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[Subtitle]

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Title
Cyclic volatile methyl siloxanes in the terrestrial and aquatic environment at remote Arctic sites

Norwegian title
Sykliske siloksaner i terrestrisk og akvatisk miljø i Arktis

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Short summary (English)
Cyclic volatile methyl siloxanes (cVMS) are widely used chemicals with high emissions to the atmosphere due to their volatility. They are found in the Arctic atmosphere, indicating potential for long-range transport. This study examined the potential for deposition of cVMS (D4, D5, D6) to surface media via snow in Arctic regions. Results showed low cVMS levels in vegetation, soil, sediment, and marine biota. D4 was detected above detection limits but generally below quantification limits, while D5 and D6 were generally not detected. This aligns with current research, suggesting negligible cVMS input from atmospheric deposition via snow and snow melt.

Short summary (Norwegian)
Sykliske metylsiloksaner (cVMS) er mye brukte kjemikalier med høye utslipp til atmosfæren på grunn av deres flyktighet. De finnes i den arktiske atmosfæren, noe som indikerer potensial for langtransport. Denne studien undersøkte potensialet for avsetning av cVMS (D4, D5, D6) til overflatemedia via snø i arktiske områder. Resultatene viste lave cVMS-nivåer i vegetasjon, jord, sediment og marine organismer. D4 ble påvist over deteksjonsgrensene, men generelt under kvantifiseringsgrensene, mens D5 og D6 generelt ikke ble påvist. Dette stemmer overens med nåværende forskning, som antyder ubetydelig cVMS-tilførsel fra atmosfærisk avsetning via snø og snøsmelting.

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Contents

Cyclic volatile methyl siloxanes in the terrestrial and aquatic environment at remote Arctic sites

1 Background

Cyclic volatile methyl siloxanes (cVMS) are high-production-volume chemicals used in a wide range of applications, including personal care products, consumer goods, construction, and industrial processes (Horii & Kannan, 2020; Wang et al., 2013).

Due to their high volatility, emissions of cVMS primarily occur to the atmosphere, where the main removal process is considered to be degradation by OH radicals into silanols (Brooke et al., 2009a, 2009b, 2009c; McLachlan, 2020). The potential for long-range atmospheric transport of cVMS is well documented, as evidenced by data from atmospheric pollutant monitoring at the Zeppelin Observatory in Svalbard, which has recorded notable concentrations of cVMS in the air (Halvorsen et al., 2023; Halvorsen, 2024; Krogseth et al., 2013). However, for cVMS to pose a risk to remote ecosystems, deposition onto surface media must occur. Most empirical studies from Arctic and Antarctic regions have shown low levels of cVMS in terrestrial or marine environments where there is no direct impact from local sources (Krogseth & Warner, 2020). Additionally, various modelling results indicate that cVMS have limited potential for deposition due to their high volatility (Breivik et al., 2022; McLachlan, 2020).

Contrarily, a study by Sanchís et al. (2015b) reported high levels of cVMS in the aquatic and terrestrial environments of Antarctic areas presumed to be unaffected by local sources. The study suggested that deposition of atmospheric cVMS via snow could explain these findings, leading to the snow scavenging and deposition hypothesis. However, no snow or air samples were analysed to support this hypothesis. It is important to note that the study's quality has been questioned, particularly regarding long-term sample storage and the lack of measures to control for sample contamination (Mackay et al., 2015; Warner et al., 2015). The authors addressed these concerns in their response (Sanchís et al., 2015a).

The objective of our study was to further investigate whether cVMS have the potential to undergo atmospheric deposition to surfaces, and thereby represent a potential risk to the terrestrial or marine environment in Arctic regions. The study is an expansion of a study centred around the Zeppelin Observatory where samples from potential recipient compartments of cVMS from snowmelt were collected and analysed (Nipen, 2024). This expanded study includes more samples from the region, including the Ny-Ålesund settlement, and a more remote location (Diesetvatna).

2 Methods

2.1 The study region

This study has been carried out in the region surrounding the atmospheric Observatory on the Zeppelin Mountain near Ny-Ålesund, Svalbard (Figure 1, Figure 2). Given the close proximity between the Zeppelin Observatory and the Ny-Ålesund settlement, we wanted to gain a better understanding of the potential for the settlement to act as a local source for cVMS at the Zeppelin Observatory. We therefore included the

Ny-Ålesund settlement itself as a study location. In addition, to shed further light on the representativeness of the Zeppelin Observatory as a remote location, we included the Diesetvatna lakes and surrounding areas as a study location. Diesetvatna are located on an uninhabited peninsula approximately 35 km from Ny-Ålesund and is assumed to have no influence from local sources of cVMS.

Environmental samples were collected from terrestrial media (soil, vegetation), air (passive sampling), and aquatic media (sediment and biota). Sample collection for terrestrial samples and air were centered around the Ny-Ålesund settlement, the Zeppelin Observatory, and a remote area near Diesetvatna. The aquatic samples were collected near the Ny-Ålesund settlement, in Kongsfjorden some distance away from Ny-Ålesund, and from Diesetvatna. Sample collection locations are shown in Figure 2.

Figure 1: NILUs atmospheric Observatory at Zeppelin. The Ny-Ålesund settlement can be seen in the background (photo NILU).

Figure 2: Left: Svalbard with study region marked with blue square. Right: Study region with sampling locations for terrestrial samples and air marked by red points, and sampling locations for aquatic samples marked by blue points. Maps from Topo Svalbard.

2.1.1 Zeppelin atmospheric Observatory and Kongsfjorden

NILU has carried out air monitoring for cVMS at the Zeppelin Observatory since 2013. From 2017 onwards, samples have been collected on a weekly basis, providing a good overview of variability and seasonal trends of cVMS concentrations in air. To investigate the potential for deposition of cVMS, potential terrestrial recipient compartments for cVMS were sampled near the Zeppelin Observatory. Potential aquatic recipient samples were collected in Kongsfjorden with some distance to the Ny Ålesund settlement assumed to be unaffected by local sources, as the location is located upstream of the settlement compared to the general fjord circulation pattern (Choi et al., 2020). The sampling sites in Kongsfjorden are assumed to be recipients of water from snow melting from surrounding mountains, including the Zeppelin Mountain, and glaciers.

2.1.2 Potential source: Ny-Ålesund settlement

The Ny-Ålesund settlement is located near the Zeppelin Observatory. Although this is a small settlement (approximately 30 inhabitants in winter, 130 in summer), Ny-Ålesund may represent a potential source region for cVMS through the inhabitant's use of cosmetics and other silicone or siloxane containing consumer products. Ny-Ålesund also have a small number of tourists visiting during the summer season via cruise ships. Samples were therefore collected from Ny-Ålesund to investigate the potential contributions of cVMS from Ny-Ålesund to the samples collected near Zeppelin. Terrestrial samples were collected on a transect covering the areas upwind and downwind from the Ny-Ålesund settlement, while passive air samples were collected within the settlement itself. Aquatic samples were sampled in Kongsfjorden near Ny-Ålesund, with sediment samples collected on a transect out from the release point of wastewater from Ny-Ålesund.

2.1.3 Remote area: Diesetvatna

A more remote location was included in the sampling to further assess the relevance of local sources for cVMS at the Zeppelin Observatory. There is no settlement of people on the peninsula where Diesetvatna are located, and as it is inland, there is less influence from cruise traffic or other boat activities compared to Ny-Ålesund. The Diesetvatna lakes are connected to the sea via a small stream (Figure 2), which means that there is some movement of fish between the lakes and the sea. Terrestrial samples were collected near Diesetvatna, and aquatic samples were collected in the southern Diesetvatna lake. The northern lake was originally targeted to maximize distance from the sea, however, ice formation at the time of sampling prevented access to the northern Diesetvatna lake.

2.2 Study design

Table 1 shows an overview of the sample collection. The main fieldwork was carried out in September 2023. Rationale for the selection of sampling media is provided below.

Table 1: Overview of sample collection

Location	Matrix	Number of samples
Ny-Ålesund settlement	Sediment	5
	Fish	5
	Air (passive)	2
	Vegetation	5
	Soil	5
Zeppelin (terrestrial samples and air), Kongsfjorden (aquatic samples)	Sediment	5
	Fish	5
	Air (passive)	2
	Vegetation	2*
	Soil	4*
Disetvatna and surrounding area	Sediment	5
	Fish	5
	Air (passive)	2**
	Vegetation	5
	Soil	5

*: Sufficient sample material could not be found at this location.
**: Air sampler lost during deployment

Vegetation, soil, and aquatic biota were included in the study by Sanchís et al. (2015b) from Antarctica with findings of high concentrations in these media. We included similar media in this study to enable comparison with a similar environment in the Northern Hemisphere.

