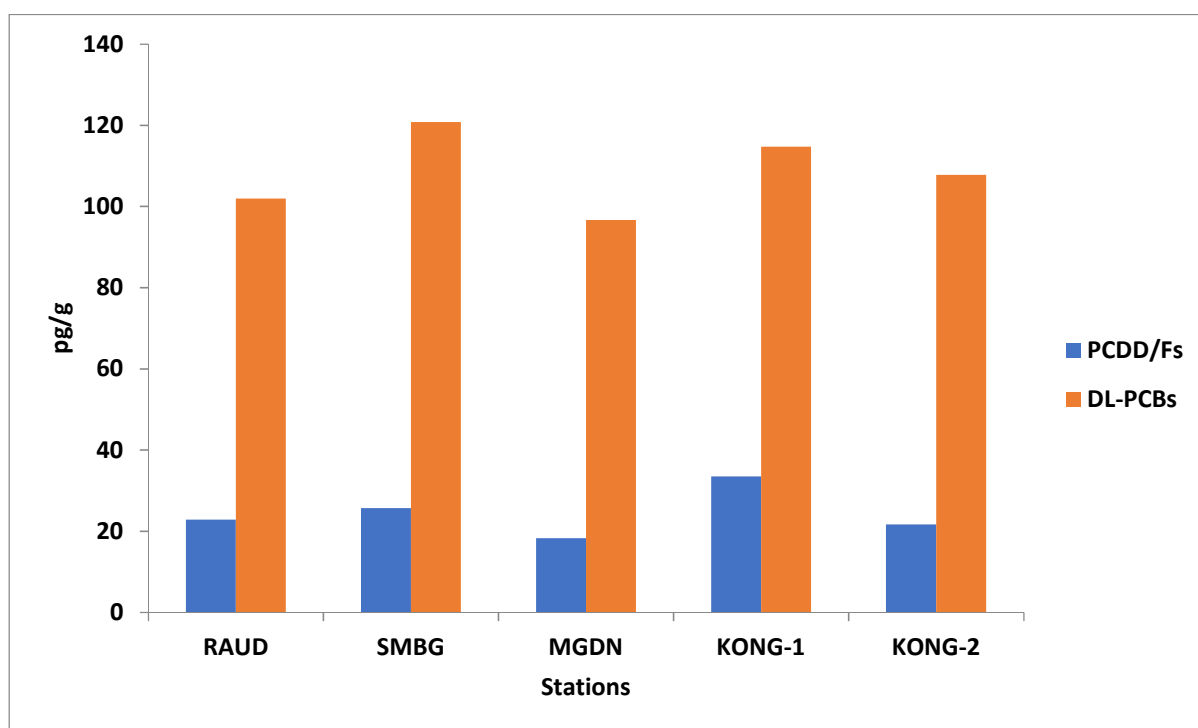


Fig. 2 Concentration of Σ PCDD/Fs and Σ DL-PCBs in the sediment

Table 3 Concentrations (ng/g dw) of NDL-PCBs in the sediment samples

Sl No	Compounds	RAUD	SMBG	MGDN	KONG-1	KONG-2
1	PCB-28	0.134	0.145	0.101	0.139	0.143
2	PCB-52	0.07	0.051	0.041	0.057	0.077
3	PCB-101	0.056	0.069	0.035	0.042	0.072

4	PCB-153	0.025	0.024	0.013	0.037	0.019
5	PCB-138	0.028	0.033	0.016	0.046	0.030
6	PCB-180	0.010	0.008	0.005	0.010	0.008
ΣNDL-PCBs		0.323	0.331	0.209	0.332	0.349

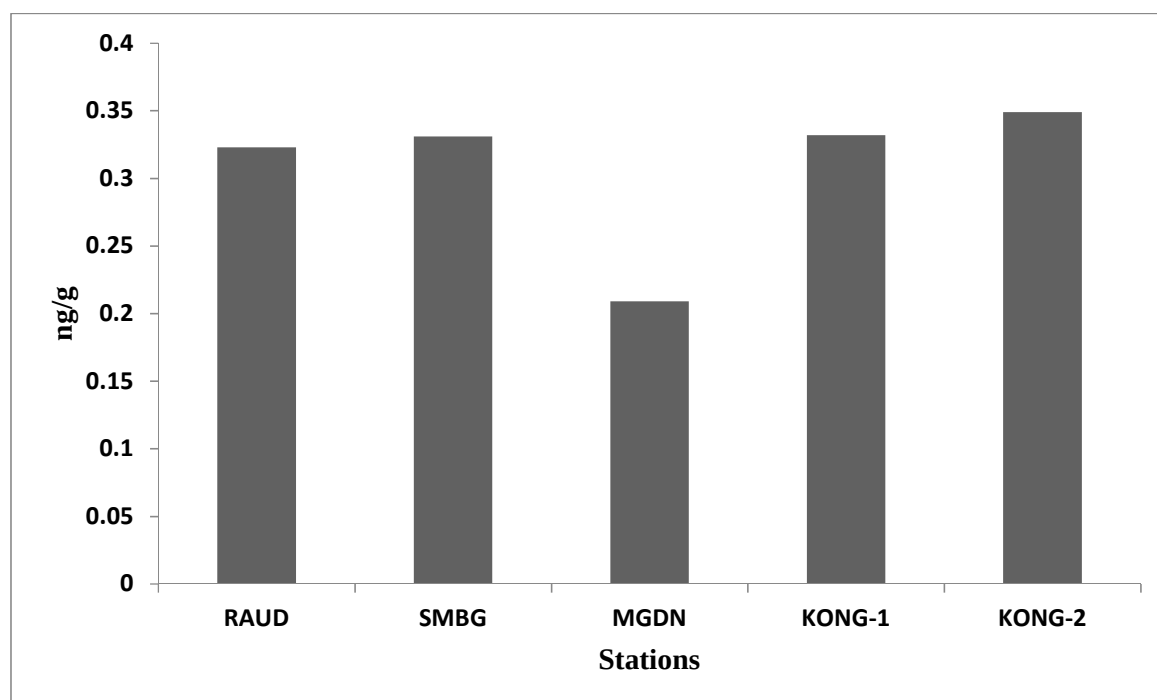


Fig. 3 Concentration of Σ NDL-PCBs in the sediment

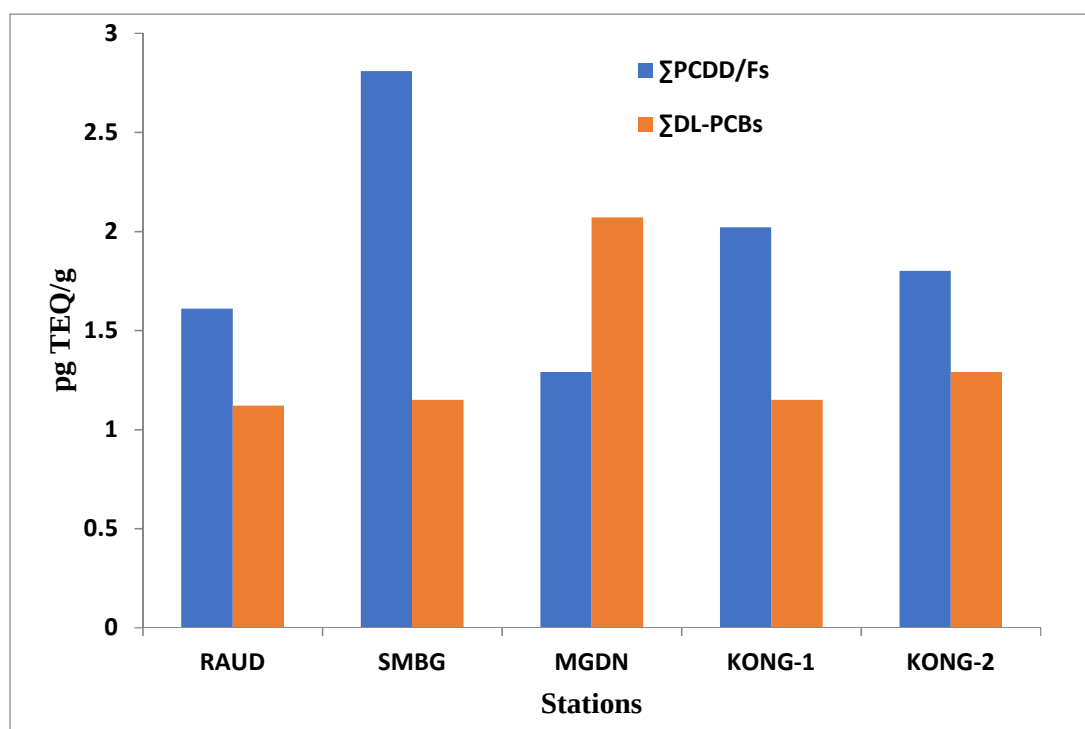


Fig. 4 WHO-TEQ of Σ PCDD/Fs and Σ DL-PCBs in the sediment

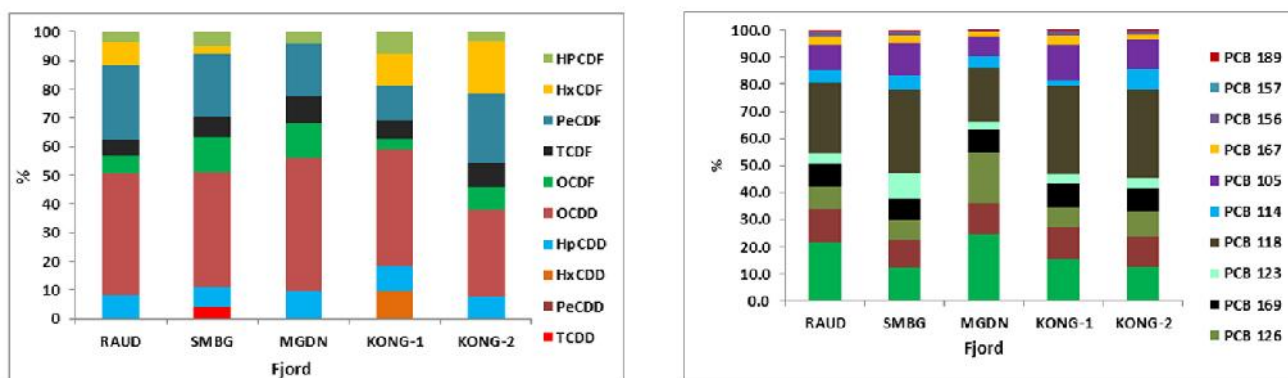


Fig. 5 Percentage contribution of PCDD/Fs congeners and DL-PCBs

Table 4 Dioxin/furan ratio of the samples

No.	Depth (m)	Locations	PCDD/PCDF ratio
1	80	RAUD	1.02
2	115	SMBG	1.04
3	80	MGDN	1.27



