Spring 2024

Community-based monitoring of contaminants in snow and lichen near the Mary River project

ArctiConnexion

Project Development & Mentorship

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Executive Summary

The Qikiqtani Inuit Association (QIA) is obligated to conduct Inuit Qaujimajatuqangit-based research of Inuit-Owned Land (IOL) water resources surrounding the Mary River Project. This work requires support from technical experts capable of designing and implementing monitoring activities, including program scoping, field program development, data analysis and reporting. QIA has mandated ArctiConnexion to investigate the impact of Baffinland Mines (BIM) ore dust production on the terrestrial and freshwater ecosystems near the Mary River project. Each year, six million tons of iron ore are extracted from the Mary River mine. Ore crushing, processing and transport are a source of fugitive red dust which is carried by wind and deposited in the surrounding environment.

The Spring 2024 Community-Based Monitoring Program, conducted near the Baffinland Mary River project area, represents the second consecutive year of sampling (see Coupel & L'Hérault 2023). The program integrated Inuit Qaujimajatuqangit (IQ) and scientific methods, focusing on snow, water, and lichen as indicators of environmental contamination. This report summarizes the sampling efforts, analytical results, and subsequent recommendations to guide ongoing monitoring and mitigation strategies.

In partnership with and under the supervision of QIA's Inuit Stewardship Program and the contribution of QIA's Nauttiqsarti Guardians, we coordinated a community-based spring sampling campaign to investigate he extent and levels of dust contamination around the Mary River project. The 2024 sampling campaign was based on findings from 2023, including Inuit Qaujimajatuqangit, and included 28 snow stations and 18 lichen stations across various proximities to the project area; the mine, the tote road, and the Milne Inlet Port, with reference sites for comparison. Our intention was to sample gradients of stations in the most impacted areas to determine the extent of contamination. Melted snow samples were analyzed at ALS Environment for trace metals (e.g., aluminum, lead, iron, mercury) and solids (Total Suspended Solids - TSS, Total Dissolved Solids - TDS). Results were compared against Canadian water quality and safety guidelines defined by the Canadian Council of Ministers of the Environment (CCME). Lichen samples were analyzed for trace metals uptake as an indicator of risk exposure for small herbivores and wildlife.

At 15 of the 28 sampling stations sampled , TSS concentrations exceeded the CCME guidelines for the protection of aquatic life. At 9 sampling stations, TSS levels were 10 to 100 times above the CCME guideline. Highest levels were found within a 10 km radius of the mine site and along the tote road near Katiktuk Lake. The visual discoloration of snow, characterized by reddish hues, was also most prominent near these industrial areas and aligned with the TSS levels measured.

At 18 stations, at least one metal exceeded the guidelines for the protection of aquatic life defined by the CCME. At 17 stations, the concentration of aluminum in snow exceeded the CCME guideline for the protection of aquatic life, at 9 of them it exceeded the guideline for drinking water quality and at 6 of them it exceeded the guideline for the protection of livestock. Chromium exceeded the guideline for the protection of aquatic life at 12 stations, copper and lead exceeded the guidelines at 9 stations, manganese at 7 stations, cadmium at 4 stations and mercury and nickel at one station.

Our findings demonstrate a clear relationship between the proximity to industrial infrastructure in the project area and the level of environmental contamination observed. Snow samples collected along gradients extending outward from the mine, the tote road, and Milne Port revealed higher concentrations of Total Suspended Solids (TSS) and trace metals closer to these sites. For example, the concentrations of aluminum in snow sampled along the tote road near Katiktuk Lake were 10 to 50 times higher than off-road stations and 10 to 100 higher the guideline for the protection of aquatic life (CCME). Dissolved aluminum also exceeded the guideline for the protection of aquatic life at one site near Katiktuk lake. The concentration of aluminum in snow was 80 times the guideline for the protection of aquatic life in snow collected 2 km from the industrial port but this effect faded by 100 times 10 km away from the port.

Contaminant levels in lichen were highest near the mine and along the tote road near Katiktutk lake, with significantly elevated concentrations of aluminum, iron, chromium, and lead compared to more distant reference stations. Despite guidelines were not available for lichen samples, comparison with other studies conducted in European industrial areas revealed similar levels of trace metals near the project area raising concerns for herbivores, such as caribou, grazing on lichen.

Results of the 2024 study are generally in congruence with our 2023 study and highlight a persistent issue of dust contamination of the terrestrial and aquatic habitats near the project area. Expanding spatial gradients and geochemical composition analyses would help to discriminate the sources and mechanisms of metal deposition. Monitoring the spring melt and summer precipitation events will be essential to assess how contaminants transition from snow and dust to aquatic and terrestrial ecosystems. Continued integration of Inuit Qaujimajatuqangit will remain critical to shaping future research and ensuring the protection of culturally and environmentally significant resources.