Vegetation can potentially function as a passive sampler for atmospheric compounds and thereby represent a source for terrestrial biota. Vegetation could also potentially be a recipient of cVMS from deposition via snow and subsequent snowmelt. In this study we targeted moss or lichen as these types of vegetation were assumed to be present at all three locations.

Depending on organic carbon (OC) content, soil generally has high fugacity capacity for organic compounds which are comparable to cVMS, and can potentially be a recipient of cVMS via snow-deposition and snowmelt.

Aquatic biota in locations receiving snowmelt may potentially also be exposed to cVMS. High concentrations of cVMS were found in Krill from Antarctica in the study by Sanchis, but sampling of Krill was not feasible for this study. Instead, we included two types of aquatic biota, but from higher in the food chain. From Kongsfjorden, we targeted Shorthorn Sculpin (*Myoxocephalus scorpius*), which is a relatively stationary benthic species, allowing for the possibility of connecting cVMS concentrations with the sampling location. In the Diesetvatna lakes, the more remote location, Arctic Char (*Salvelinus alpinus*) was

targeted. Diesetvatna is connected to the sea, and a fraction of the Char in the lake is anadromous. We targeted stationary individuals, to better ensure any cVMS detected could be attributed to local exposure.

In addition to the environmental media investigated by Sanchís et al. (2015b), we included sediment and air in this study. cVMS are very hydrophobic and will to a large extent partition to particles and sediments in water (Panagopoulos & MacLeod, 2018). Sediments may therefore represent a sink for cVMS deposited via snow following snowmelt. Sediments were collected at two locations in Kongsfjorden, one near the Ny-Ålesund settlement, and one some distance from the settlement. Sediments were also collected from the southern Diesetvatna lake.

High air concentrations of cVMS are a prerequisite for cVMS to potentially enter ecosystems via snow deposition and subsequent snowmelt. Air concentrations of cVMS are well documented via weekly active air sampling at the Zeppelin Observatory (Halvorsen et al., 2023), but no current data exist for the Ny-Ålesund settlement and the area near Diesetvatna. Therefore, air sampling using a XAD-2 based passive sampling technique as described in Wania et al. (2023) were conducted at all three locations for terrestrial sampling. Passive air samples from the Zeppelin Observatory was included to avoid potential bias due to different sampling techniques when comparing results between the locations.

The compounds targeted are shown in Table 2. For cVMS, the list includes D4, D5, and D6. In addition, HCHs were included in this study as a benchmark compound, as this is a compound which is known to have high potential for snow scavenging and deposition, shown through modeling studies (Lei & Wania, 2004), and studies of snow from Antarctica (Kang et al., 2012).

Table 2: Target compounds

Compound	Abbreviation	Cas-no
Octamethylcyclotetrasiloxane	D4	556-67-2
Decamethylcyclopentasiloxane	D5	541-02-6
Dodecamethylcyclohexasiloxane	D6	540-97-6
α-Hexachlorocychlohexane	α-HCH	319-84-6
γ-Hexachlorocychlohexane	γ-HCH	58-89-9

2.3 Sample collection

2.3.1 Vegetation

In this study, moss or lichen was originally targeted. Near the Zeppelin Observatory however, vegetation is very sparse, and only plants of the Saxifraga family were found. Two locations with Saxifraga plants could be found (Figure 3), and enough material for two samples was collected (Location A and B from the Zeppelin Mountain, Figure 4). Leaves, stem and flowers of the plants were collected directly into a 100 mL sample jar using tweezer and scissors. Roots and soil were avoided. Saxifraga were also collected at the Ny-Ålesund sites. At the remote location, snow cover made it difficult to locate Saxifraga in sufficient amounts to sample. Instead, moss was collected at the remote location. Figure 4 shows the locations where vegetation and soil were collected.

Figure 3: Examples of Saxifraga, the vegetation sampled for the study (Photos: NILU).

2.3.2 Soil

Soil samples were collected using a stainless-steel spoon, after removal of litter layer where this was necessary. Locations are shown in Figure 4. Given its mountain top location, the soil near the Zeppelin Observatory is rocky and with little organic matter. Soil near Ny-Ålesund and Diesetvatna were more peat-like with high organic matter content. Larger rocks and fragments were avoided during sampling. Soil was collected from at least four spots within an area of approximately one square meter and placed on a piece of aluminium foil. The stainless-steel spoon was used to homogenize the collected soil on the aluminium foil, and a subsample from the collected soil was transferred into a 100 mL sample jar.

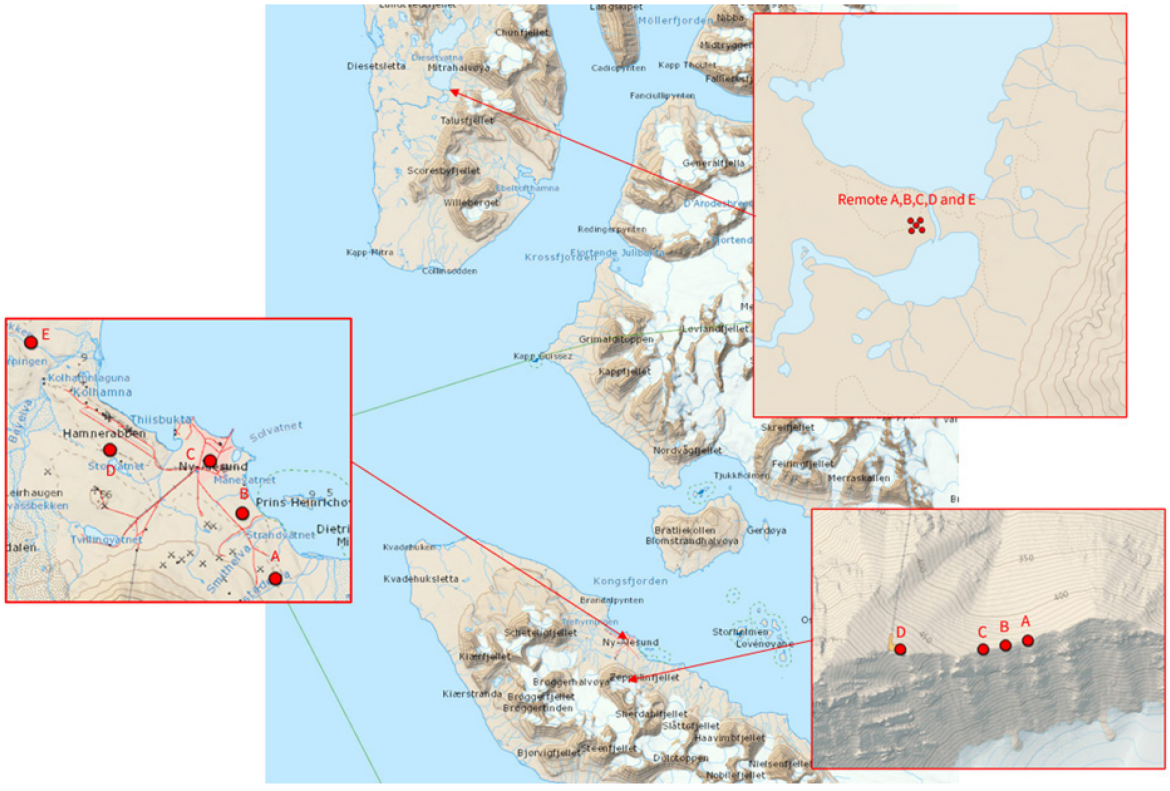

Figure 4: Map showing sampling locations for soil and vegetation. Maps from Topo Svalbard.

2.3.3 Fish

Locations for sampling of fish are shown in Figure 5. For the fish sampled in the Diesetvatna lake, the map provides a rough guide only. In this study, Shorthorn Sculpin and Arctic Char were targeted to represent aquatic biota. Fishing was done using nets, and the fish was dissected outdoors immediately after arrival back at the shore. Fish muscle was selected to ensure sufficient sample material. Muscle was placed in 100 mL sample jars.