4	225	KONG-1	1.45
5	150	KONG-2	0.62

Total WHO-TEQ in sediments

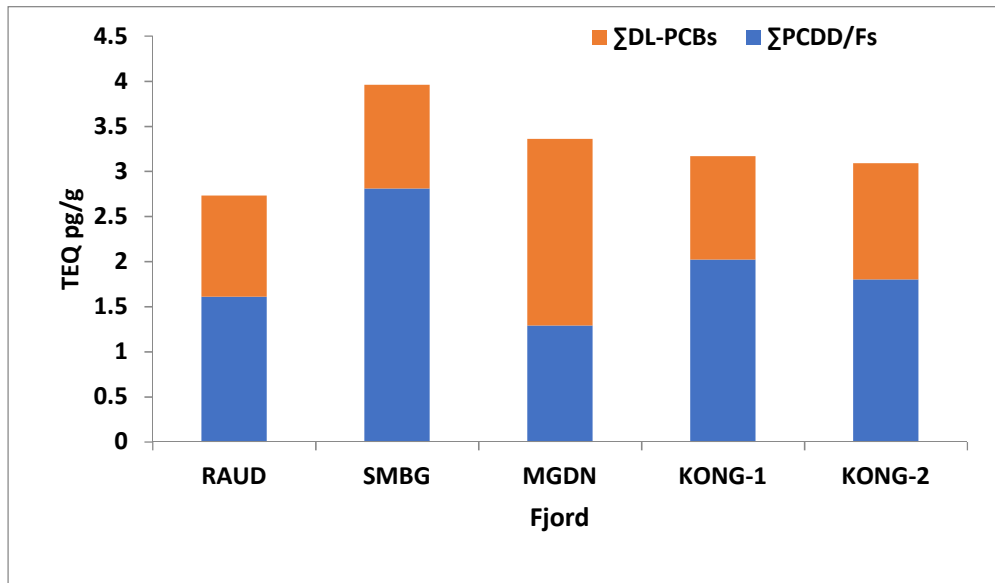


Fig. 6 TEQ of Σ PCDD/Fs+ Σ DL-PCBs in different stations

Pharmaceuticals and Personal Care Products (PPCPs)

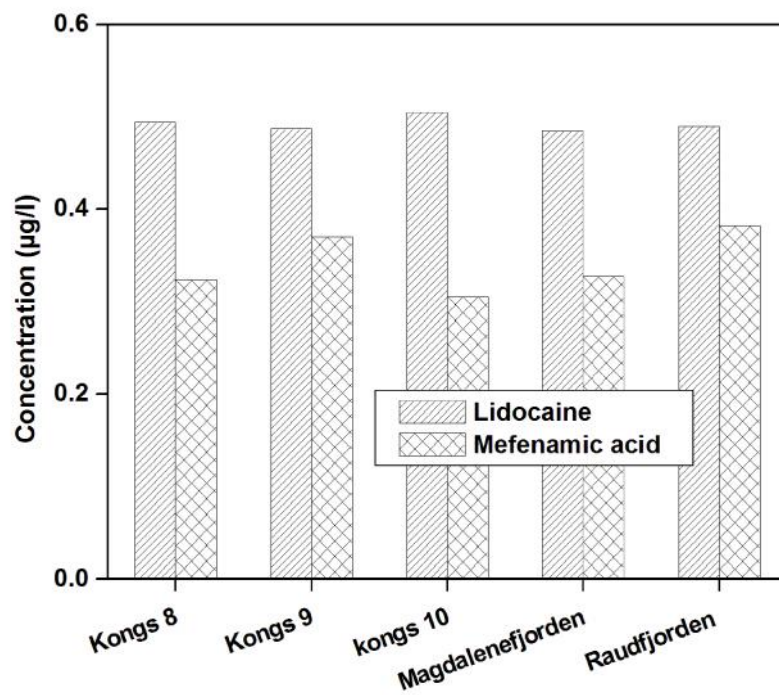
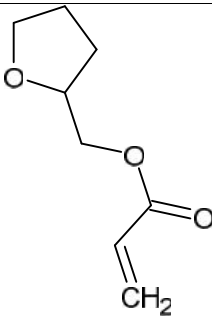
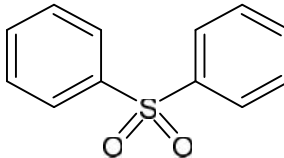
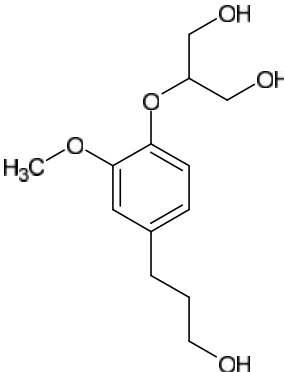
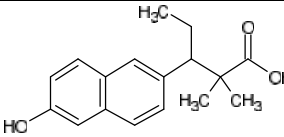
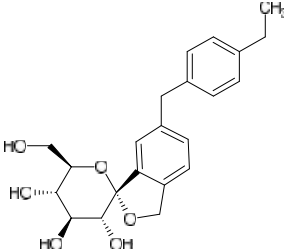
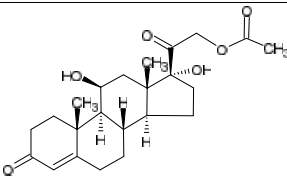
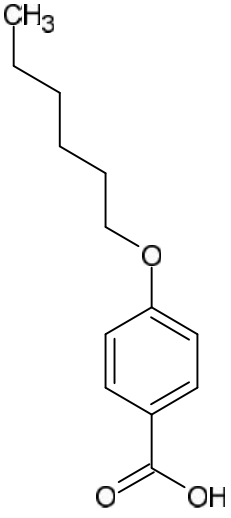
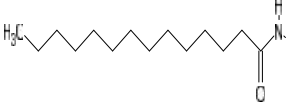
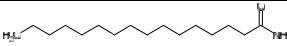
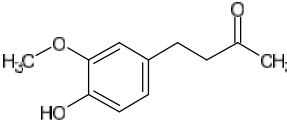


Fig. 7 Quantification of identified lidocaine and mefenamic acid in arctic region during the period 2018

Table 5 Identified organic compounds with elemental composition, structure experimental mass, ppm error and polarity

Sl no	Identified compound name	Elemental composition	Structure	m/z value	ppm error	Polarity	Uses
1	Tetrahydrofurfuryl acrylate	C ₈ H ₁₂ O ₃		157.08 66	4.4	[M+H] ⁺	Adhesive
2	Diphenyl sulfone	C ₁₂ H ₁₀ O ₂ S		219.04 85	5	[M+H] ⁺	High temperature solvent
3	2-[4-(3-hydroxypropyl)-2-methoxyphenoxy] propane-1,3-diol	C ₁₃ H ₂₀ O ₅		257.13 99	6.2	[M+H] ⁺	Regulates melanogenesis and lipolysis
5	Methallenestriol	C ₁₇ H ₂₀ O ₃		273.14 96	4.02	[M+H] ⁺	synthetic, nonsteroidal estrogen
6	Tofogliflozin	C ₂₂ H ₂₆ O ₆		387.18 15	3.3	[M+H] ⁺	Drug for Diabetes Mellitus

7	Hydrocortisone acetate	$C_{23}H_{32}O_6$		405.22 70	-0.24	$[M+H]^+$	Anti-inflammatory and immunosuppressive corticosteroid
8	p-Hexyloxybenzoic Acid	$C_{13}H_{18}O_3$		221.11 74	-4.07	$[M-H]^-$	Solvent
9	Myristamide	$C_{14}H_{29}NO$		228.23 22	0.43 81	$[M+H]^+$	Primary fatty amide
10	Palmitamide	$C_{16}H_{33}NO$		256.26 46	4.68	$[M+H]^+$	Primary fatty amide
11	Zingerone	$C_{11}H_{14}O_3$		195.10 22	3.58 7	$[M+H]^+$	Flavour additive

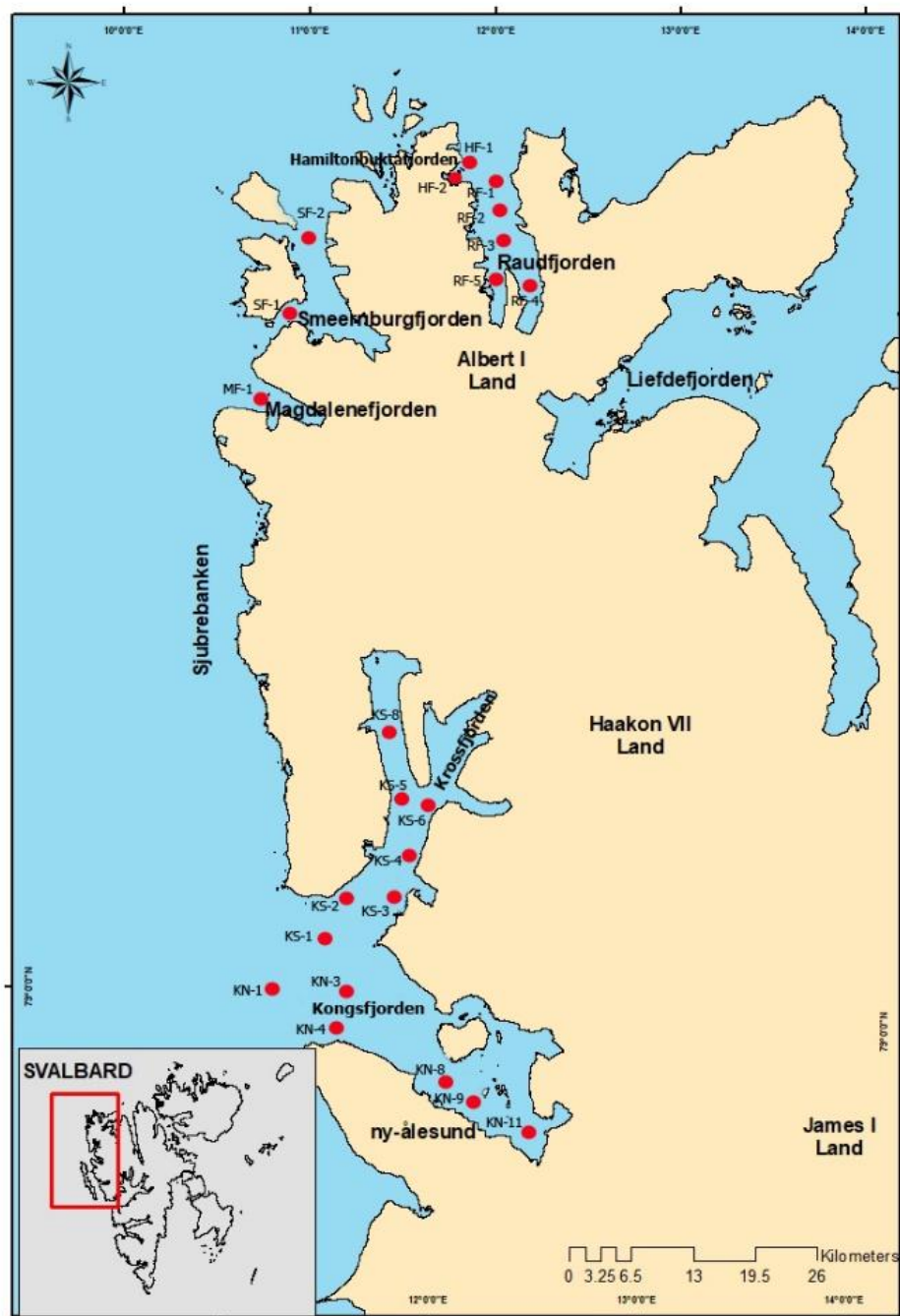


Figure 8 Study area showing sampling

Perfluorinated Compounds (PFCs) - Perfluorooctanoic acid (PFOA)