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1 - Introduction

The Mary River Mine is operating since 2015 on Baffin Island approx. 120km southwest of Pond Inlet. The project annually extracts and ships six million tonnes of iron ore (Neary, 2020). The activities of ore crushing, processing and transport are the source of fugitive red dust which is carried by wind with potential impacts on aquatic life and the terrestrial ecosystem near the mine site and along the tote road, and on the marine ecosystem near Milne Inlet. Elsewhere on planet Earth, life-cycle assessments of iron mine have revealed the emission of chrome, zinc, and lead in the air, as well as the release of cadmium, arsenic, nickel, copper in the water with important ecotoxic impacts on the ecosystem and carcinogenic impacts on people (Ferreira and Leite, 2015). Nonessential metals such as mercury and cadmium are especially of concern because they bioaccumulate in organisms and biomagnify throughout food webs. In addition, chemists have revealed that trace metals can be transported over long distance through its adsorption onto sedimentary particles enriched in iron oxides and can be released far from the origin site (Cagnin et al., 2017; Michel et al., 1997; Pierce and Moore, 1982). The mobilization and bioavailability of trace metals in the environment increase the chance of exposure and intake by aquatic life and wildlife (Nriagu et al., 1988).

From the beginning of the mining operations and before, local land users/hunters in Pond Inlet have repeatedly reported observations of the dust pollution near the project area including the discolouration and melting of the snow and the water (photo #1) and the discolouration of small games such as ptarmigan, rabbit and Arctic fox (photo #2). The spreading of dust has been observed kilometres away from the project area in the natural calving and migratory habitat of the barren-ground caribou. The caribou can potentially graze on contaminated food such as lichens and plants. Contamination of freshwater sources can affect fish habitats and aquatic life and could be harmful to local land users fetching water during their hunting and fishing trips on the land.

Photo 1 - *Discoloured and melted snow on a lake photographed 2 km southeast of the Mary River mine (photo courtesy Andrew Jaworenko)*

Photo 2 - *Discoloured Arctic fox tail and rear paws sampled near the Mary River mine (photo courtesy Pierre-Yves Daoust)*

In the spring of 2023, we ran a community-based snow monitoring program with the objective to investigate the extent and magnitude of dust accumulation in snow, water, and lichen near the project area, 2) to measure the concentration of different contaminants, trace metals and petroleum hydrocarbons, in the samples collected and 3) to compare the concentrations observed with Canadian water guidelines. Our results showed that Total Suspended Solids (TSS) levels exceeded Canadian water quality guidelines for aquatic life in the majority of the snow samples collected. Trace metals, including aluminum, lead, and manganese, were frequently found above toxicity thresholds for aquatic organisms and drinking water, with aluminum exceeding livestock safety thresholds at multiple sites. Elevated levels of aluminum and iron in lichen, comparable to those in polluted European industrial areas, suggested potential impacts on terrestrial ecosystems, including lichen grazers like caribou. Trace metals concentrations and petroleum hydrocarbons were low in water samples collected in aquatic habitats beneath the lake ice.

Building on the previous year's findings and recommendations, our objectives for the 2024 snow monitoring program were to:

1) Investigate dust contamination at several stations located near Katiktuk Lake; a hotspot of snow contamination identified in 2023;
2) Investigate gradients of snow contamination along different distances to the Mary River mine and Milne Inlet port;
3) Investigate concentrations of dissolved aluminum in snow samples near the project area;
4) Investigate dust contamination in lichen samples as indicator of terrestrial impacts

We ran a community-based monitoring program in partnership with QIA's Inuit Stewardship Program in Pond Inlet. We developed our fieldwork and sampling design based on the previous knowledge and observations documented from Elders and land users (Inuit Qaujimajatuqangit). Fieldwork was conducted at the end of April 2024 when we hired and trained the QIA Nauttiqsarti Guardians and local assistants in Pond Inlet.

2 - Methods

2.1 Sampling stations

Field work was conducted at spring 2024 (April 30 to May 03) at 28 stations located at various distances from three main areas: the Mine Site, Katiktuk Lake, and Milne Port (Figure 1, Table 1). Sampling various distances was important to depict gradients of concentration and study the geographical extent of dust contamination. Three references sites (unaffected and remote) were sampled.