2.3.4 Sediment

Locations for sediment sampling are shown in Figure 5. Outside the Ny-Ålesund settlement, sediment samples were collected on a transect out from the wastewater outlet. Sediments were also collected in Kongsfjorden some distance from the Ny-Ålesund settlement, and in the Diesetvatna lake. Sediments were collected using a van Veen grab. Samples were collected from the surface layer of sediment (approximately 0-3 cm) from the grab into a 100 mL sample jar using a stainless-steel spoon. Sediment which had been in direct contact with the surface of the grab was avoided.

All samples were stored frozen (approximately -20°C) until analysis. Transport from Ny-Ålesund to NILUs laboratories in Tromsø was conducted with express air freight.

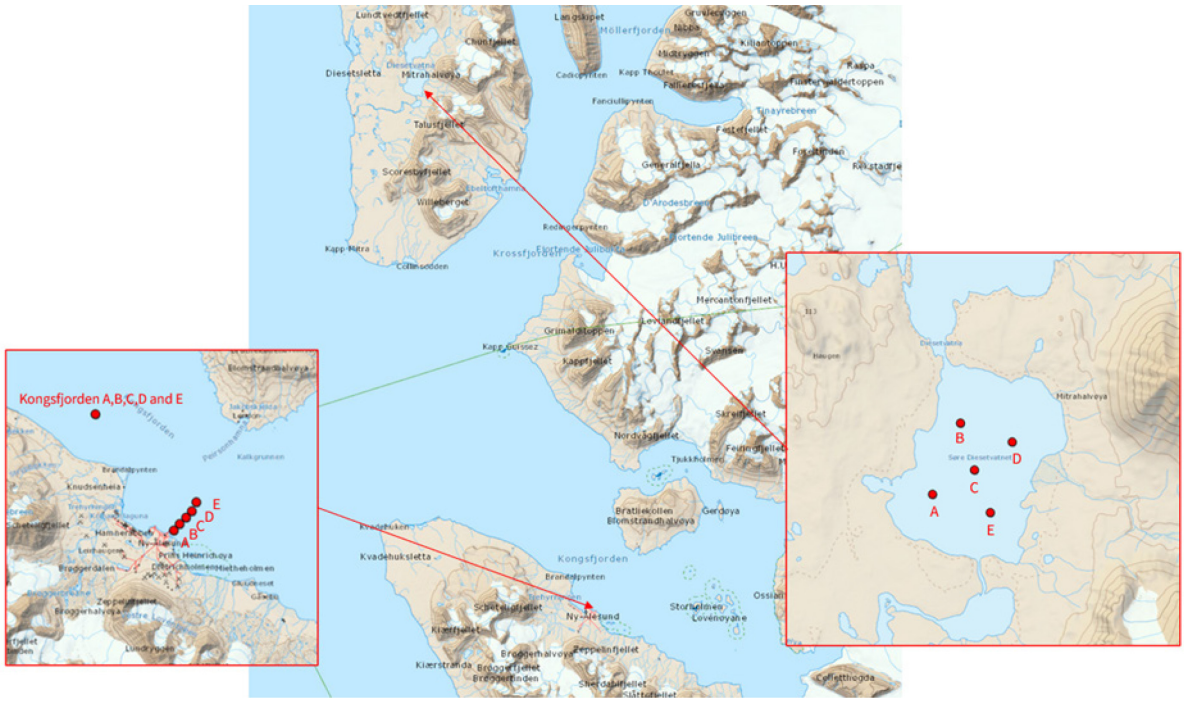

Figure 5: Map showing locations for collection of sediment samples. Samples of Shorthorn Sculpin and Arctic Char were collected in the same areas. Maps from Topo Svalbard.

2.3.5 Air

The method used for passive air sampling of cVMS has previously been described by Wania et al. (2023). Stainless-steel mesh cylinders were pre-cleaned, pre-weighed and filled with about 20-25 g of the pre-cleaned ultra-clean XAD-2 sorbent (XAD-2). Each cylinder was placed inside a pre-cleaned copper shipping tube, and the opening was covered with baked aluminum foil before being closed with a Teflon screw cap and Teflon tape. The tubes were then placed inside metal cans ("Paint cans") with a sealed lid during shipping and storage. One housing containing two parallel mesh cylinders with XAD-2 were deployed at three locations (Figure 6). Figure 7 shows the housing containing the mesh cylinders used for passive sampling of cVMS in air. At the Zeppelin Observatory and the Ny-Ålesund settlement, the housing was attached to existing structures. At the remote location (Diesetvatna), a ground anchor was deployed, and the passive sampler housing was attached to this. Sampling was conducted for approximately seven months over the winter season (late September 2023 to late April 2024). The samples from the remote location, near Diesetvatna, were unfortunately lost during the winter.

Figure 6: Map showing locations for air sample collection. Maps from Topo Svalbard.

Figure 7: XAD-2 based passive sampler for cVMS in air (Photo: NILU)

2.4 Materials

XAD-2 (Ultra-clean resin, a styrene/divinylbenzene polymer, equivalent to XAD-2 resin) was obtained from Teknolab AS (Ski, Norway) and pre-washed with cVMS-free n-hexane (HPLC grade, Fisher Scientific). Unlabeled D4, D5 and D6 used as standards had purities > 98%. 13C-D4, D5 and D6 used as internal standards (ISTDs) were all from CIL and with isotopic purities of >98% for 13C-D4, D5 and D6, respectively.

2.5 Analysis

All sample preparation in the lab was kept to a minimum in order to avoid loss of cVMS by volatilization and to avoid contamination. For air samples, the XAD-2 was placed in a gas-tight jar along with hexane and C^{13} labelled D4, D5 and D6 for internal standards, and extracted using an orbital shaker as described in Wania et al. (2023). Sample preparation methods for the terrestrial and aquatic samples was carried out as described in previous studies (Heimstad et al., 2023; Ingjerd Sunde Krogseth et al., 2017). Briefly, for soil and sediment, the material was homogenized by stirring with a spoon or spatula, while for biota, sample material was homogenized as fine as possible using Ultra-Turrax stainless steel mixer which was washed with water, acetone and hexane between each sample. Approximately 1.0 ± 0.2 g of material was transferred to a centrifuge tube and internal standard was added. Sediment samples were centrifuged to remove excess water. Samples were extracted with hexane and acetonitrile as solvent with ultrasonication, followed by shaker table. Then, the extract was centrifugated. As much as possible of the supernatant was transferred from the centrifuge tube to a 2 ml GC vial and stored at -20 ^{O}C overnight to precipitate out lipids and other biological material. Recovery standard was added before analysis on Gas Chromatography/Mass Spectrometry Detector (GC/MSD). Extracts were concentrated and analysed for HCHs using GC-Orbitrap high resolution mass spectrometry (GC/HRMS).

For soil and sediment, total organic carbon (TOC) was determined by a thermal oxidation/reduction method (SoliTOC cube) by Akvaplan NIVA (Tromsø). Lipid content of fish was determined using a gravimetric method after extraction using cyclohexane/acetone (3:1).

2.6 Quality control measures

Strict quality control measures during field and lab work is essential to achieve reliable results for siloxanes (Gerhards et al., 2022; Homem & Ratola, 2020). A range of measures were implemented in this study to minimize bias due to sample contamination or other analytical challenges, such as loss from volatilization during storage or sample treatment.

In the field, it was required that anyone taking part in sampling were not using personal care products (e.g. shampoo, deodorant, skin cream, etc.) on the day of sampling. Also, use or handling of any silicone containing materials (lubricants, sealants, etc.) on a day of sampling was avoided.
All equipment used was baked and/or solvent rinsed before use. The sample jars used have previously been tested to document that they are gas tight. All sample preparation was carried out in ISO class 6 clean room conditions in order to minimize contamination from the indoor laboratory environment and personnel.

For passive air, a sampler containing approximately 20 g of XAD-2 was used as a field blank. The field blank was stored in copper shipping tube, which were placed inside “Paint cans” with a sealed lid, similar to the samples. Field blanks for air were treated as described in Wania et al. (2023). Briefly, this involved removing the field blank from the paint can and opening the copper tube, hooking the filed blank to the sampler lid, exposing the field blank for approximately one minute, before unhooking from the sampler lid and resealing into the copper tube and paint can. The field blank was then stored sealed in the copper tube and paint can in the field on the same location as the associated sampler.

For vegetation, soil, fish and sediments, field blank matrices with known, low cVMS concentrations and similar properties as these environmental media should ideally be used (Warner et al., 2013). However, such field blank matrices were not available within the timeframe of the study. Therefore, XAD-2 was used as field blank matrix, as it is well characterized and has potential to sorb cVMS present during sampling, transport and storage. It should be noted that in general, XAD-2 has a higher potential for sorbing ambient cVMS compared to soil, vegetation, sediment and fish. However, this was assessed to be the more robust choice compared to other available materials which have less potential for sorbing cVMS compared to the sampled environmental media.