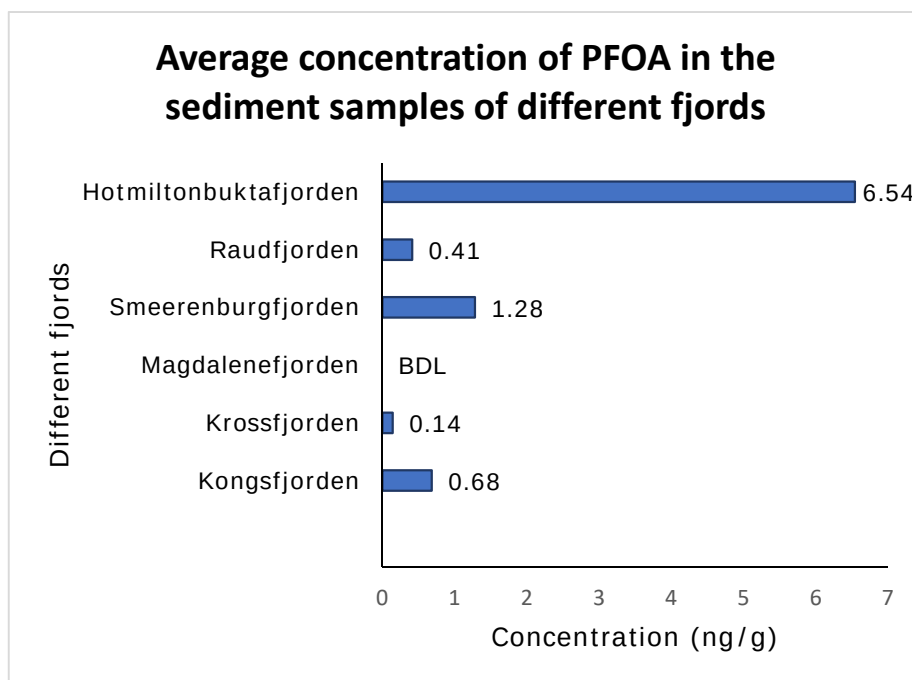


Figure.9 Average concentration of PFOA in sediment samples of the different fjord system

Table 6 Concentration of PFOA in the sediment samples of Different Fjords (ng/g)

Sample	Fjords	Concentration of PFOA (ng/g)
KS1	Krossfjorden	0.11 ng/g
KS 2	Outer	BDL
KS 3		BDL
KS 4		0.20 ng/g
KS 5	Krossfjorden Middle	BDL
KS 6	Krossfjorden	BDL
KS 8	Inner	0.11 ng/g
KN1	Kongs fjord	0.82 ng/g
KN 3	Outer	0.97 ng/g
KN4		0.01 ng/g

KN8	Kongs fjord Inner	0.33 ng/g
KN9		0.09 ng/g
KN11		1.83 ng/g
HF 1	Hotmiltonbuktafjorden	12.09 ng/g
HF 2		0.99 ng/g
RF 1	Raudfjorden	0.67 ng/g
RF 2		0.16 ng/g
RF 3		BDL
RF 4		BDL
RF 5		BDL
SF 1	Smeerenburgfjorden	0.26 ng/g
SF 2		2.31 ng/g
MF 1	Magdalenefjorden	BDL



Figure 10 Study area showing sampling locations for perfluorinated compounds

Microplastics

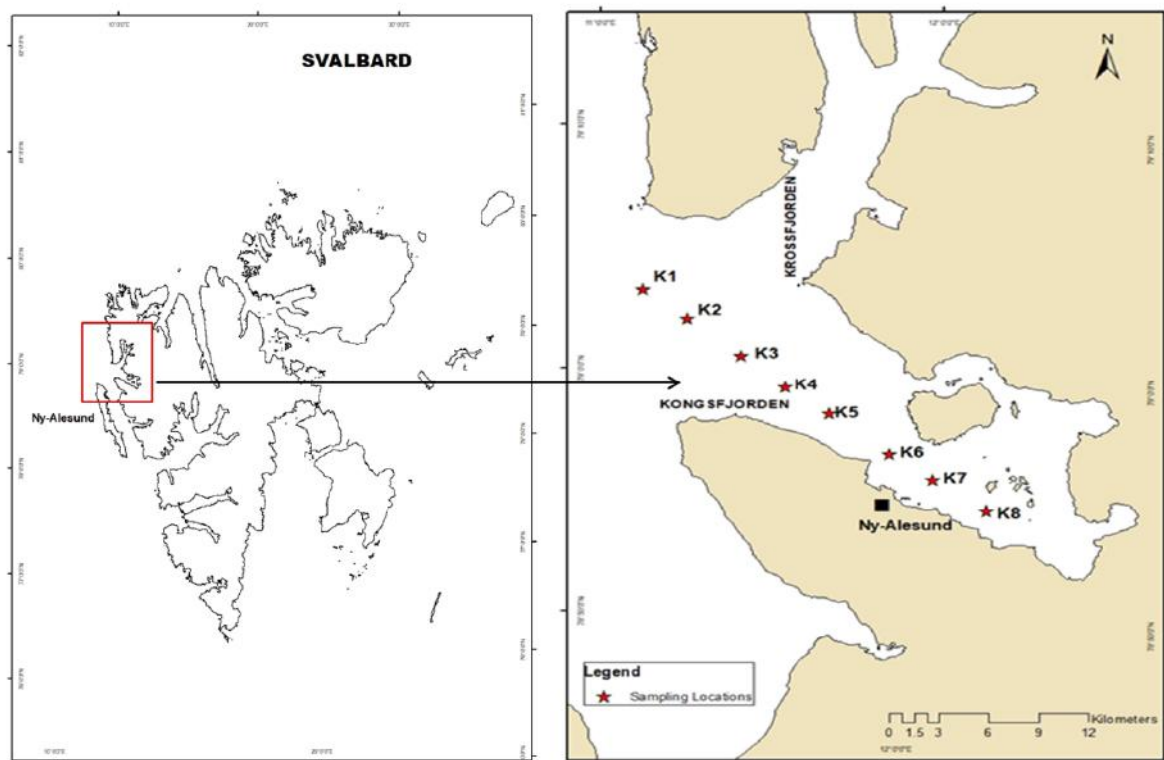


Figure 11 Study area showing sampling site, Kongsfjorden, Svalbard

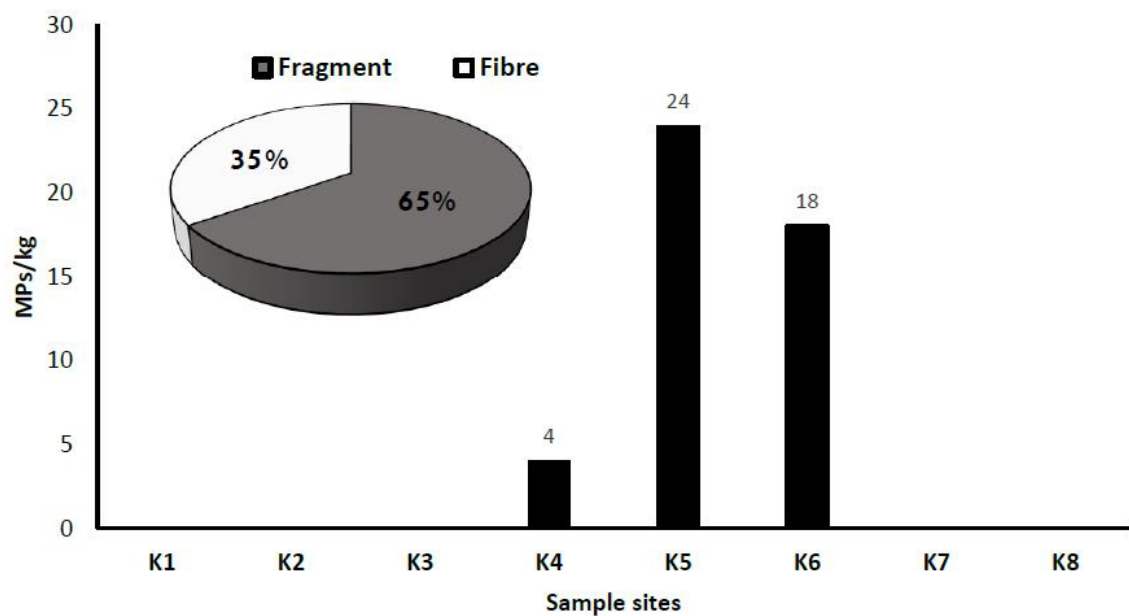


Figure 12 Abundance of microplastics in Kongsfjorden sediments

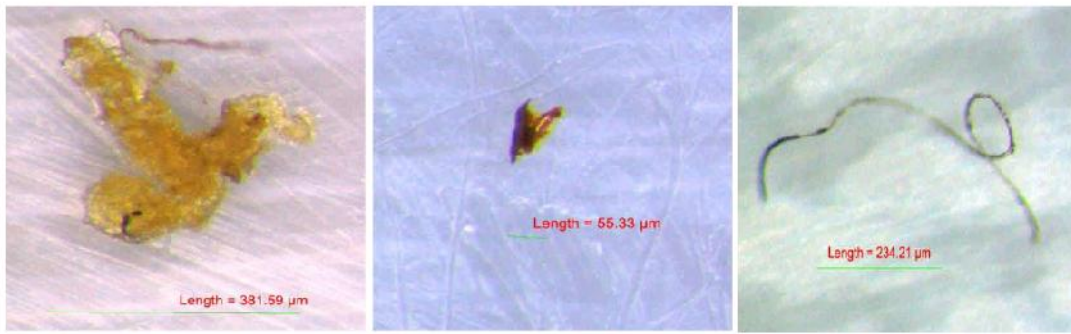


Figure 13 Microplastics representing fragment and fiber shapes extracted from sediment samples of Kongsfjorden

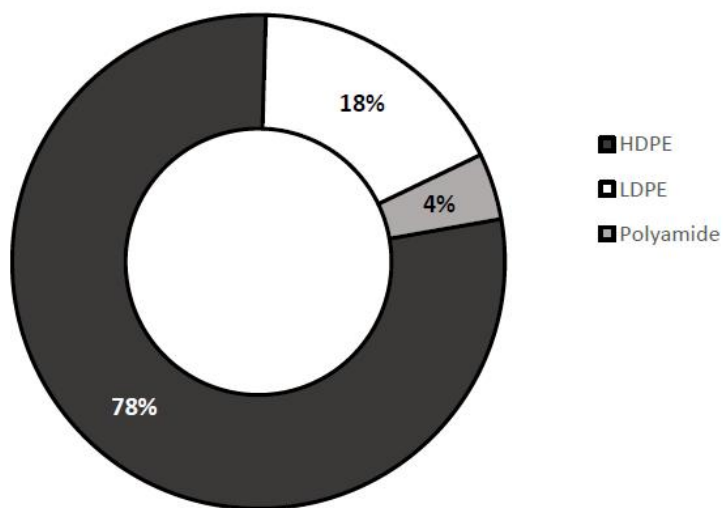


Figure 14 Proportion of High Density Poly Ethylene (HDPE), Low-density polyethylene (LDPE), and Polyamide (PA) polymers in sediment samples