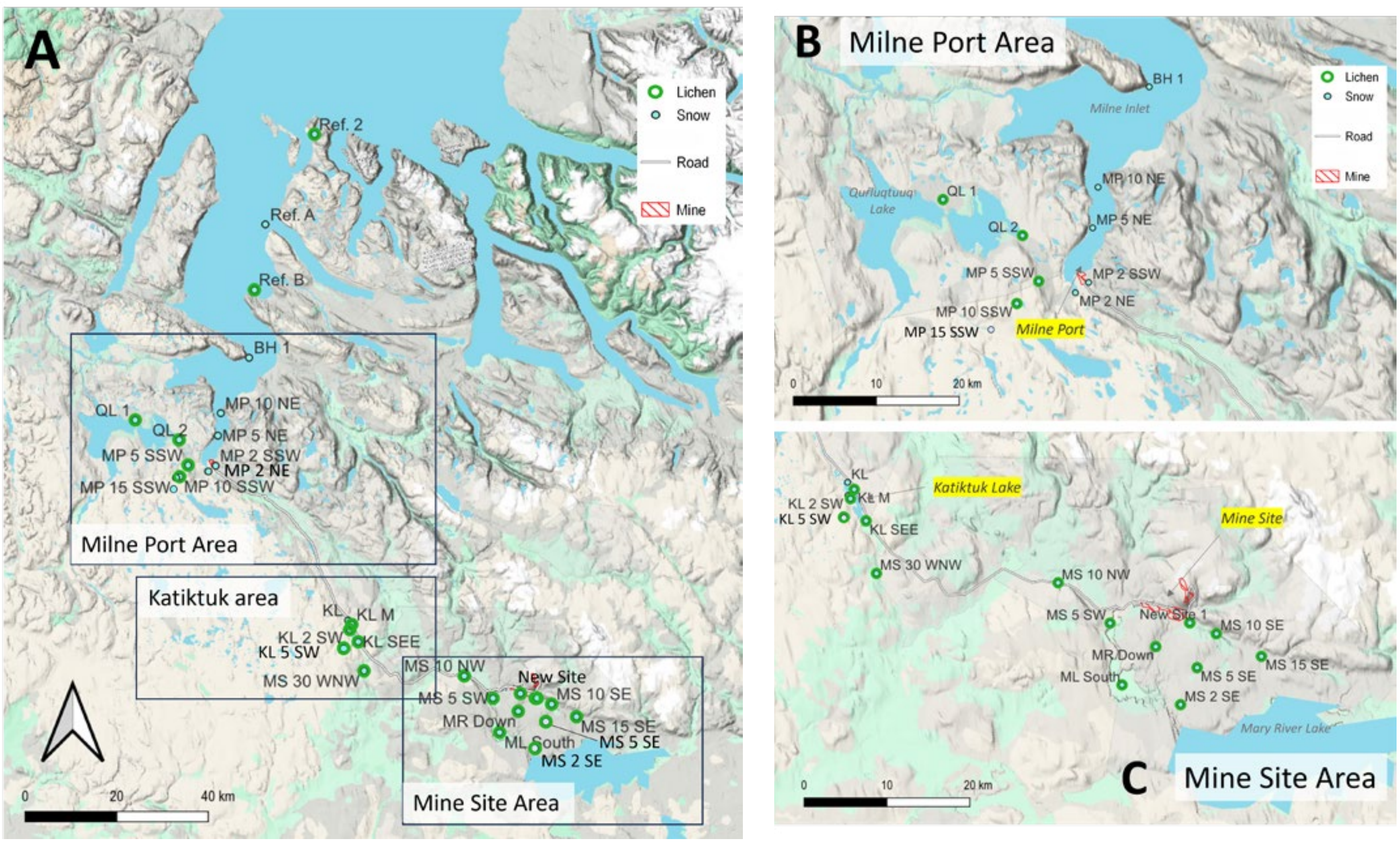

Figure 1: *Location of sampling stations near Baffinland's project area at spring 2024. A: General View; B: zoom on the Milne Port area; C: zoom on the Mine Site area.*

2.2 Sample collection

2.2.1 Snow

Snow was sampled at 28 stations (Table 1). Field crew approached each station facing the wind and they parked snow machines downwind no closer than 10 m from the sampling sites to avoid potential contamination. Field crew dug a hole to access the entire vertical snow layer from the ground to the surface. The full thickness of the snow was measured, and photographs of the snowpack were taken prior to sampling. Date, time, GPS coordinates, Inuktitut name of the location, and the name of the sampler were compiled on a data sheet. The darkest/most reddish layer of snow was sampled using a plastic shovel previously cleaned with surface snow and wearing lab gloves. 20 L Ziploc bags were filled with the snow, zip tied and labelled.