In order to determine any possible influence of ambient cVMS during fieldwork, transport and storage, 100 mL sample jars containing a few grams of XAD-2 was used as field blanks. During sample collection, the field blank jars were opened as sampling started, and left open for the duration of the sampling procedure. Storage and transport for the field blanks was identical to the samples.

In the lab, solvent blanks and XAD-2 blanks were included along with each batch of samples. The cVMS concentrations in samples were blank corrected based on solvent blanks only. XAD-2, which was used as filed blank matrix, may contain background contamination of cVMS. To account for this, and isolate the cVMS contribution from the field work, storage and transport, XAD-2 which had been stored in the lab, and not been in the field was analysed (XAD-2 blanks). Field blanks were blank corrected based on XAD-2 blanks to account for any XAD-2 background contamination.

Detection limits for vegetation, soil, fish and sediments were determined in two ways: i) based on three and ten times the standard deviation of the solvent blanks analysed along with each batch of samples, and ii) three and ten times the standard deviation of the corrected field blanks. Whichever of these values was higher was used as method limit of detection (MLD) and limit of quantification (MLQ) respectively. MLDs and MLQs were determined for each individual sample based on the sample amount. Furthermore, concentrations in samples were evaluated against the individual field blank results. One individual high field blank was excluded from the detection limit calculations.

Detection limits for air samples could not be based on field blanks, as only two field blanks were available due to the lost samples from the remote location. Therefore, detection limits for air samples were based on XAD-2 blanks analysed along with the samples. Furthermore, air concentrations were evaluated against the individual field blank results.

3 Results and discussion

3.1 Quality control results

Average concentrations of blank samples are shown in Table 3. Solvent blanks from the lab analysed along with the vegetation, soil, fish and sediment samples showed low cVMS concentrations. Overall, this indicates low background from lab facilities and personnel, as well as solvents, equipment, and during instrumental analysis. One high value was excluded from the averages presented (Appendix Table A1). The solvent blank with a high value was not used for correction of samples. Solvent blank corrected XAD-2 blanks showed somewhat higher concentrations compared to solvent blanks, indicating some additional background from the XAD-2. Field blanks, which were corrected for cVMS contributions from solvent and XAD-2, indicated low, but somewhat variable (at least for D5 and D6) additional cVMS background during sampling, transport, extraction and/or storage. The MDLs derived from averages of field blanks, are shown in Table 4. The variability in concentrations of D4 in field blanks were lower, and as a consequence, detection limits for D4 were very low. It should be noted, however, that there was one individual field blank with particularly high concentrations of D4 (3.93 ng/g D4, 1.38 ng/g D5, and 0.56 ng/g D6 after solvent and XAD-2 blank correction) which was excluded from the calculations of averages and detection limits. The high field blank was associated with soil samples from the Zeppelin Observatory, and the results from soil for this location therefore needs to be interpreted with caution as we cannot exclude that these samples have been exposed to cVMS contamination during the field work.

Table 3: Average and standard deviation of cVMS concentrations in blank samples

Blank type	Unit	D4	D5	D6	Std. Dev D4	Std. Dev D5	Std. Dev D6
Solvent blanks	ng	0.19	0.59	0.39	0.09	0.23	0.25
XAD-2 blanks (solvent blank corrected)	ng/g	0.52	2.25	0.21	0.52	0.89	0.36
Field blanks (solvent and XAD-2 blank corrected)	ng/g	0.034	0.15	0.073	0.067	0.32	0.13

For air samples, the detection limits were determined using XAD-2 blanks. The resulting MDLs are shown in Table 4. Air samples were deployed in duplicate and the deviation between the parallels varied between 4.2% (D4 at Ny-Ålesund) to 17.6% (D6 at Zeppelin). The concentrations in the air samples were between 10 (D6 at Zeppelin) and >50 times (D5 at Ny-Ålesund) higher than the concentrations in the field blanks, indicating minimal contamination during sampling and transport.

Table 4: Average detection limits (MDL/MLQ) for vegetation, soil, sediment, marine biota, and air

	Unit	MDL D4	MDL D5	MDL D6	MLQ D4	MLQ D5	MLQ D6
Vegetation	ng/g ww	0.24	1.09	0.47	0.71	3.29	1.41
Soil	ng/g dw	0.34	1.57	0.68	1.02	4.75	2.03
Sediment	ng/g dw	0.29	1.34	0.58	0.86	4.03	1.72
Fish	ng/g ww	0.24	1.09	0.47	0.71	3.29	1.41
Air	ng/m^3	0.10	0.13	0.13	0.33	0.43	0.45

3.2 Results from samples

3.2.1 Vegetation

Results from cVMS and HCH analysis of vegetation are shown in Table 5. D4 was detected above MDL in two samples from Zeppelin, three samples from Ny-Ålesund, and three samples from Diesetvatna. D5 and D6 were not detected in any vegetation sample. Of the HCHs, only α-HCH was detected, in one sample from Ny-Ålesund, and one from the remote location. Measured values and average MDLs and MLQs for vegetation are shown in Figure 8.

Table 5: Results from analysis of vegetation. Values in green italic indicate above MDL, but below MLQ, values in bold indicate above MLQ

Location	Location type	Sample type	D4 (ng/g ww)	D5 (ng/g ww)	D6 (ng/g ww)	α-HCH (pg/g ww)	γ-HCH (pg/g ww)
Zeppelin A	Observatory	Saxifraga	*0.25*	<1.09	<0.47	<60	<300
Zeppelin B	Observatory	Saxifraga	*0.31*	<1.17	<0.51	<60	<300
Ny-Ålesund A	Settlement	Saxifraga	*0.61*	<1.26	<1.06	<60	<300
Ny-Ålesund B	Settlement	Saxifraga	<0.23	<1.07	<0.90	<60	<300
Ny-Ålesund C	Settlement	Saxifraga	<0.23	<1.07	<0.90	<60	<300
Ny-Ålesund D	Settlement	Saxifraga	*0.42*	<1.03	<0.87	<60	<300
Ny-Ålesund E	Settlement	Saxifraga	*0.39*	<1.06	<0.89	**33**	<300
Diesetvatna A	Remote	Moss	*0.53*	<1.10	<0.92	<60	<300
Diesetvatna B	Remote	Moss	<0.21	<0.99	<0.84	<60	<300
Diesetvatna C	Remote	Moss	*0.42*	<0.94	<0.79	<60	<300
Diesetvatna D	Remote	Moss	*0.25*	<1.04	<0.87	<60	<300
Diesetvatna E	Remote	Moss	<0.23	<1.05	<0.88	**21**	<300