Microplastic results of Arctic water and sediment samples collected during 2019

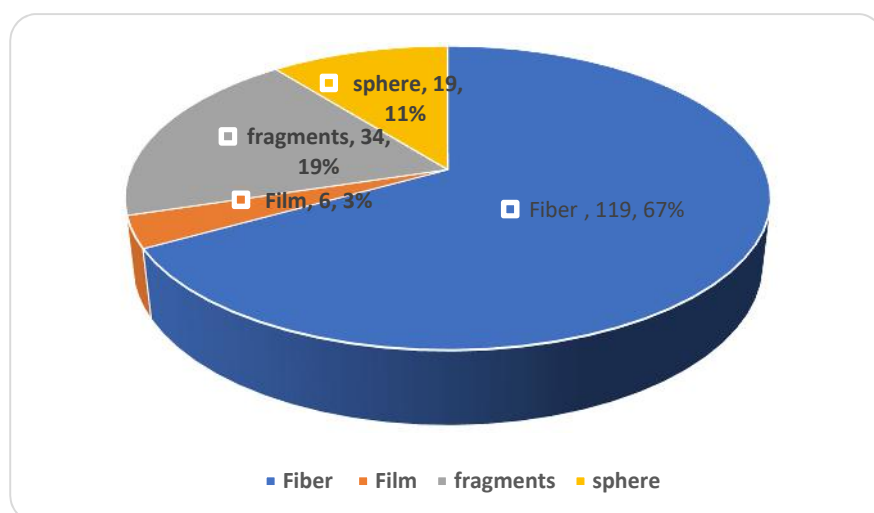
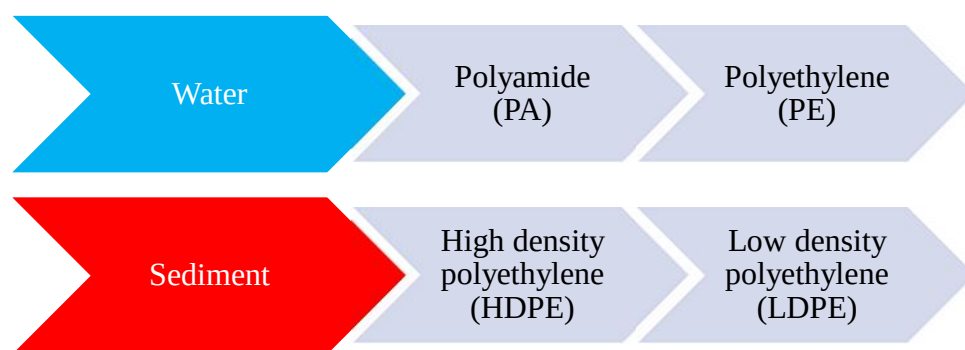


Figure 15 Morphological distribution on microplastic particles in water samples of Kongsfjord, Ny-Ålesund, Svalbard.



Organochlorine pesticides

The presence of the following organochlorine pesticides (**ng/g**) is observed from the Kongsfjorden sediment samples. More specific studies are required to study the fate and transport of organochlorine pesticides in the Arctic.

Table 7 Organochlorine pesticides in the sediment samples of Kongsfjorden

	KN02	KN05	KN06	KN07	KN08
Endosulfan-1	BDL	BDL	BDL	BDL	BDL
Endosulfan sulfate	2.93	1.1		1.9	0.75

DDT	BDL	BDL	BDL	BDL	BDL
DDE	BDL	BDL	BDL	BDL	BDL
DDD	BDL	BDL	BDL	BDL	BDL
Methoxychlor	BDL	BDL	2.44	5.3	1.18
Heptachlor	0.91	BDL	BDL	BDL	BDL
Alpha HCH	BDL	BDL	0.8	BDL	BDL
Beta HCH	BDL	4.5	3.65	4.68	3.6
Lindane	8.6	0.01	3.04	0.01	1.63
Delta HCH	BDL	BDL	BDL	BDL	BDL
Endrin	6.67	BDL	BDL	BDL	BDL
Endrin aldehyde	BDL	BDL	BDL	BDL	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL

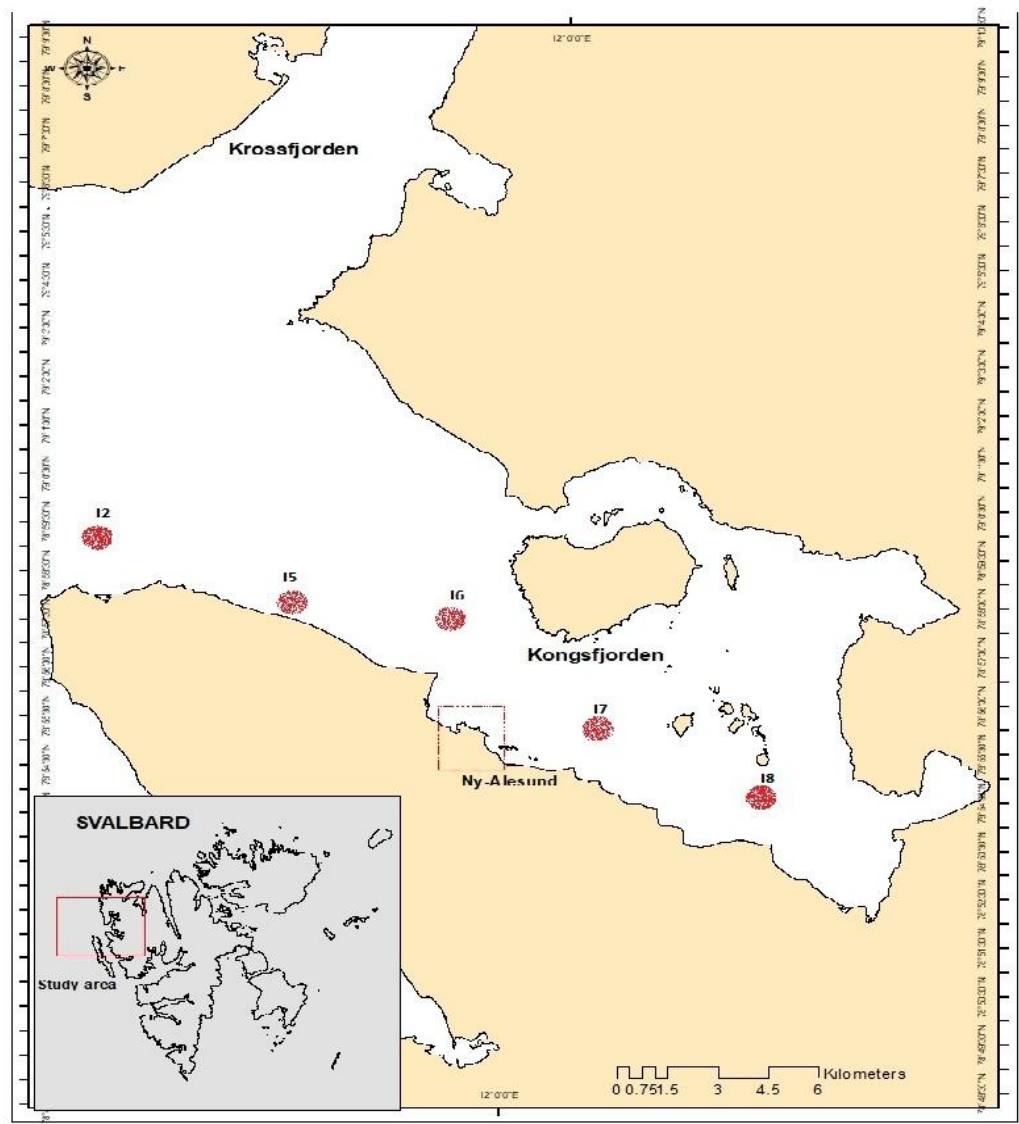
BDL : below detectable limit

Table 8 Comparison with other high Arctic Lakes and Fjords

Reference	Site	HCH (ng/g)	DDT (ng/g)	Endosulfan(ng/g)
Muir et al,1995	Canadian Lake sediment	1.11-3.08		
Macdonald et al,2000	Canadian Lake sediment	0.3-3.1	0.4-1.7	
Savinos et al, 2003	Barent Sea	0.2-1		
Jiao et al,2009	Svalbard Lake sediment	2.9-6.5	2.7-5.4	