Snow samples were kept frozen and away from direct sunlight during the remaining field work and transported back to the Government of Nunavut's Department of Environment Laboratory in Pond Inlet. Snow samples were melted at ambient temperature (20oC) and transferred into test bottles for analysis. Bottles were stored in the fridge at 4oC and ship down to ALS Environmental Ltd. Laboratory in Burlington, ON. ALS is accredited by the Canadian Association for Laboratory Accreditation Inc.

2.2.2 Lichen

Lichen samples were collected at 18 sites (Table 1). 10g of lichen was taken from the ground under the snowpack and stored in a plastic bag. Field crew used lab gloves for sampling and did not use metallic instruments to prevent contamination. Samples were kept cool during field work and stored in the fridge at 4oC back at the laboratory in Pond Inlet. Samples were shipped down to ALS Environmental Ltd. for analysis.

2.3 Laboratory work

Melted snow samples were tested for Total Suspended Solids (TSS) by filtration through a glass fibre filter, drying of the filter at 104 ± 1°C and the gravimetric measurement of the filtered solids. Total Dissolved Solids (TDS) were determined by filtration through a glass fibre filter with the evaporation of the filtrate at 180 ± 2°C for 16 hours and the gravimetric measurement of the residue. Total trace metals concentrations in melted snow were measured at ALS Environmental Inc. Laboratory in Vancouver, BC. Melted snow samples were digested with nitric and hydrochloric acids and analyzed by Collision/Reaction Cell by Inductively coupled plasma mass spectrometry (ICPMS). Dissolved trace metals in melted snow were analyzed by Collision/Reaction Cell by ICPMS after filtering on 0.45 μm and preservation with nitric acid.

For the analysis of Total mercury, water samples underwent a cold oxidation using bromine monochloride prior to reduction with stannous chloride and analyzed by cold vapor atomic absorption spectrometry (CVAAS).

Lichen samples were tested for total trace metals by homogenization and sub-sampled prior to hot block digestion with HNO3, HCl, and H2O2. Analyses were made by Collision/Reaction Cell ICPMS. Lichen contaminants analysis was proceeded in wet (ww) and dry weight (dw).

The analytical methods used by ALS are developed using internationally recognized reference methods (where available), such as those published by US EPA, APHA Standard Methods, ASTM, ISO, Environment Canada, BC MOE, and Ontario MOE. Reference methods may incorporate modifications to improve performance.

Table 1: *Stations, nature of samples and parameters tested near Baffinland's project area at spring 2024*

Stations	ID	Longitude °W	Latitude °N	Snow depth (cm)	SNOW			LICHEN
					Hardness pH	TDS TSS	Metals	Metals
New Reference 2	Ref. 2	79,8	72,46	19	1	1	1	1
New Reference-A	Ref. A	80,2	72,31	25	1	1	1	
New Reference-B	Ref. B	80,40	72,19	20	1	1	1	1
Bruce Head 1	BH 1	80,53	72,06	15	1	1	1	
Qurluqtuuq Lake 1	QL 1	81,31	71,99	48	1	1	1	1
Qurluqtuuq Lake 2	QL 2	81,07	71,93	47	1	1	1	1
Milne Port 2 NE	MP 2 NE	80,92	71,86	25	1	1	1	
Milne Port 5 NE	MP 5 NE	80,82	71,93	40	1	1	1	
Milne Port 10 NE	MP 10 NE	80,77	71,97	15	1	1	1	
Milne Port 2 SSW	MP 2 SSW	80,87	71,87	20	1	1	1	
Milne Port 5 SSW	MP 5 SSW	81,04	71,88	45	1	1	1	
Milne Port 10 SSW	MP 10 SSW	81,11	71,86	23	1	1	1	1
Milne Port 15 SSW	MP 15 SSW	81,13	71,86	30	1	1	1	
Mine Site 30 WNW	MS 30 WNW	80,39	71,70	15	1	1	1	1
Katiktuk Lake	KL	80,26	71,52	25	1	1	1	
Katiktuk Lake 2 SW	KL 2 SW	80,70	71,51	24	1	1	1	
Katiktuk Lake 5 SW	KL 5 SW	80,27	71,50	20	1	1	1	1
Katiktuk Lake SEE	KL SEE	80,23	71,47	24	1	1	1	1
Katiktuk Lake-Middle	KL M	80,25	71,51	20	1	1	1	1
Mary Lake South	ML South	79,51	71,29	25	1	1	1	1
Mary River Downstream	MR Down	79,37	71,28	50	1	1	1	1
Mine Site 10 NW	MS 10 NW	79,64	71,37	29	1	1	1	1
Mine Site 5 SW	MS 5 SW	79,50	71,31	20	1	1	1	1
Mine Site 2 SE	MS 2 SE	79,30	71,21	60	1	1	1	1
Mine Site 5 SE	MS 5 SE	79,24	71,24	52	1	1	1	1
Mine Site 10 SE	MS 10 SE	79,16	71,27	27	1	1	1	1
Mine Site 15 SE	MS 15 SE	79,03	71,24	29	1	1	1	1
New Site 1	New Site 1	79,23	71,29	45	1	1	1	1
TOTAL					**28**	**28**	**28**	**18**