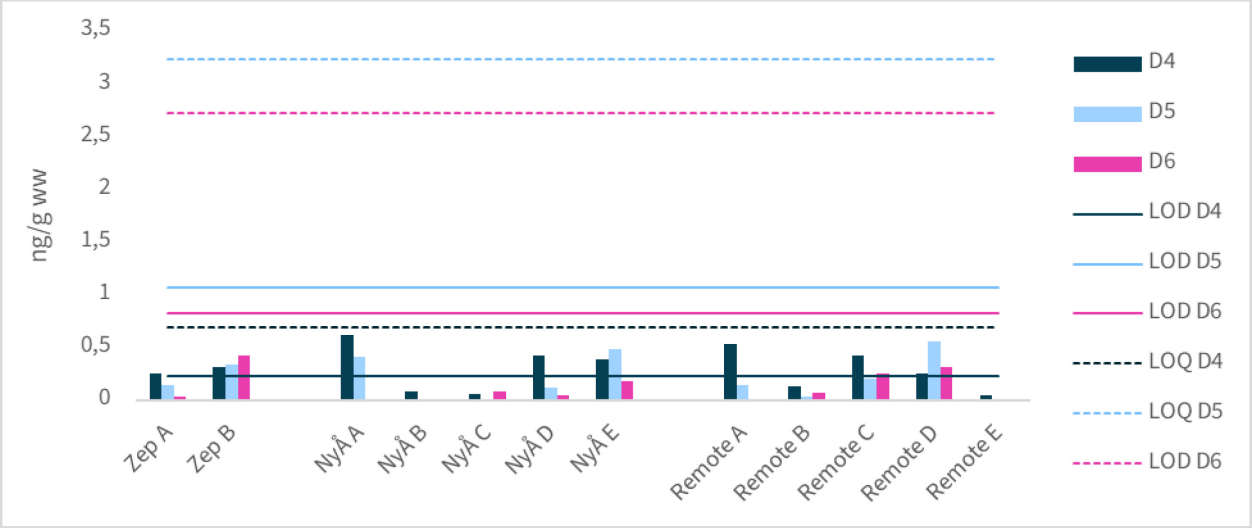

Figure 8: Measured values and average MDLs and MLQs for vegetation

In Antarctic vegetation, Sanchís et al. (2015b) reported nd – 21 ng/g dw, nd – 55 ng/g dw and nd – 88 ng/g dw for D4, D5 and D6 respectively. As far as we are aware, no other studies on vegetation from polar regions have been conducted. Heimstad et al. (2023) looked for cVMS in vegetation in an urban area in Norway, but neither D4, D5 or D6 was detected (MDLs ranging from 0.42 to 1.07 ng/g ww). Despite the latter study being from an urban area, where air concentrations of cVMS are orders of magnitude higher compared to polar regions (Halvorsen, 2024), our findings are more consistent with the findings of Heimstad et al. (2023), compared to the findings by Sanchís et al. (2015b) from Antarctica. We do however note the difference in units (ww, dw).

3.2.2 Soil

Results from soil analysis are shown in Table 6. D4 was detected above the MDL but below MLQ in two samples and above the MLQ in two samples close to the Zeppelin Observatory, and detected above MDL but below MLQ in one sample from Diesetvatna. D6 was detected above MDL but below MLQ in one sample of the samples close to the Zeppelin Observatory. D5 was not detected. It should be noted that the soil samples from Zeppelin were associated with a high field blank (approximately four times higher concentration for D4 compared to samples, and comparable concentrations for D6). These results should therefore be interpreted with caution. Of the HCHs, α-HCH was detected in two samples from the vicinity of Ny-Ålesund. The highest concentration of α-HCH was found in soil from the location within the settlement itself (Ny-Ålesund C, Figure 4) and the other sample with detected levels was close to the settlement, indicating that sources of α-HCH may be related to human activity in Ny-Ålesund. Measured values and average MDLs and MLQs for soil are shown in Figure 9.

Table 6: Results from analysis of soil samples. Values in green italic indicate above MDL, but below MLQ, values in bold indicate above MLQ

Location	Location type	Total organic carbon (TOC, % dw)	D4 (ng/g dw)	D5 (ng/g dw)	D6 (ng/g dw)	a-HCH (pg/g dw)	g-HCH (pg/g dw)
Zeppelin A	Observatory	0.27	**0.85***	<1.20	*0.52**	<60	<300
Zeppelin B	Observatory	0.16	*0.72**	<1.22	<0.53	<60	<300
Zeppelin C	Observatory	0.17	*0.64**	<1.17	<0.50	<60	<300
Zeppelin D	Observatory	0.13	**1.07***	<1.32	<0.57	<60	<300
Ny-Ålesund A	Settlement	n.a.	<0.44	<2.21	<1.34	<60	<300
Ny-Ålesund B	Settlement	9.62	<0.61	<3.09	<1.87	**150**	<300
Ny-Ålesund C	Settlement	13.84	<0.51	<2.57	<1.55	**583**	<300
Ny-Ålesund D	Settlement	5.88	<0.51	<2.56	<1.55	<60	<300
Ny-Ålesund E	Settlement	7.21	<0.48	<2.41	<1.46	<60	<300
Diesetvatna A	Remote	17.51	*1.18*	<3.90	<2.36	<60	<300
Diesetvatna B	Remote	10.78	<0.74	<3.73	<2.26	<60	<300
Diesetvatna C	Remote	4.97	<0.54	<2.72	<1.65	<60	<300
Diesetvatna D	Remote	2.37	<0.40	<2.04	<1.24	<60	<300
Diesetvatna E	Remote	12.00	<0.71	<3.60	<2.18	<60	<300

* Values are lower than their associated field blank.

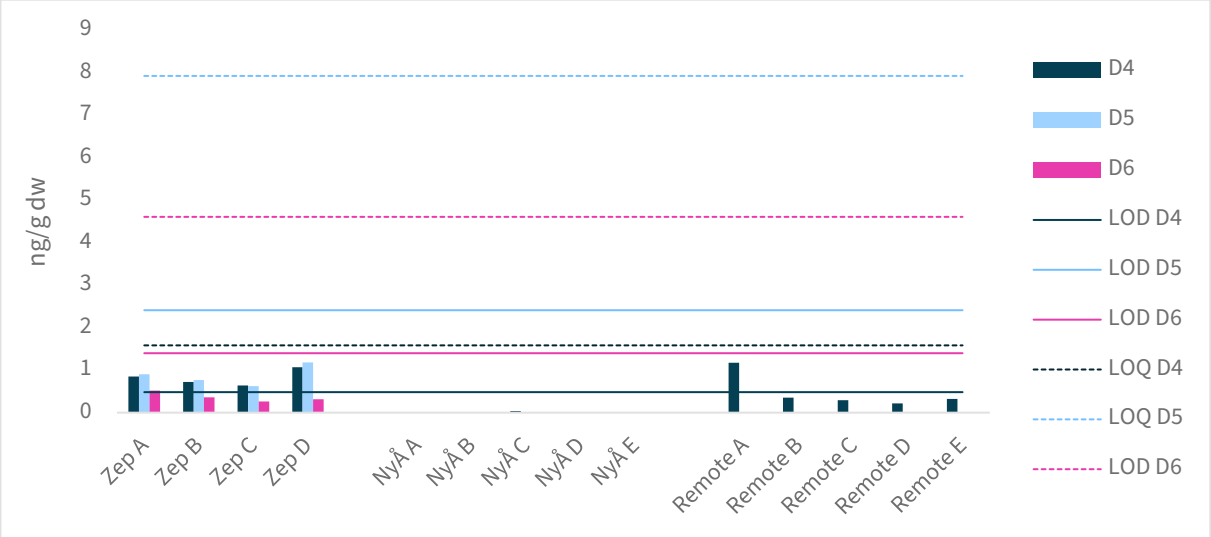

Figure 9: Measured values and average MDLs and MLQs for soil

The soil collected near the Zeppelin Observatory had a very low content of organic matter and was coarse and sandy. The soils from Ny-Ålesund and the remote location contained approximately 10 to 100 times more organic matter compared to the soils from near the Zeppelin Observatory. It has been suggested that soil with high content of organic matter will have higher potential to sorb cVMS following cVMS

deposition via snow and subsequent snowmelt (Sanchís et al., 2015b). We therefore investigated the correlation between TOC and D4, the only cVMS detected in more than one sample. As the detection frequency was low, the measured concentrations were included "as-is" in the correlation analysis, also for concentrations below the MDL, to avoid potential bias from using censored data. The correlation coefficients are shown in Table 7. Correlation coefficients are numerical measures that quantifies the strength and direction of a relationship between two variables. No significant correlation ($p > 0.05$) was seen between D4 and TOC (Table 7). It should be noted that the low concentrations and detection frequency may influence the possibility of identifying such a correlation.

Table 7: Correlation coefficients between D4 and organic carbon in soil

	TOC	*D4*
TOC	1	
D4	-0.198	1

Sanchís et al. (2015b) reported concentrations of cVMS from Antarctic soil of nd – 24 ng/g dw, nd – 110 ng/g dw and nd – 42 ng/g dw for D4, D5 and D6 respectively. As far as we are aware, no other studies on soil from Arctic or Antarctic regions have been conducted. Heimstad et al. (2023) looked for cVMS in soil in an urban area in Norway, but neither D4, D5 or D6 was detected (MDLs ranging from 1.26 to 2.04 ng/g dw). Despite the latter study being from an urban area, our findings are more consistent with the findings of Heimstad et al. (2023) compared to the findings by Sanchís et al. (2015b) from Antarctica. The uncertainty of the results in the study of Sanchís et al. (2015b) due to possible bias from blank contribution should be emphasised, as field blanks are crucial for the interpretation of analytical results, particularly from remote regions.