Present study	Kongsfjord	4.5-8.6	-	0.75-3.1



Study area 16

Toxic Metals in the Sediments of High Arctic Fjords

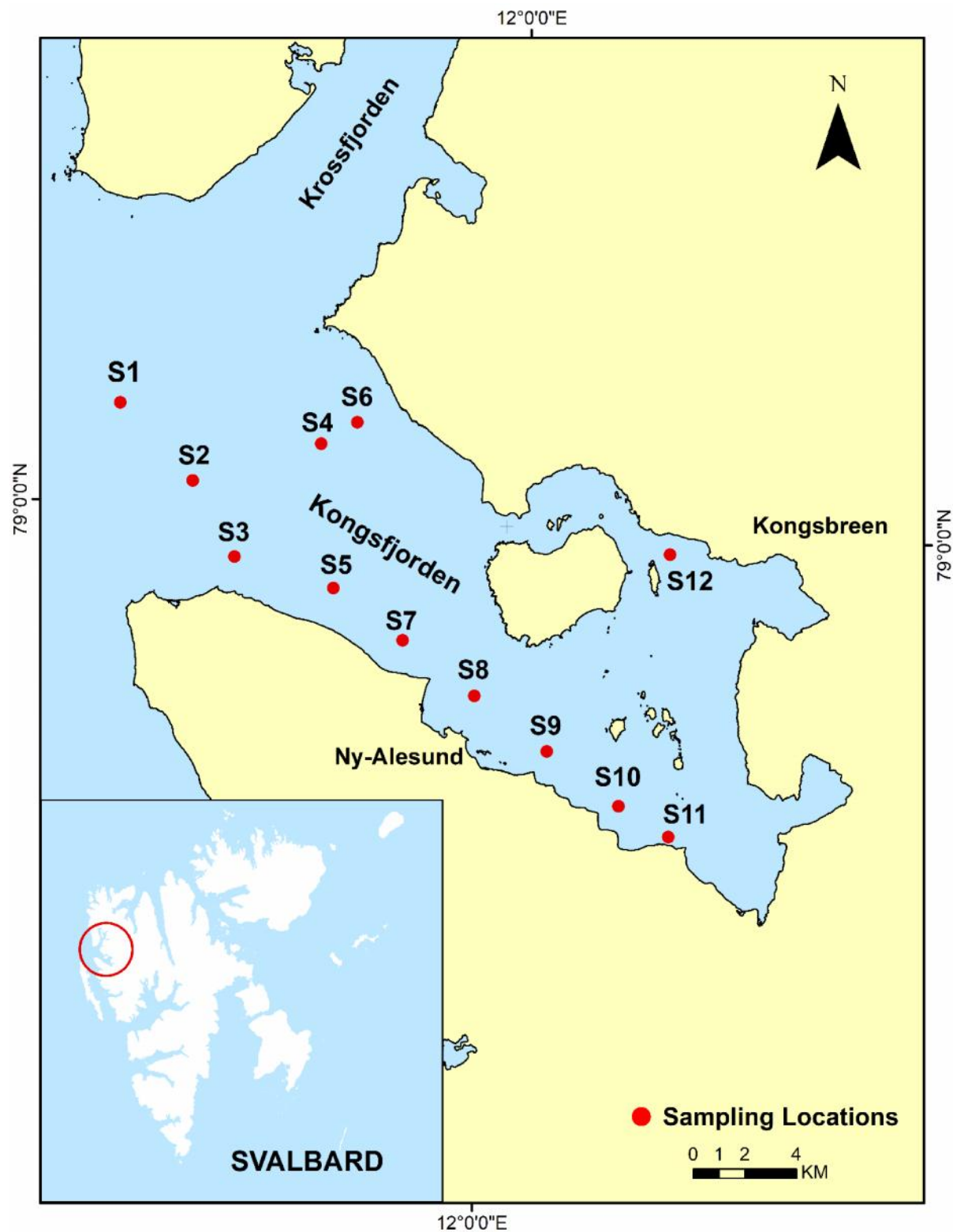


Figure 17 Study area showing sampling locations

Table 9 : Average concentration of metals (mg kg⁻¹) in the inner and outer part of Kongsfjorden

	Cr	Co	Ni	Cu	Zn	Sr	Cd	Pb	Al	Fe	Mn
Outer zone average	43.25	13.12	38.69	195.10	145.18	81.82	0.243	44.18	19750.98	14007.52	478.07
Inner zone average	28.96	12.88	26.96	40.43	43.11	71.13	0.205	15.89	17523.89	12325.81	508.43
Total Mean	36.1	13	32.83	117.76	94.14	76.47	0.22	30.04	18637.43	13166.66	493.25

Table 10: Geochemistry of Kongsfjorden surface sediments

Sl. No	Sample	Organic Carbon (OC) (%)	Inorganic Carbon (CaCO ₃) (%)	Total Nitrogen (TN) (%)	Total Phosphorus (TP) (%)	Sand (%)	Silt (%)	Clay (%)	Mud (%)
1	S1	2.17	4.5	0.38	0.11	32.02	27.96	40.00	67.97
2	S2	1.86	5.5	0.23	0.10	34.76	27.33	37.44	64.78
3	S3	1.64	7.5	0.22	0.11	39.37	24.2	37.15	61.36
4	S4	1.26	8	0.21	0.08	40.6	31.63	27.76	59.39
5	S5	1.41	7.5	0.21	0.10	36.59	34.29	29.92	64.22
6	S6	1.66	9.5	0.16	0.08	36.74	31.02	32.22	63.25
7	S7	1.84	11	0.18	0.06	36.61	34.34	29.04	63.38
8	S8	1.1	10	0.15	0.07	65.35	12.85	21.78	34.64
9	S9	0.94	12	0.14	0.07	57.52	21.07	21.39	42.47
10	S10	0.78	14	0.133	0.07	59.47	18.27	22.25	40.52
11	S11	0.26	16	0.14	0.06	65.81	14.56	19.62	34.18
12	S12	0.63	16.5	0.11	0.08	52.71	31.48	15.79	47.28
	Mean	1.30	10.17	0.19	0.08	46.46	25.75	27.86	53.62
	SD	0.57	3.89	0.07	0.02	12.72	7.51	7.83	12.79

Table 11 Geoaccumulation index (*I_{geo}*) for surface sediments

Sl.No	Sample ID	Cr	Co	Cu	Zn	Cd	Pb
1	S1	-1.44	-1.10	-0.67	-0.17	-1.12	0.70
2	S2	-1.52	-1.25	1.91	0.83	-0.63	0.80
3	S3	-1.58	-1.23	3.35	0.82	-2.68	1.40
4	S4	-1.93	-1.02	-0.60	-1.61	-1.79	-0.32

5	S5	-1.65	-1.25	0.45	-0.38	-2.49	0.24
6	S6	-1.80	-0.91	-0.46	-0.79	0.60	-0.22
7	S7	-2.98	-1.56	0.71	-1.84	-1.17	-0.90
8	S8	-3.23	-1.60	-2.25	-2.05	-0.85	-1.38
9	S9	-2.61	-1.19	-1.52	-1.54	-2.17	-0.56
10	S10	-1.75	-0.95	-1.18	-1.86	-2.49	-0.86
11	S11	-2.11	-1.18	-1.87	-1.90	-2.91	-1.29
12	S12	-1.46	-0.64	-0.55	-1.30	0.26	-0.68

Table 12 Potential risk of the individual elements (E_r^i) of surface sediments

Sl.No	Sample ID	Potential risk of the individual elements (E_r^i)					
		Cr	Cu	Zn	Cd	Pb	Ni
1	S1	1.72	8.42	1.80	44.36	13.91	7.60
2	S2	1.63	50.40	3.59	62.14	14.93	7.70
3	S3	1.56	137.10	3.58	15.00	22.63	7.81
4	S4	1.23	8.86	0.66	27.86	6.89	6.37
5	S5	1.49	18.30	1.56	17.14	10.17	7.35
6	S6	1.34	9.75	1.17	145.71	7.38	7.44
7	S7	0.59	21.93	0.56	42.86	4.59	4.22
8	S8	0.50	2.83	0.49	53.57	3.29	3.60
9	S9	0.76	4.69	0.70	21.43	5.81	4.75
10	S10	1.39	5.91	0.56	17.14	4.73	6.17
11	S11	1.08	3.69	0.54	12.86	3.53	4.79
12	S12	1.69	9.19	0.82	115.71	5.37	7.32

Table 13 Average concentration of heavy metals (mg kg^{-1}) in the surface sediments of Kongsfjorden and different Arctic systems.

Sl. No	Location	Year of study	Cr	Co	Ni	Cu	Zn	Cd	Pb	Mn	References
1	Kongsfjorden	2009	64.71	15.07	29.97	26.38	85.47	0.194	22.6	440	Lu et al, 2013
2	Kongsfjorden	2012	92.67	12.02	41.02	19.9	75.15	0.315	17.67	446	Grotti et al, 2013
3	Kongsfjorden	2011-13	58.21	12.41	-	14.92	46.8	-	23.99	-	Singh et al., 2018

4	Kongsfjorden	2014	94.5	13.3	48.9	69.9	92.5	3.08	14.8	532	Ardini et al, 2016
5	Kongsfjorden	2014	69.55	10.91	31.4	18.3	75.2	0.301	13.58	485.42	Grotti et al, 2017
6	Kongsfjorden	2016	17.6	16.9	26.32	22.9	72.77	0.2	13.4	-	Choudhary et al, 2020
7	Beaufort Sea	2008	20.67	-	-	8.38	49.92	0.21	2.25	-	Cai et al.,2011
8	White Sea	2001-03	123.00	19.6	59.4	29.3	-	0.11	13.6	-	Liudmila et al.,2018
9	Kara Sea	2015	-	20.00	44.00	10.00	62.00	0.10	14.00	-	Rusakov et al.,2017
10	Kongsfjorden	2018	36.10	13	32.83	117.76	94.14	0.22	30.04	493.25	Present study

Table 14 Correlation between geochemical parameters and heavy metals in surface sediments

	OC	IC	TN	TP	Sand	Silt	Clay	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn
OC	1														
IC	-.875**	1													
TN	.759**	-.829**	1												
TP	.581*	-.690*	.687*	1											
Sand	-.873**	.758**	-.692*	-.709**	1										
Silt	.536	-.348	.317	.503	-.825**	1									
Clay	.906**	-.903**	.823**	.689*	-.841**	.389	1								
Al	-.084	.096	.065	.507	-.261	.455	-.011	1							
Cr	.210	-.270	.434	.779**	-.476	.376	.420	.836**	1						
Mn	.108	-.120	.292	.687*	-.393	.489	.176	.941**	.873**	1					
Fe	-.455	.539	-.318	.060	.165	.184	-.447	.852**	.500	.741**	1				
Co	-.325	.376	-.173	.170	.012	.256	-.270	.920**	.634*	.814**	.965**	1			
Ni	.401	-.439	.464	.843**	-.655*	.523	.573	.779**	.949**	.837**	.387	.549	1		
Cu	.354	-.365	.214	.519	-.359	.077	.531	.004	.318	.140	-.217	-.178	.426	1	
Zn	.558	-.635*	.503	.722**	-.567	.184	.753**	.176	.580*	.288	-.258	-.107	.673*	.816**	1
Cd	.142	.090	-.167	-.044	-.196	.346	-.029	.404	.188	.362	.423	.499	.278	-.207	-.04
Pb	.600*	-.677*	.619*	.813**	-.617*	.231	.799**	.202	.601*	.378	-.200	-.070	.703*	.858**	.935