2.4 Water quality guidelines

The results presented in this report are compared to several Canadian guidelines for water quality:

- The Canadian Council of Ministers of the Environment (CCME, 2007) Freshwater Aquatic Life Guidelines identify potential concerns for aquatic life (shells, crustaceans, fishes). We use the long-term (chronic) exposure threshold provided by the CCME when available. Indeed, the pollution released in the environment (e.g. dust) from mining operations is a long-lasting contamination.
- The Canadian Drinking Water Quality Guidelines (CDWQGs, Health Canada, 2019) to identify potential concerns for human drinking water.
- The CCME guidelines for the protection of livestock identify potential concerns for wildlife living the land (caribou, small games).

3 - Results

3.1 Snow

3.1.1 Visual observations

The observed red discoloration of the snowpack from dust deposition was related to the proximity of the station to the project area: mine infrastructures, transport infrastructures and stock piling. Areas close to the mine site and to the tote road exhibited significant discoloration, particularly in the lower snowpack layers indicating dust accumulation early in the winter. Snow samples collected at stations located farther from activity sites, such as Qurluqtuq Lake and reference stations, remained visually clean, suggesting a gradient of dust deposition.

MINE SITE

Near the Mine Site, significant red discoloration of the snowpack was observed (Figure 2). The density and distribution of the discoloration varies based on the distance and direction relative to the Mine Site:

- **SOUTHEAST TO THE MINE SITE:**
  Stations southeast of the Mine Site exhibited varying levels of red discoloration as the distance increased from Mine Site. Near the mine (MS 2 SE and New Site 1), thick layers of dark red discoloration were found throughout the snowpack. 5km from mine site (MS 5 SE), the upper snow layers were distinctly red indicative of late winter dust accumulation. As distance increased (MS 10 SE, MS 15 SE), the intensity of the discoloration progressively decreased.
- **SOUTHWEST OF THE MINE SITE:**
  At stations farther southwest of the Mine Site (MS South, MR Downstream), the snowpack also exhibited red discoloration. However, the discoloration was notably lighter compared to the snow near the mine site indicative of a gradient of dust deposition.
- **WEST OF THE MINE SITE:**
  Discoloration of the snow was absent at MS 30 WNW, a station located farther west and away from the road, suggesting limited red dust deposition in this area.