3.2.3 Fish

Results from analysis of Shorthorn Sculpin and Arctic Char are shown in Table 8. D4 was detected above the MDL but below MLQ in muscle from all Shorthorn Sculpin from the Kongsfjorden site, four Shorthorn Sculpin from outside Ny-Ålesund, and four Arctic Char from Diesetvatna. In one Shorthorn Sculpin from outside Ny-Ålesund, D4 was detected above the MLQ, at 0.87 ng/g ww. D5 was detected with concentration above the MDL but below the MLQ in one Shorthorn Sculpin from outside Ny-Ålesund. Measured values and average MDLs and MLQs for aquatic biota are shown in Figure 10.

Table 8: Results from analysis of Shorthorn Sculpin muscle and Arctic Char muscle. Values in green italic indicate above MDL, but below MLQ, values in bold indicate above MLQ

Location	Location type	Species	Size (cm)	Lipid content (% ww)	D4 (ng/g ww)	D5 (ng/g ww)	D6 (ng/g ww)	a-HCH (pg/g ww)	g-HCH (pg/g ww)
Kongsfjorden A	Fjord	Shorthorn Sculpin	22	0.44	*0.61*	<1.07	<0.46	<60	<300
Kongsfjorden B	Fjord	Shorthorn Sculpin	22	0.47	*0.59*	<1.09	<0.47	<60	<300
Kongsfjorden C	Fjord	Shorthorn Sculpin	20	0.46	*0.77*	<1.23	<0.53	<60	<300
Kongsfjorden D	Fjord	Shorthorn Sculpin	20	0.30	*0.50*	<1.01	<0.50	<60	<300
Kongsfjorden E	Fjord	Shorthorn Sculpin	21	0.33	*0.32*	<1.13	<0.55	<60	<300
Ny-Ålesund A	Settlement	Shorthorn Sculpin	23	0.51	*0.29*	<1.13	<0.56	<60	<300
Ny-Ålesund B	Settlement	Shorthorn Sculpin	22	0.59	*0.26*	<1.11	<0.55	<60	<300
Ny-Ålesund C	Settlement	Shorthorn Sculpin	21	0.51	**0.87**	<1.11	<0.54	<60	<300
Ny-Ålesund D	Settlement	Shorthorn Sculpin	20	0.18	*0.31*	<1.09	<0.54	<60	<300
Ny-Ålesund E	Settlement	Shorthorn Sculpin	20	0.23	*0.33*	*1.04*	<0.51	<60	<300
Diesetvatna A	Remote lake	Arctic Char	<25	3.60	*0.36*	<1.08	<0.53	**78**	<300
Diesetvatna B	Remote lake	Arctic Char	<25	0.46	<0.24	<1.12	<0.55	<60	<300
Diesetvatna C	Remote lake	Arctic Char	<25	0.74	*0.26*	<1.07	<0.53	<60	<300
Diesetvatna D	Remote lake	Arctic Char	<25	1.00	*0.27*	<1.16	<0.57	<60	<300
Diesetvatna E	Remote lake	Arctic Char	<25	0.28	*0.27*	<1.18	<0.58	<60	<300

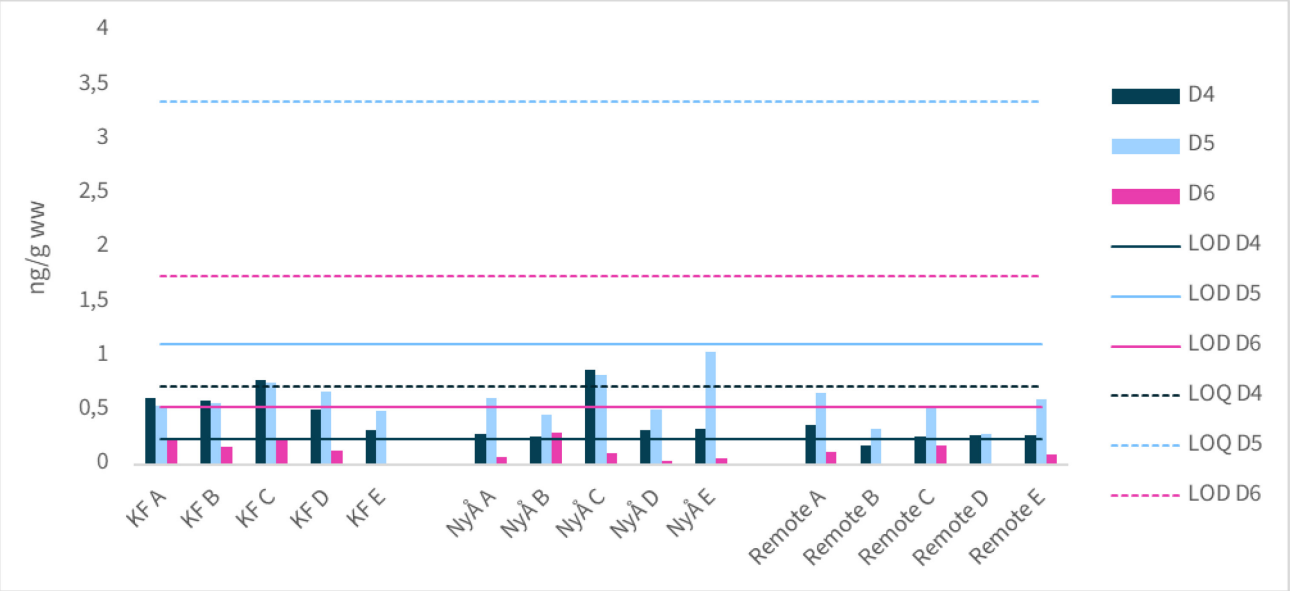

Figure 10: Measured values and average MDLs and MLQs for aquatic biota

The Shorthorn Sculpin and Arctic Char muscle analysed had low lipid content, varying between 0.23 and 0.59% for Shorthorn Sculpin, and 0.28 and 3.60% for Arctic Char. Given the low lipid content, we present

the results on a wet weight basis, rather than lipid normalized, to avoid the added uncertainty associated with lipid normalization when lipid content is low. Correlation between lipid content and concentrations of D4 and D5 was investigated, but no significant correlation ($p > 0.05$) was seen (Table 9). It should be noted that the low concentrations and detection frequency may influence the possibility of identifying such a correlation.

Table 9: Correlation coefficients between D4, D5, and lipid content

	Lipid	D4	D5
Lipid	1		
D4	-0.088	1	
D5	-0.024	0.49	1

In the study from Antarctica by Sanchís et al. (2015b), no fish species were included. Instead, Krill, located lower in the food chain, were studied, and concentrations of 12.3 – 117 ng/g dw for D4, 21.3 – 63.1 ng/g dw for D5, and 11.5 – 72.7 ng/g dw for D6, were reported. Given differences in sample type and methods, these results are not directly comparable to ours. However, we would expect higher concentrations than what we have found of cVMS in fish muscle, if the input from snow scavenging and deposition were significant.

cVMS has previously been reported in shorthorn sculpin liver from two Svalbard fjords by Warner et al. (2010). In a remote fjord (Liefdefjorden) they found nd – 11 ng/g lw D5, and nd – 10 ng/g lw D6 in shorthorn sculpin liver. D4 was not detected. In Adventfjorden, which receives wastewater from Longyearbyen, they found 54 – 2 150 ng/g lw D5 and nd – 31 D6 in shorthorn sculpin liver. D4 was not detected. It should be noted that the results in Warner et al. (2010) are from liver, and are lipid normalized, which makes them not directly comparable to data from this study, where we included non-lipid normalized muscle. cVMS content in trout muscle from the Norwegian lakes Mjøsa (near the cities Hamar and Lillehammer) and Femunden (a remote lake), have been reported by Økelsrud et al. (2024). Concentrations of D4 from the current study are in the lower range of what was reported in Mjøsa. The single detection of D5 in this study is an order of magnitude lower than D5 levels in Mjøsa. D4 and D5 were not detected in trout muscle from Femunden, but their detection limits for D4 were somewhat higher than the current study, with 0.95 ng/g ww, while their detection limits for D5 were comparable to the current study.

3.2.4 Sediment

Results from analysis of sediments are shown in Table 10. D4 was detected above MDL but below MLQ in three samples from Kongsfjorden. No D5, D6, or HCHs were detected in any of the samples. Measured values and average MDLs and MLQs for sediments are shown in Figure 11.