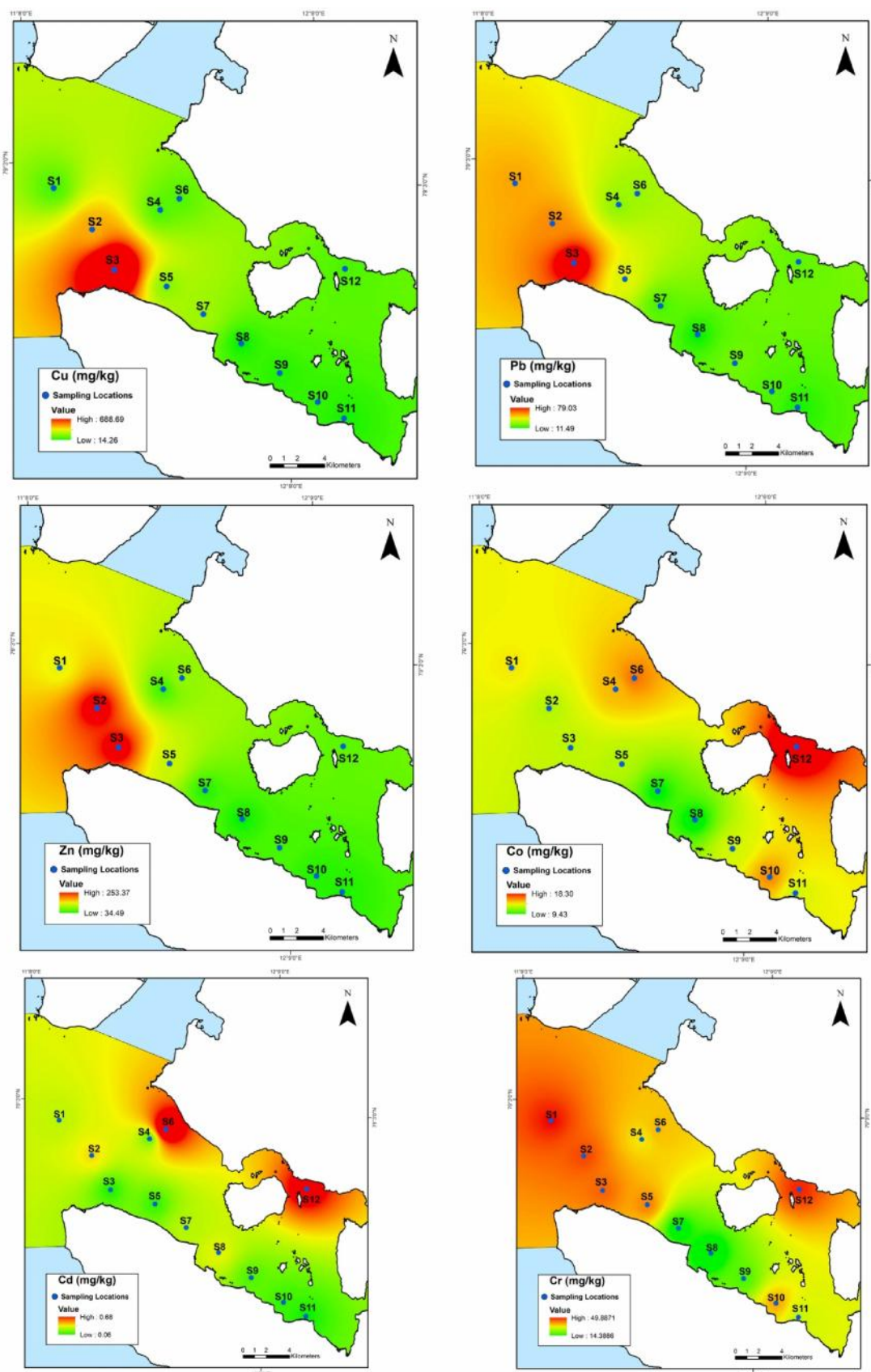


Figure 18 Dispersion of metals (Cu, Pb, Zn, Co, Cd and Cr) in the sediments of Kongsfjorden

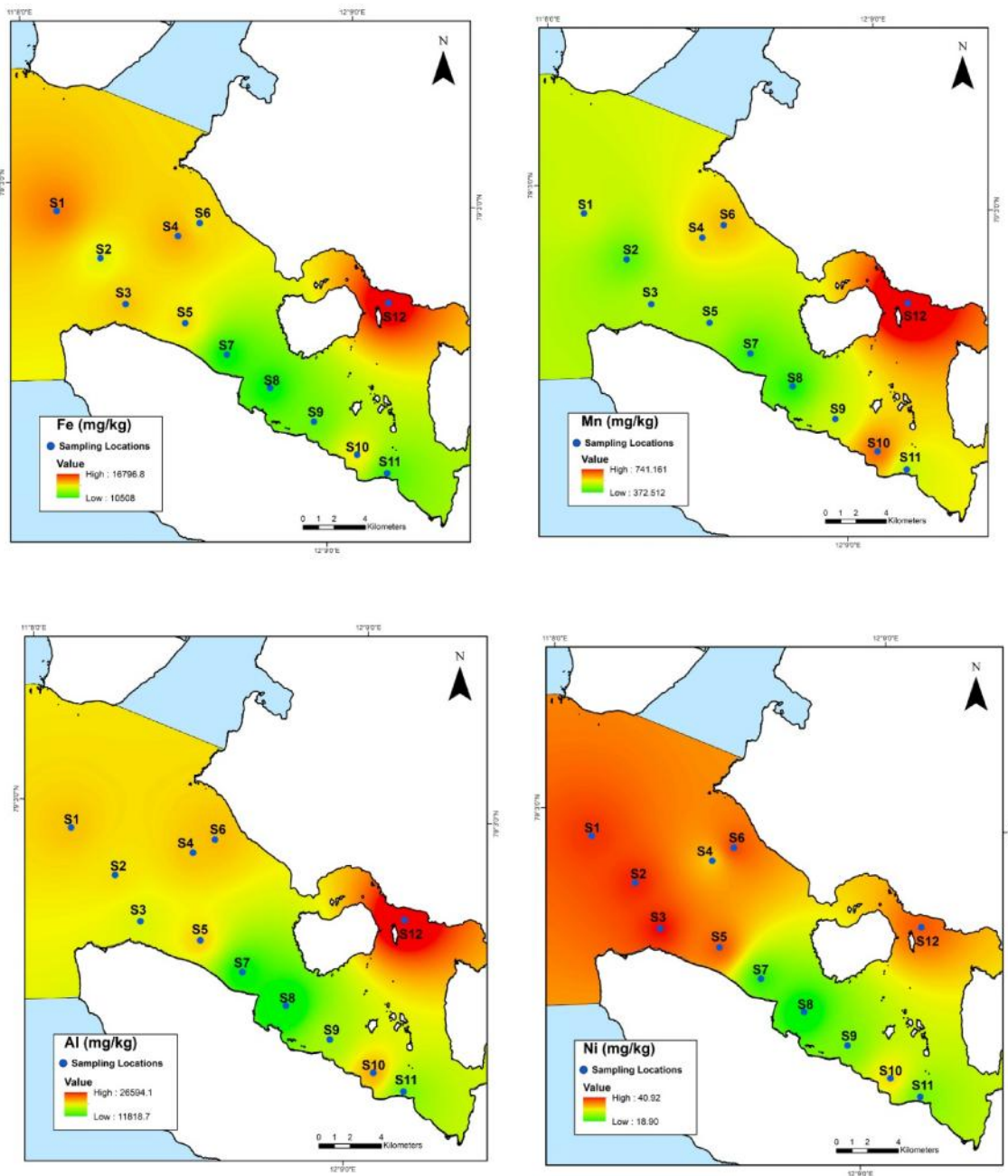


Figure 19 Dispersion of metals (Fe, Mn, Al & Ni) in the sediments of Kongsfjorden