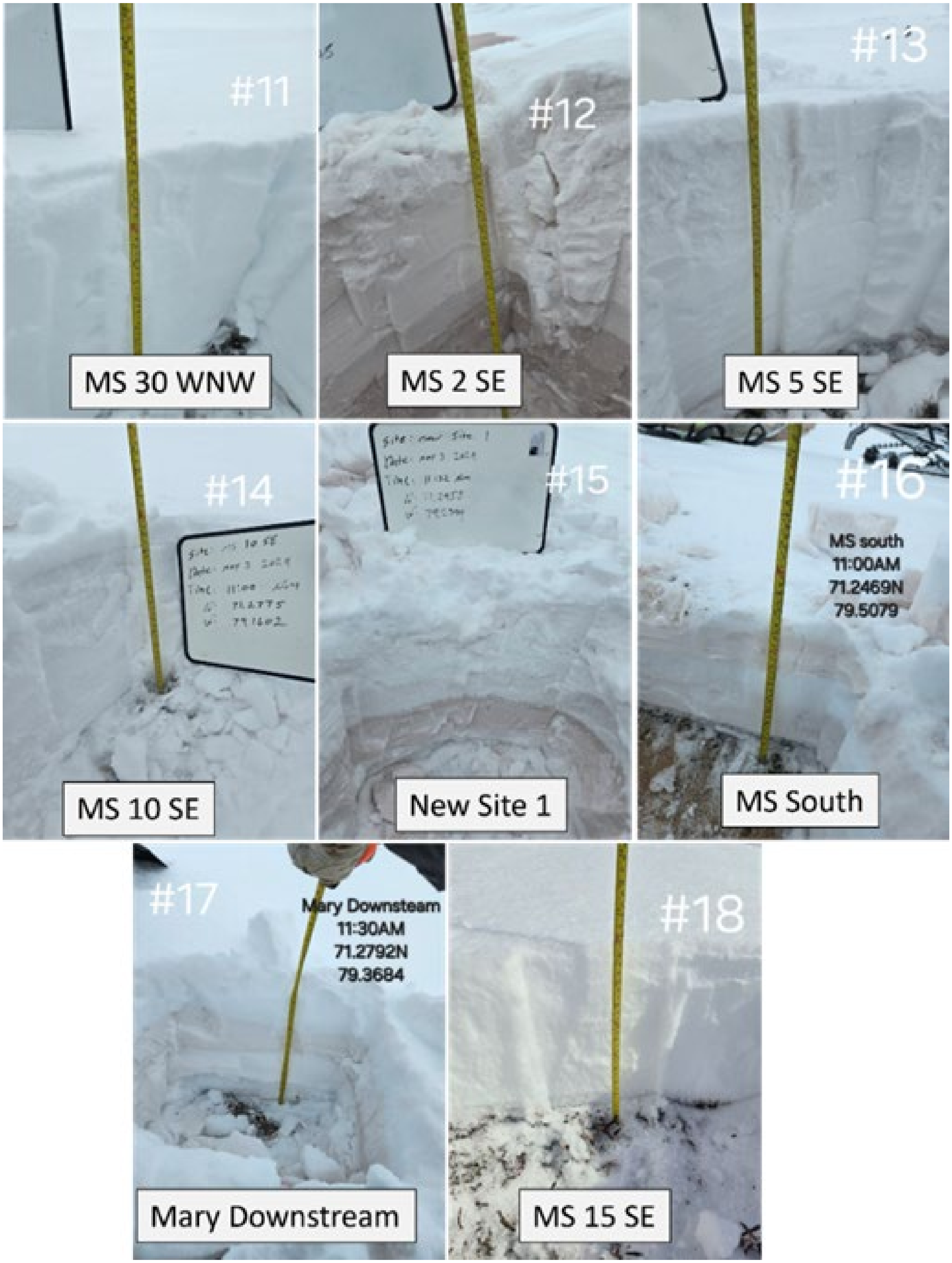

Figure 2: *Vertical cut of snowpacks sampled near the Mary River mine at spring 2024*

MILNE PORT

Compared to the Mine Site area, snow discoloration around Milne Port was less pronounced (Figure 3):

- **NORTHEAST OF THE PORT:**
  Red discoloration was visible in the lower snowpack layers at stations northeast of Milne Port (e.g., MP 2 NE, MP 5 NE). The coloration diminished with increasing distance from the port (e.g., MP 10 NE).
- **SOUTHWEST OF THE PORT:**
  Minimal discoloration was observed southwest of the port (MP SSW 2, MP SSW 5). Snow farther from Milne Port appeared clean (MP SSW 10, MP SSW 15).