Table 10: Results from sediment samples. Values in italic indicate above MDL, but below MLQ

Location	Location type	Depth (m)	Total Organic Carbon (% dw)	D4 ng/g dw	D5 ng/g dw	D6 ng/g dw	a-HCH (pg/g dw)	g-HCH (pg/g dw)
Kongsfjorden A	Fjord	150	0.66	*0.72*	<1.49	<0.65	<60	<300
Kongsfjorden B	Fjord	150	0.66	*0.59*	<1.58	<0.68	<60	<300
Kongsfjorden C	Fjord	150	0.64	*0.49*	<1.55	<0.67	<60	<300
Kongsfjorden D	Fjord	150	0.68	<0.18	<0.81	<0.35	<60	<300
Kongsfjorden E	Fjord	150	0.70	<0.21	<0.95	<0.41	<60	<300
Ny-Ålesund A	Settlement	8-16	0.59	<0.26	<1.21	<0.53	<60	<300
Ny-Ålesund B	Settlement	8-16	0.70	<0.20	<0.94	<0.41	<60	<300
Ny-Ålesund C	Settlement	8-16	0.67	<0.24	<1.12	<0.48	<60	<300
Ny-Ålesund D	Settlement	8-16	0.69	<0.21	<0.98	<0.43	<60	<300
Ny-Ålesund E	Settlement	8-16	1.28	<0.48	<2.21	<0.96	<60	<300
Diesetvatna A	Remote lake	8-15	0.33	<0.44	<2.05	<0.89	<60	<300
Diesetvatna B	Remote lake	8-15	0.36	<0.39	<1.79	<0.77	<60	<300
Diesetvatna C	Remote lake	8-15	0.35	<0.38	<1.76	<0.76	<60	<300
Diesetvatna D	Remote lake	8-15	0.32	<0.29	<1.33	<0.57	<60	<300
Diesetvatna E	Remote lake	8-15	0.32	<0.47	<2.18	<0.95	<60	<300

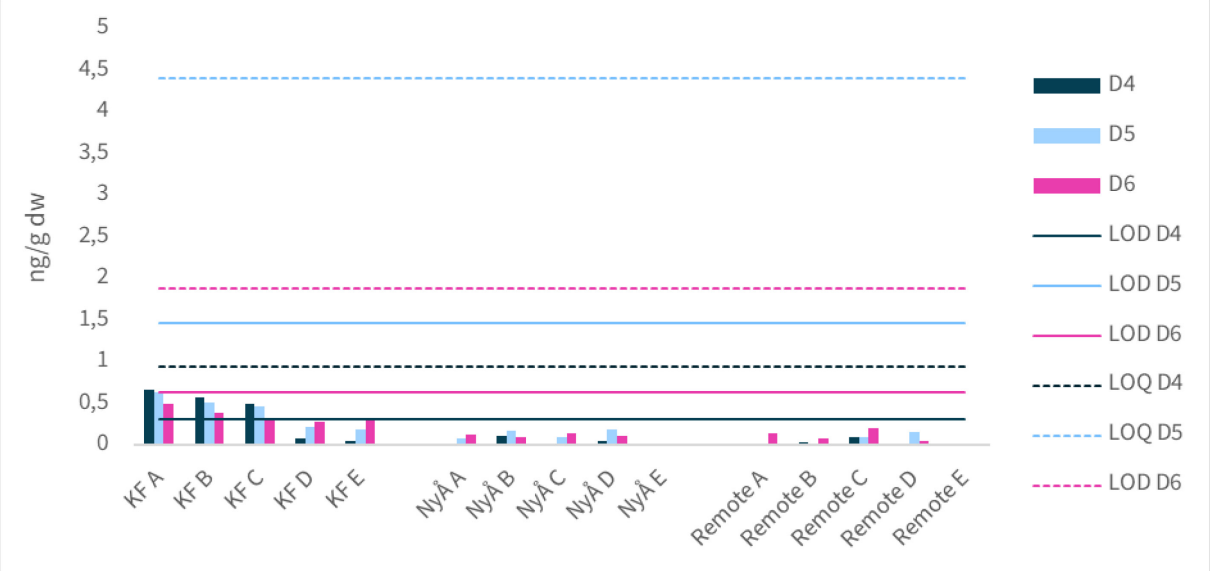

Figure 11: Measured values and average MDLs and MLQs for sediments

In the study by Warner et al. (2010), D4, D5 and D6 were not detected in sediments from Liefdefjorden and Kongsfjorden, the latter being the same fjord as one of the sampling sites included in the our study. In our study, the sampling was performed in a similar manner to Warner et al. (2010), i.e. outside the Ny-Ålesund

wastewater outlet. In sediments from Adventfjorden, they found 0.7 – 2.1 ng/g dw D5, while D4 and D6 were not detected. In a study from Hammerfest (Ingjerd Sunde Krogseth et al., 2017), cVMS in an urban lake receiving wastewater was studied, and they found 4 - 16 ng/g dw D4, 73 – 328 ng/g dw D5 and 17 – 75 ng/g dw D6 in sediments (Ingjerd Sunde Krogseth et al., 2017).

3.2.5 Air samples

Results from passive air samples collected at the Zeppelin Observatory and the Ny-Ålesund settlement are shown in Table 11. The passive sampler deployed by Diesetvatna was unfortunately lost during sampling.

Table 11: Results from air samples. Values in italic indicate above MDL, but below MLQ, values in bold indicate above MLQ

Location	D4 (ng/m^3)	D5 (ng/m^3)	D6 (ng/m^3)
Zeppelin	**1.64**	**2.99**	<0.13
Ny-Ålesund	**2.32**	**7.75**	*0.30*

For weekly monitoring of cVMS at the Zeppelin observatory using active sampling, the winter average for 2023, covering approximately the same time period as the deployment of the passive samplers, was 2, 2.8 and 0.3 ng/m^3 for D4, D5, and D6, respectively (Halvorsen et al., 2023; Halvorsen, 2024). For D4 and D5 this fits very well. There is very low detection frequency for D6 at the Zeppelin observatory for the active sampling, so the difference for D6 is caused by differences in detection limits (detection limits for the active sampling is higher). Overall, the results from the passive sampling of cVMS at Zeppelin underlines the good performance of the XAD-2 based passive sampling technique for cVMS.

Concentrations of cVMS in the Ny-Ålesund settlement were higher compared to Zeppelin Observatory. This was expected because of local emissions. However, the difference was somewhat smaller than expected given the presence of multiple potential sources for cVMS associated with human presence. We were unable to compare the air concentrations of cVMS at Zeppelin and Ny-Ålesund to the air concentrations at Diesetvatna (the more remote location) due to the loss of the passive sampler at this location.

3.2.6 HCHs

HCHs were included in this study as a benchmark compound, as this is a compound which is known to have high potential for snow scavenging and deposition, as shown through modeling studies (Lei & Wania, 2004), and studies of snow from Antarctica (Kang et al., 2012). However, concentrations of HCHs are declining quite rapidly in the Arctic atmosphere (Halvorsen, 2024) which limits the potential for snow scavenging to act as a source of HCHs to recipient compartments. We were unable to detect HCHs in the majority of samples. Nevertheless, correlation between α-HCH and cVMS was investigated across individual environmental compartments and across all samples. No significant correlation was seen between α-HCH and the detected cVMS ($p > 0.05$, Table 12). The correlations between D4, D5, and D6 were all significant ($p < 0.05$). It should be noted that the low concentrations and detection frequency may influence the possibility of identifying correlations.

Table 12: Correlation coefficients between α-HCH, D4, and D5

	D4	D5	D6	α-HCH
D4	1			
D5	0.67	1		
D6	0.41	0.56	1	
α-HCH	-0.16	-0.15	-0.15	1

3.2.7 Implications of findings and concluding remarks

Overall, the concentrations of cVMS in vegetation, soil, fish, sediment and air found in this study were below or in the very lowest range of reported data from other studies. Furthermore, the findings from Sanchís et al. (2015b) could not be confirmed by studying similar sample types in the Arctic, in the current study. This is despite that air concentrations of cVMS are higher in the Northern Hemisphere including the Arctic, compared to Antarctica (Durham, 2023), and that the climate conditions in terms of temperature (annual average daily mean -4.2 and -1.0°C, respectively) and annual precipitation (460 and 380 mm, respectively) are similar between Ny-Ålesund, Svalbard, and Livingston Island, where the study by Sanchís et al. (2015b) was carried out (climate data collected from Wikipedia).