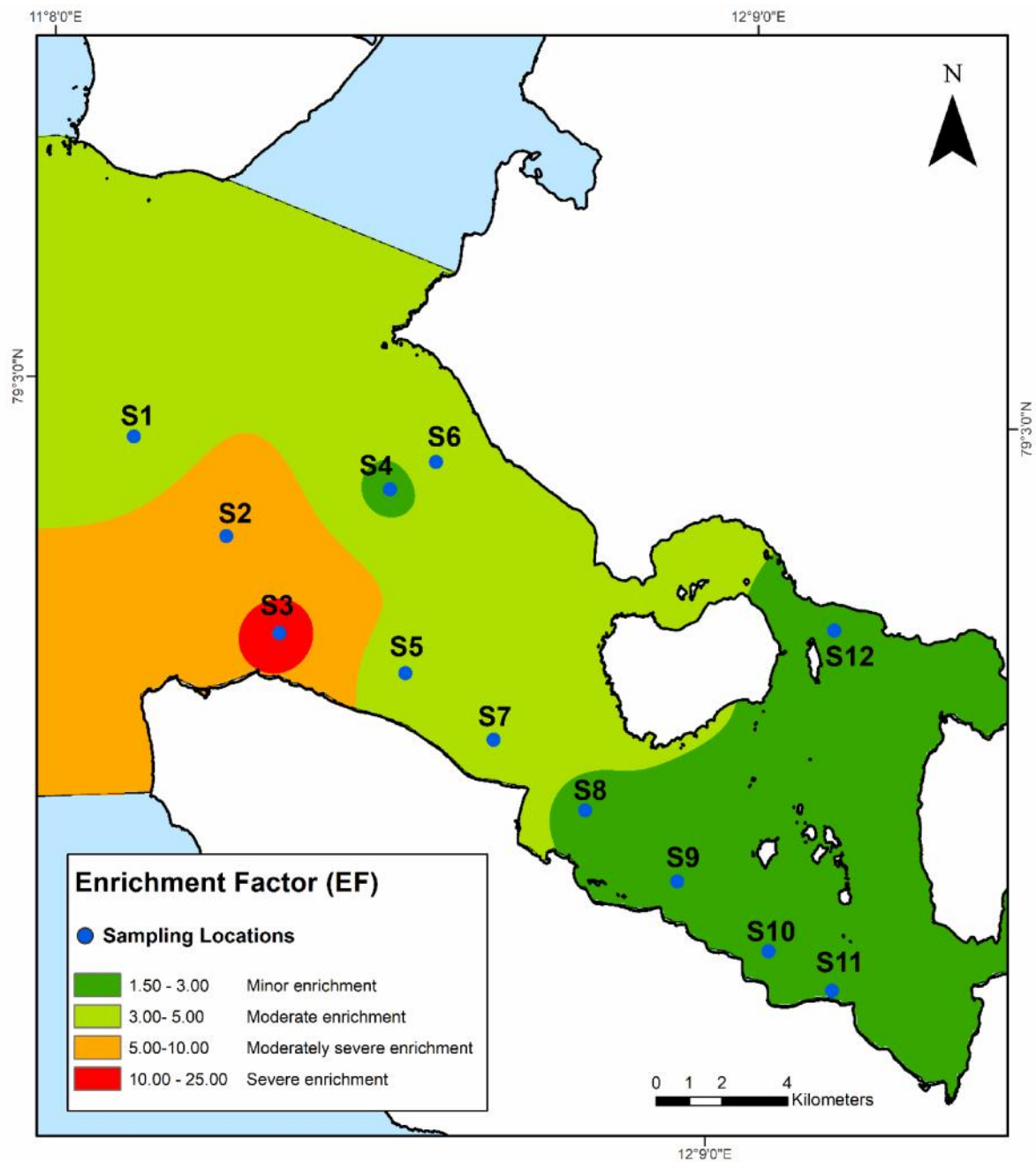


Figure 20 Enrichment factor of metals in the sediments of Kongsfjorden

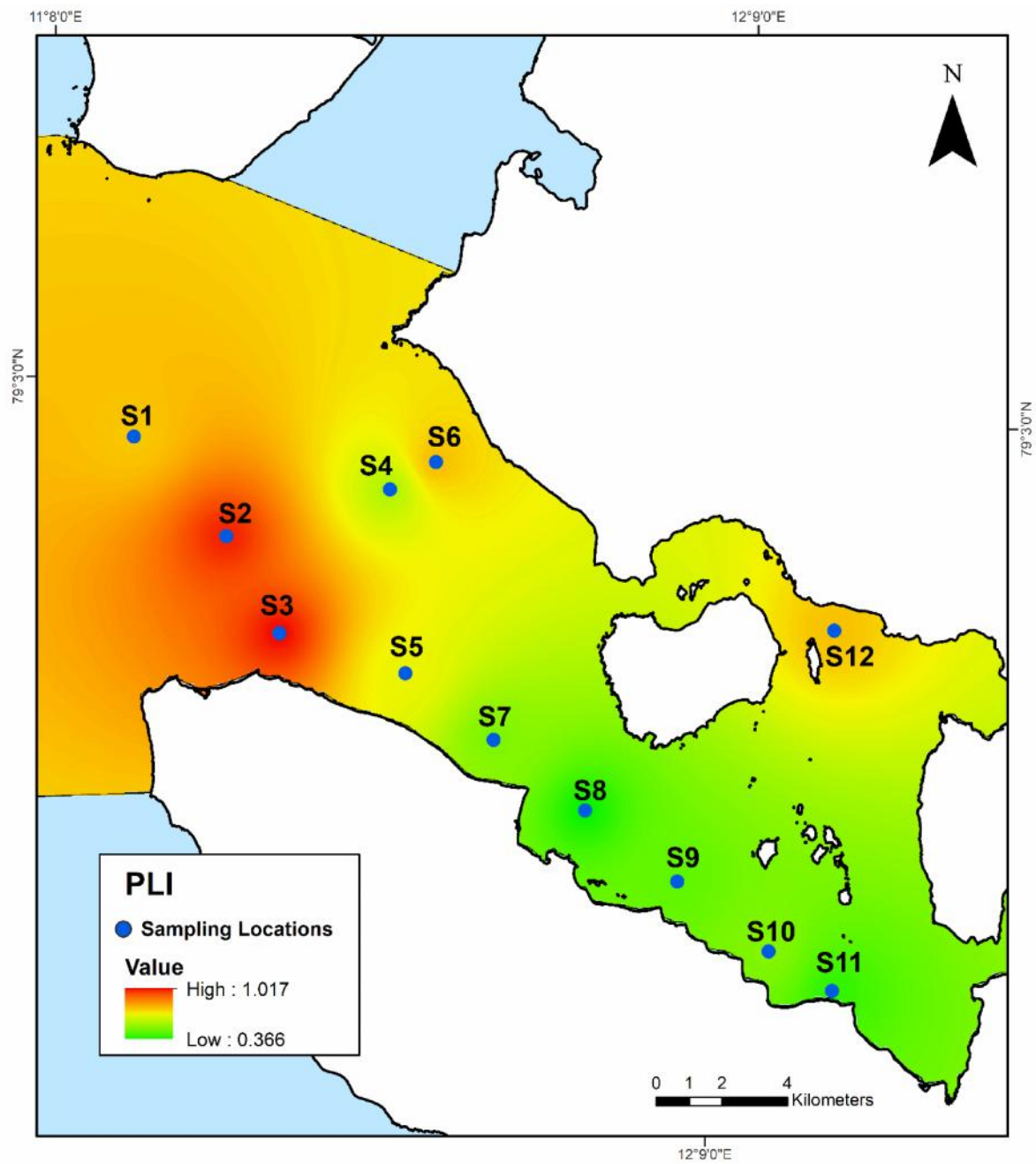


Figure 21 PLI of metals in the sediments of Kongsfjorden

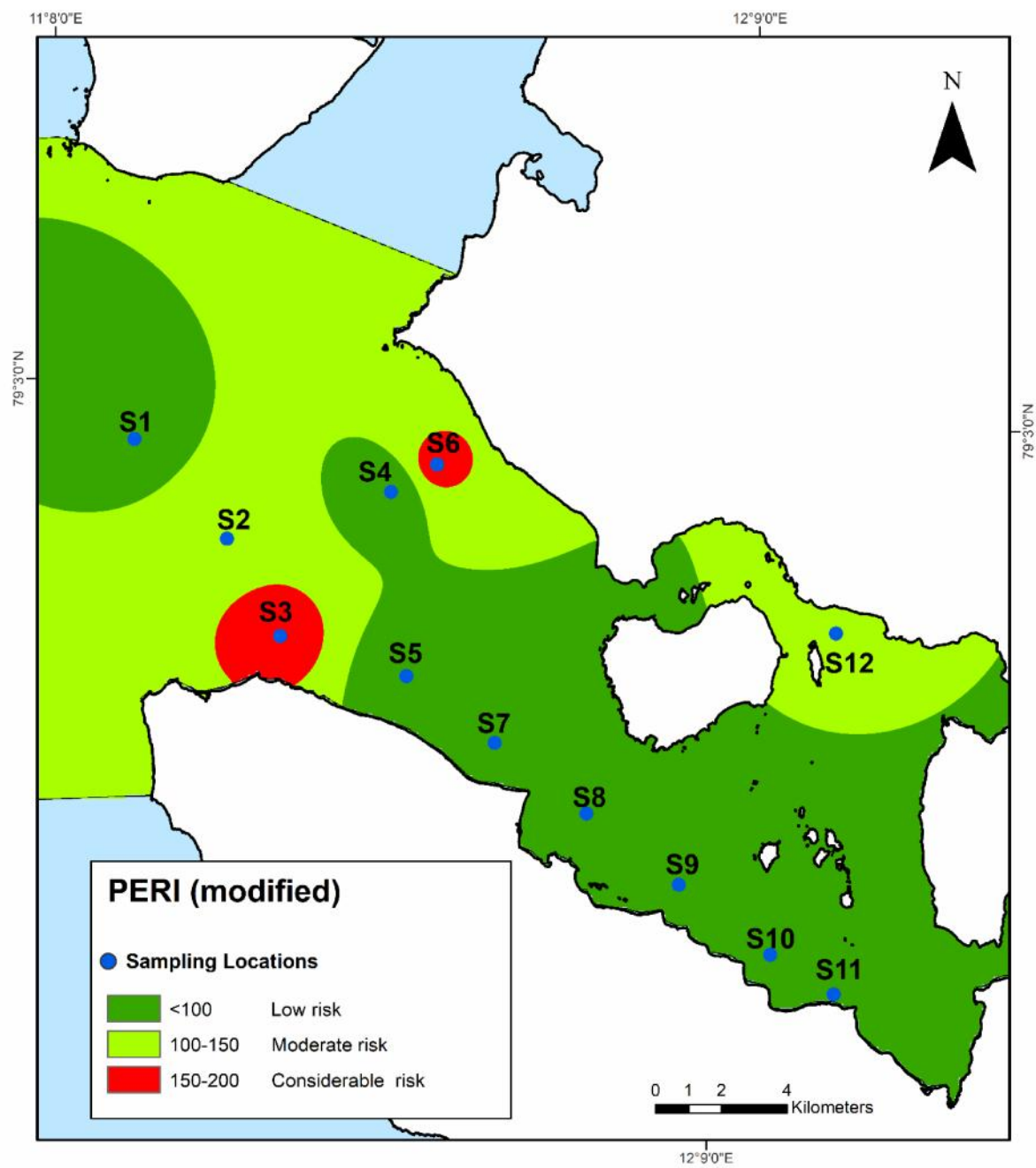


Figure 22 PERI of metals in the sediments of Kongsfjorden

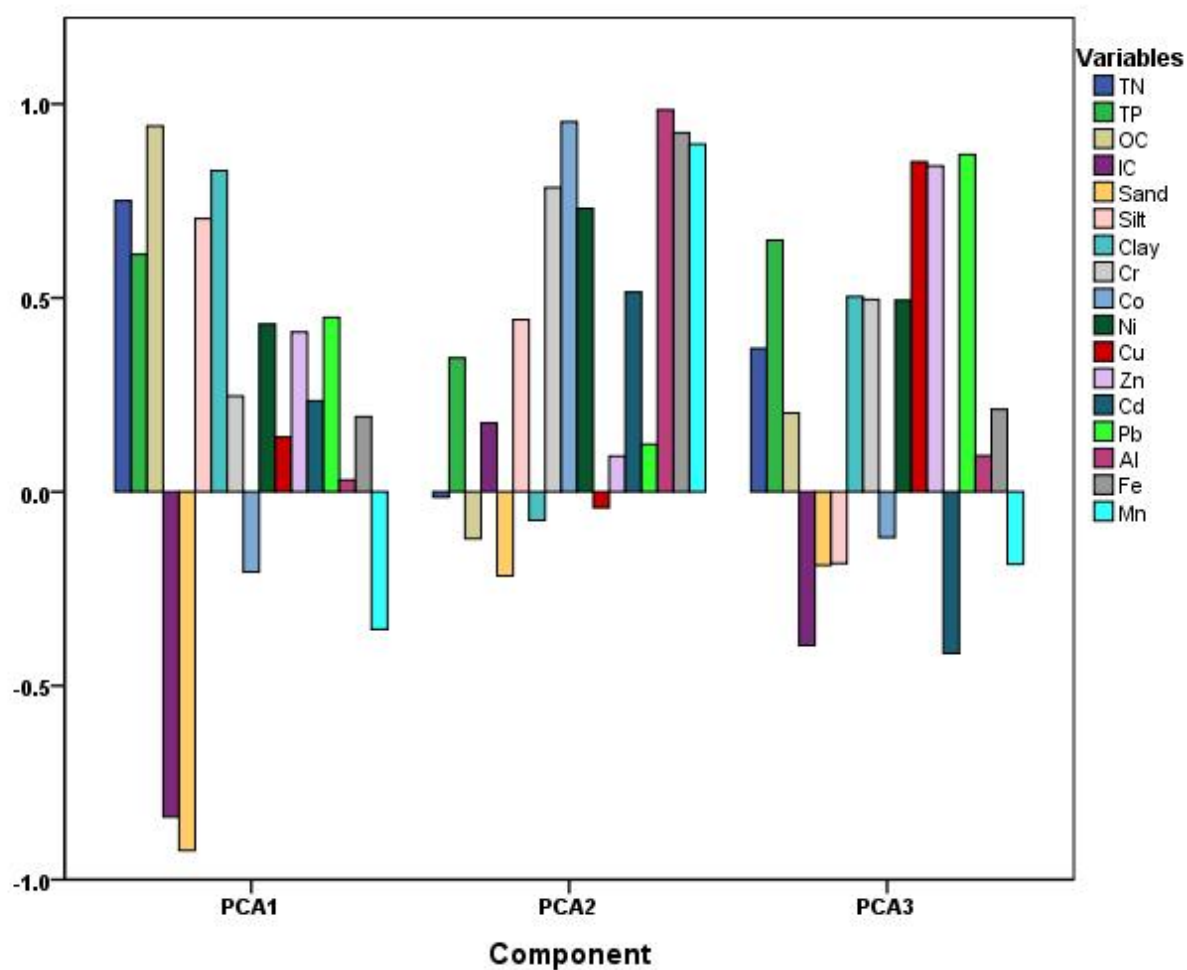


Figure 23 PCA loading plots of Geochemical parameters and heavy metals in Kongsfjorden.