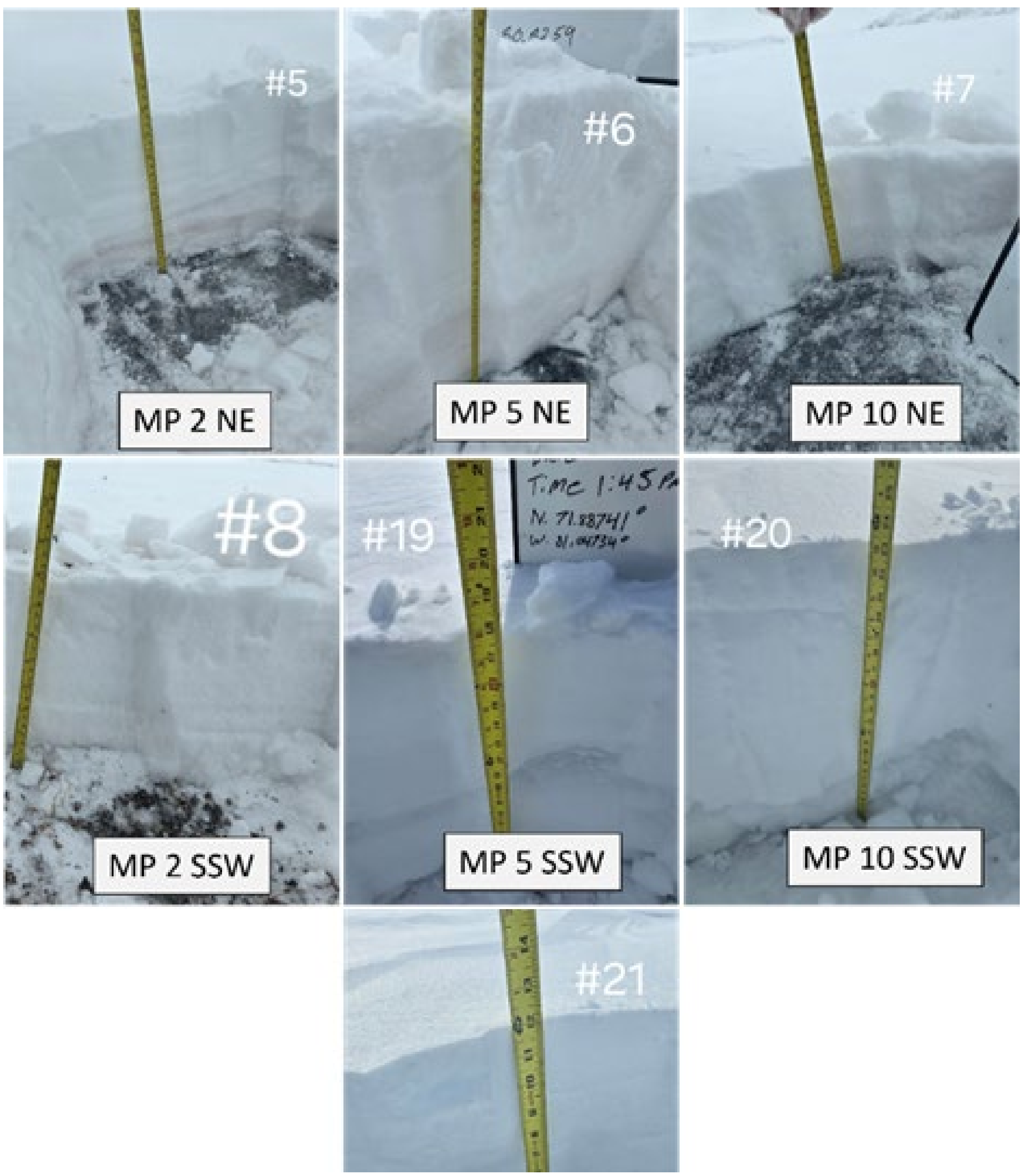

Figure 3: Vertical cut of snowpacks sampled near the Milne Inlet Port (MP) at spring 2024

KATIKTUK LAKE

The snowpack near Katiktuk Lake displayed varying levels of red discoloration, primarily influenced by proximity to the tote road (Figure 4):

- **NEAR THE TOTE ROAD:**
  Stations along Tote Road (KL, KL -SEE, KL-M) exhibited red discoloration throughout the snowpack with higher concentrations in the bottom layers indicative of early winter dust deposition. The discoloration density declined toward the southern end of the lake (KL -SEE).
- **OFF THE TOTE ROAD:**
  Stations located on the opposite/western side of the lake (e.g., KL 2 SW, KL 5 SW) displayed minimal discoloration marking the end of the gradient of dust deposition.