In our study, we detected D4 above MDL (but generally below MLQ) in vegetation, soil, fish, and sediment, while D5 and D6 generally were below MDL. This is not the pattern we would expect to find if snow scavenging was a driver for cVMS concentrations in this region. On the contrary, we would expect D5 and D6 to be more prominent. D5 has been shown to have higher potential to be scavenged by snow compared to D4, and the potential for D6 to be scavenged by snow is expected to exceed that of D5 (Xu & Vogel, 2021). Snow scavenging also depends on the concentrations in air. The higher air concentration of D5 than D4 wintertime, (Table 11), would imply that more D5 should be retained by snow. Hence, our results support modelling results and rules out that snow scavenging is a major deposition pathway of cVMS.

Three main locations were included in this study, the Zeppelin Observatory and marine areas nearby expected to receive water from snowmelt, the Ny-Ålesund settlement and marine areas nearby expected to be influenced by the settlement representing a potential local source location, and a more remote location, Diesetvatna. The results from our study show somewhat elevated cVMS levels in Ny-Ålesund in terms of higher air concentrations compared to air concentrations at the Zeppelin Observatory, but the difference in air concentrations was not reflected in higher concentrations of cVMS in vegetation, soil, fish and sediment in Ny-Ålesund. Overall, there was little difference between cVMS concentrations between the sampling locations for the potential recipient compartments. This indicates that, contrary to what was expected, the Ny-Ålesund settlement does not appear to be a major source of cVMS to the local environment compared to other larger settlements in the Arctic (Ingjerd S Krogseth et al., 2017; Ingjerd Sunde Krogseth et al., 2017).

It should be noted that the difference in properties between the field blanks and the vegetation, soil, aquatic biota and sediment samples in this study limited the possibility of direct comparison and correction of sample levels based on field blanks, and added some uncertainty when calculating detection

limits based on field blanks. This uncertainty is not carried through to the low measured concentrations of cVMS in aquatic and terrestrial samples, as these were not corrected based on field blanks. We do however emphasize the importance of including field blanks with comparable properties in future studies to ensure robust detection limits can be determined.

Our investigation of cVMS content in environmental compartments which may be recipients of cVMS from snow melt does contribute to the ongoing debate on the potential for cVMS to undergo long-range atmospheric transport and subsequent deposition during snowfall. The data show that the cVMS concentrations are low in soil, vegetation, sediments, and fish, which is in line with most current research on cVMS in remote regions, as well as model calculations. Together, this suggest that the input of cVMS from atmospheric deposition via snow and snow melt is not a major contributing source to cVMS levels in remote Arctic sites.

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Appendix

Table A 1: Solvent blanks analysed with the different sample batches, and used for correction of cVMS concentrations in samples, XAD-2 blanks and field blanks. Numbers in red not included in corrections.

	D4 (ng)	D5 (ng)	D6 (ng)
Solvent blank 1 fish	0,21	13,05	44,53
Solvent blank 2 fish	0,075	0,316	0,246
Solvent blank 3 fish	0,108	0,527	0,536
Solvent blank 4 fish	0,091	0,286	0,193
Solvent blank 1 NEA	0,273	0,705	0,212
Solvent blank 2 NEA	0,303	0,743	0,228
Solvent blank 3 NEA	0,285	0,741	0,217
Solvent blank 1 soil	0,387	1,505	0,97
Solvent blank 2 soil	0,215	0,516	0,459
Solvent blank 3 soil	0,169	0,48	0,295
Solvent blank 1 veg	0,167	0,405	0,31
Solvent blank 2 veg	0,227	0,788	0,918
Solvent blank 3 veg	0,212	0,528	0,456
Solvent blank 1 sed	0,115	0,397	0,219
Solvent blank 2 sed	0,094	0,49	0,399
Solvent blank 3 sed	0,092	0,385	0,243

Table A 2: Solvent blank corrected XAD2 blanks analysed with the different sample batches, and used for correction of cVMS concentrations in field blanks. Numbers in red not included in correcctions.

	D4 ng/g	D5 ng/g	D6 ng/g
XAD-2 blank 1 fish	0,401	1,342	0,063
XAD-2 blank 2 fish	0,462	1,527	0,119
XAD-2 blank 3 fish	0,390	1,372	0,608
XAD-2 blank 4 fish	0,254	1,281	0,077
XAD-2 blank 1 NEA	0,303	2,835	0,114
XAD-2 blank 2 NEA	0,229	2,636	0,024
XAD-2 blank 3 NEA	0,174	1,229	0,000
XAD-2 blank 1 soil	0,245	1,593	0,000
XAD-2 blank 2 soil	2,353	3,899	1,346
XAD-2 blank 3 soil	7,371	9,588	12,738
XAD-2 blank 1 veg	0,410	1,885	0,000
XAD-2 blank 2 veg	0,599	3,645	0,468
XAD-2 blank 3 veg	0,391	2,216	0,060
XAD-2 blank 1 sed	0,637	3,240	0,166
XAD-2 blank 2 sed	0,478	2,667	0,059
XAD-2 blank 3 sed	0,460	2,432	0,085

Table A 3: Solvent blanks corrected field blanks

Sample code	Location	Matrix	D4 ng/g	D5 ng/g	D6 ng/g
2023-NÅ -FI-FB	Ny-Ålesund	Fish	0,460	2,149	0,712
2023-RM-FI-FB-A	Diesetvatna	Fish	0,611	1,385	0,037
2023-KF-FI-FB	Kongsfjorden	Fish	0,317	1,657	0,058
2023-NÅ-SL-FB-C	Ny-Ålesund	Soil	0,124	0,950	-0,198
2023-NÅ-SL-FB-E	Ny-Ålesund	Soil	0,226	2,375	-0,239
2023-RM-SL-FB-A	Diesetvatna	Soil	0,241	0,847	-0,268
2023-RM-SL-FB-B	Diesetvatna	Soil	0,207	0,823	-0,201
2023-ZP-SL-FB-A	Zeppelin	Soil	4,165	3,612	0,605
2023-ZP-VG-FB-A	Zeppelin	Vegetation	0,347	3,245	0,168
2023-NÅ-VG-FB-A	Ny-Ålesund	Vegetation	0,316	2,849	0,116
2023-NÅ-VG-FB-D	Ny-Ålesund	Vegetation	0,262	1,077	0,326
2023-RM-VG-FB-A	Diesetvatna	Vegetation	0,248	1,399	0,166
2023-RM-VG-FB-B	Diesetvatna	Vegetation	0,258	1,276	0,252
2023-NÅ-SD-FB	Ny-Ålesund	Sediment	0,371	2,951	0,025
2023-RM-SD-FB-A	Diesetvatna	Sediment	0,395	1,825	0,250
2023-RM-SD-FB-B	Diesetvatna	Sediment	0,326	1,081	0,000

Table A 4: XAD-2 corrected FBs, negative values were assigned zero values, extreme values (marked in red) were not included in MDL and MLQ calculation

Sample code	Location	Matrix	D4 ng/g	D5 ng/g	D6 ng/g
2023-N -FI-FB	Ny-Ålesund	Fish	0,08	0,77	0,50
2023-RM-FI-FB-A	Diesetvatna	Fish	0,23	0,00	0,00
2023-KF-FI-FB	Kongsfjorden	Fish	0,08	0,00	0,01
2023-NÅ-SL-FB-C	Ny-Ålesund	Soil	0,00	0,00	0,00
2023-NÅ-SL-FB-E	NyÅlesund	Soil	0,00	0,00	0,00
2023-RM-SL-FB-A	Diesetvatna	Soil	0,00	0,00	0,00
2023-RM-SL-FB-B	Diesetvatna	Soil	0,00	0,00	0,00
2023-ZP-SL-FB-A	Zeppelin	Soil	3,93	1,38	0,56
2023-ZP-VG-FB-A	Zeppelin	Vegetation	0,11	1,01	0,12
2023-NÅ-VG-FB-A	Ny-Ålesund	Vegetation	0,00	0,27	0,00
2023-NÅ-VG-FB-D	Ny-Ålesund	Vegetation	0,00	0,00	0,18
2023-RM-VG-FB-A	Diesetvatna	Vegetation	0,00	0,00	0,02
2023-RM-VG-FB-B	Diesetvatna	Vegetation	0,00	0,00	0,11
2023-NÅ-SD-FB	Ny-Ålesund	Sediment	0,00	0,17	0,00
2023-RM-SD-FB-A	Diesetvatna	Sediment	0,00	0,00	0,15
2023-RM-SD-FB-B	Diesetvatna	Sediment	0,00	0,00	0,00
Average			0,034	0,148	0,073
Standard deviation			0,067	0,315	0,133
MDL			0,24	1,09	0,47
MLQ			0,71	3,29	1,41

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