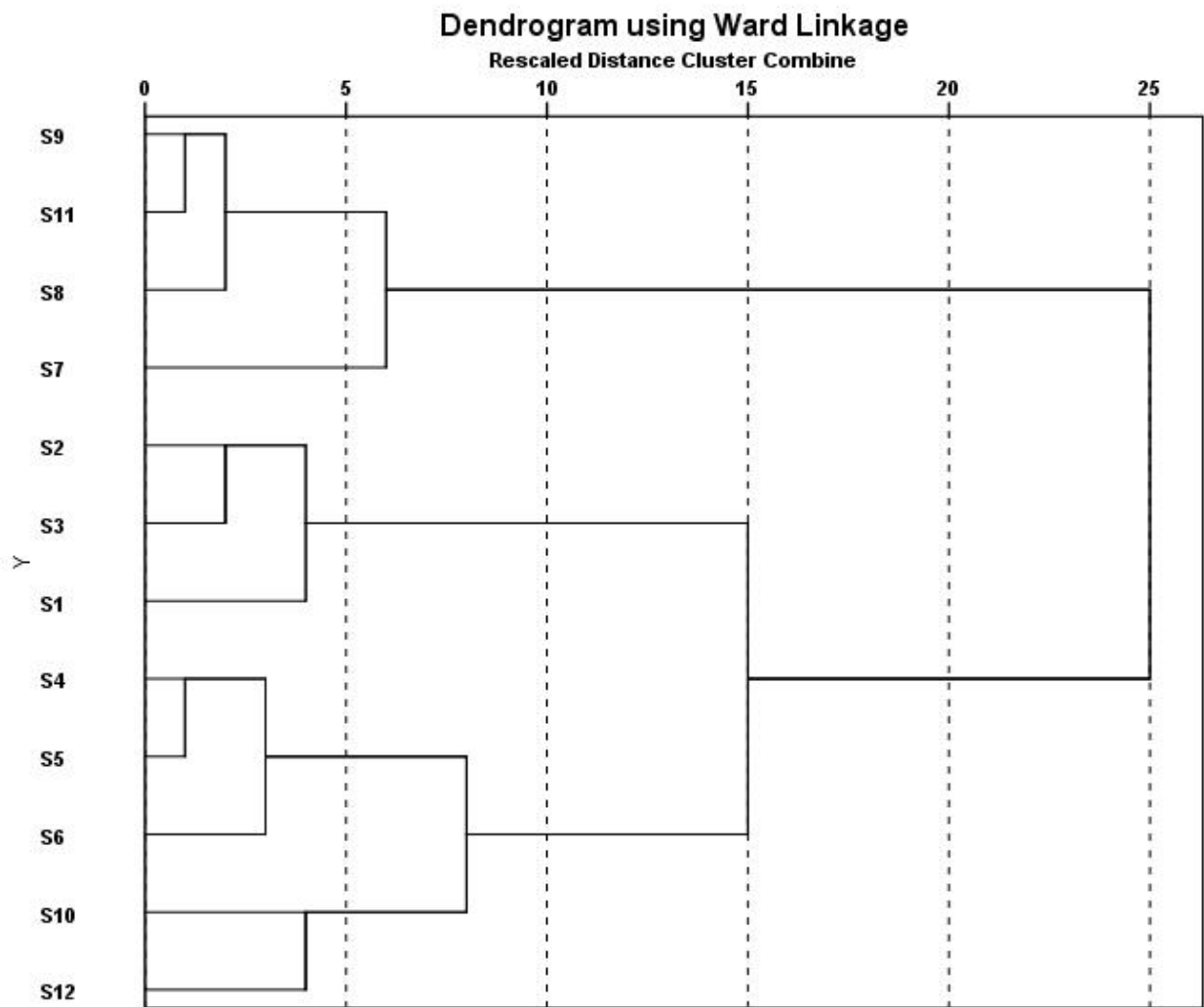
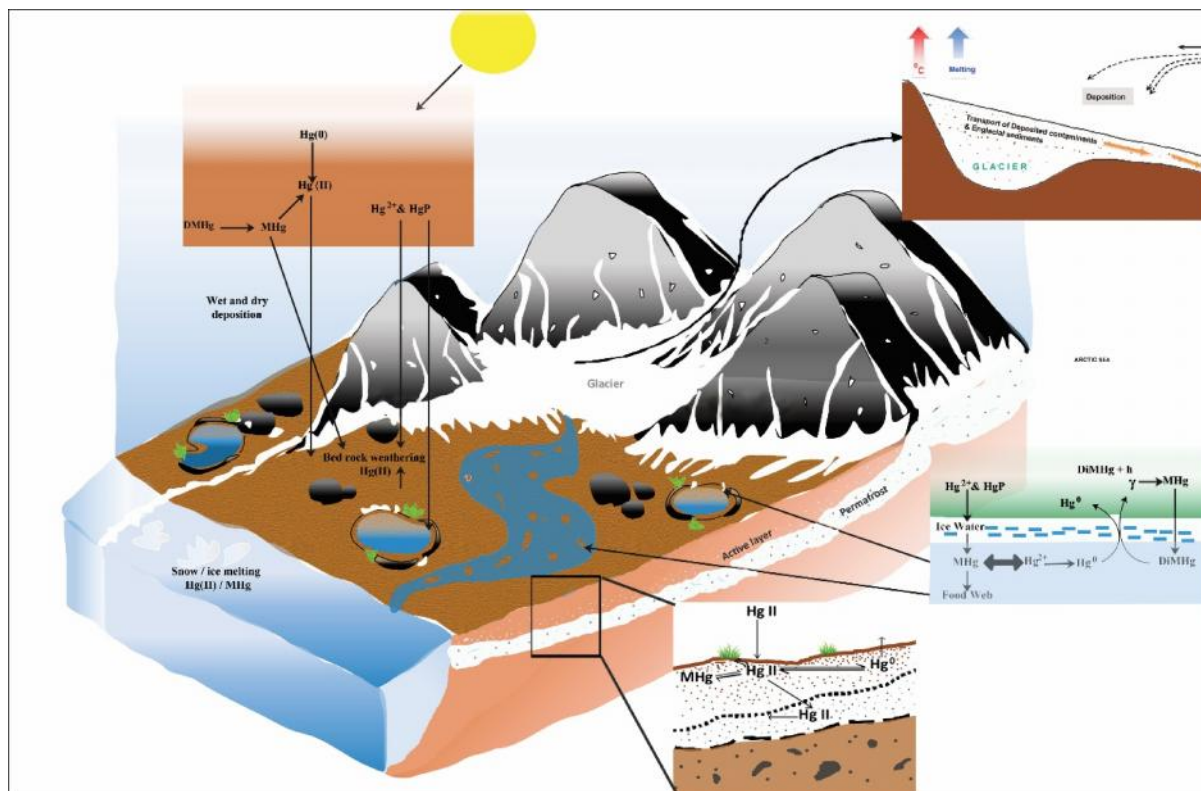


Figure 24 cluster diagram for the linkage between the different sampling locations

Mercury in the environmental matrices of Arctic



Gopikrishna et al.,2022

Mercury content in the sediments of High Arctic fjords (CLIONE Expedition)

Table 15 Mercury in the sediments of high Arctic fjords

Sl.No.	Stations	Fjord	THg (ng/g)
1	3	Holmiabuktafjord	55.3
2	5	Open sea	62.2
3	7		69.3
4	12		48.1
5	8	Raudfjorden	38.1
6	9		90.7
7	10		25.6
8	11		200



9	13	Smeerenburgfjorden	85.3
10	14	Magdalenefjorden	16
11	15		43
12	16		33.2

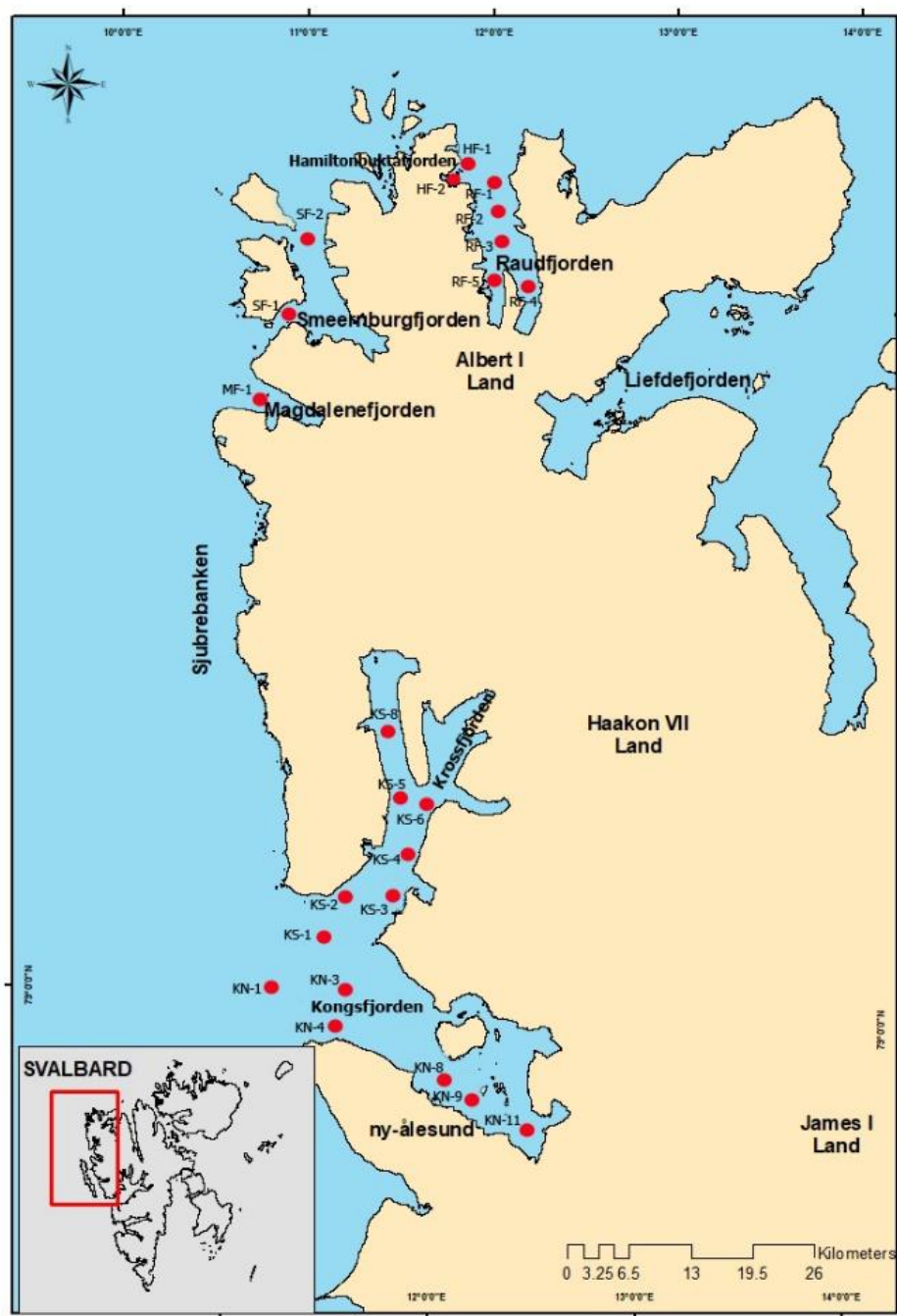


Figure 25 Study area showing sampling