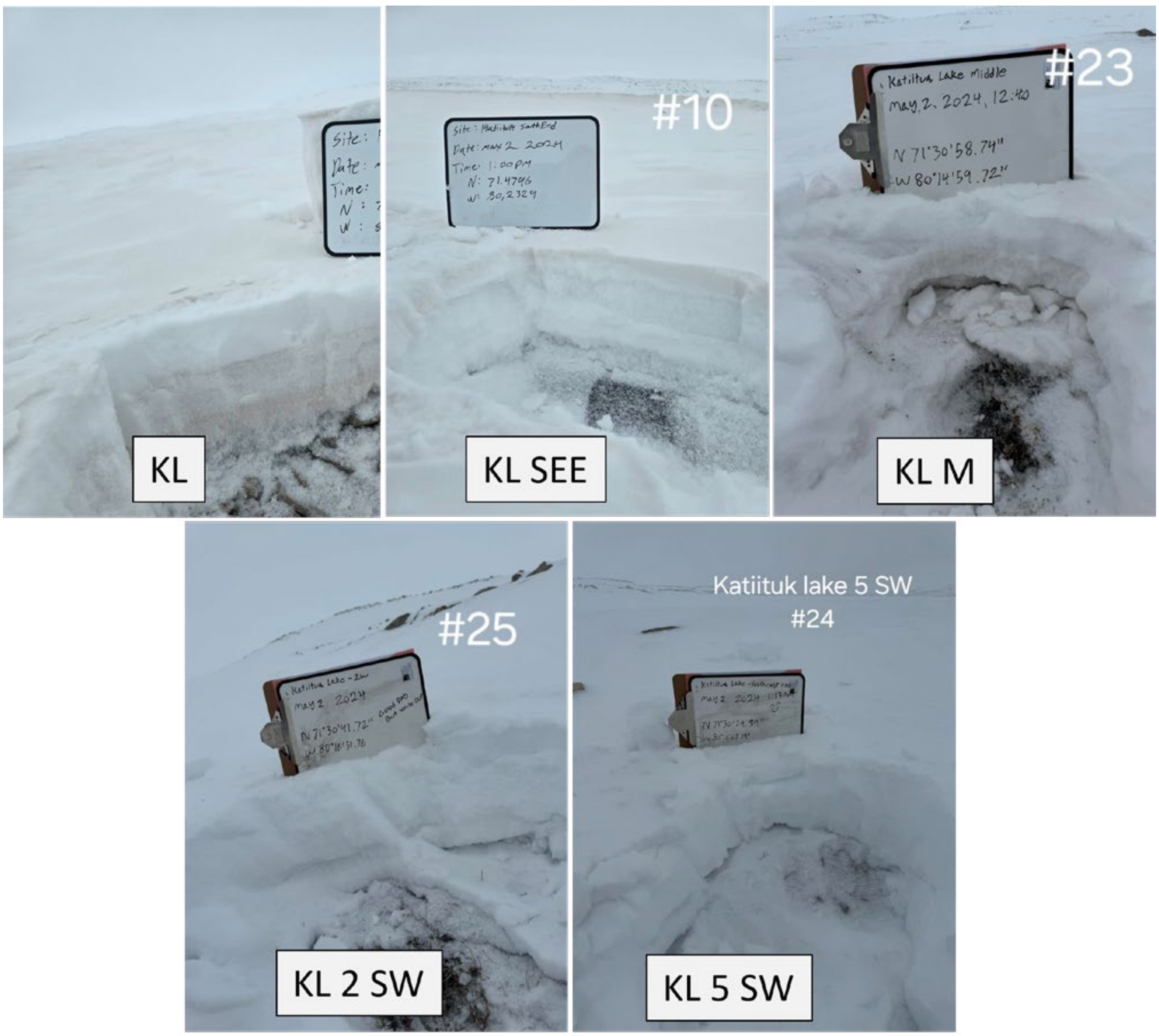

Figure 4: *Vertical cut of snowpacks sampled around Katiktuk Lake (KL) at spring 2024*

- **QURLUQTUQ LAKE:**
  The snowpack at Qurluqtuq Lake stations (QL 1, QL 2) was notably deep but showed no significant red discoloration (Figure 5).
- **MILNE INLET:**
  The snowpack on the ice sheet at Bruce Head (BH1) was thin and visually clean.
- **REFERENCE STATIONS:**
  Snowpack at reference stations (Ref. 2, Ref A, Ref B) was apparently clean.

__Figure 5:__ Vertical cut of snowpacks sampled in Milne Inlet (BH1 and reference stations) and at Qurluqtuuq Lake (QL 1 and QL 2) at spring 2024

3.1.2 TSS/TDS

The Canadian Council of Ministers of the Environment (CCME) water quality guideline for the protection of aquatic life for TSS is set at 5 mg/L above the natural baseline concentration found in a given environment. Based on our baseline TSS concentration of 5 mg/L measured at our reference site (Figure 1), our TSS guideline was fixed at 10 mg/L. 15 out of 28 snow samples tested have exceeded the TSS guideline for the protection of aquatic life (Figure 6, Table 2 and 3). Among the 15 positive samples, 9 of them showed TSS levels between 10 and 100 times above the CCME guideline for the protection of aquatic life (Figure 6). Three samples were situated along the Tote Road at Katiktuk Lake (KL, KL-M, KL -SEE), one near Milne Port infrastructure (MP 2 SSW) and five in a 10 km radius around the Mine Site (MS 2 SE, New Site 1, MS 5 NW, MS 10 NW and ML South). Snow samples at the remaining stations, including our 3 references stations, showed TSS concentrations below the CCME guideline (QL1, QL2, BH 1, MP 10 NE, MP 5 SSW, MP 10 SSW, MP 15 SSW, KL 2 SW, MS 30 WNW, MS 15 SE).

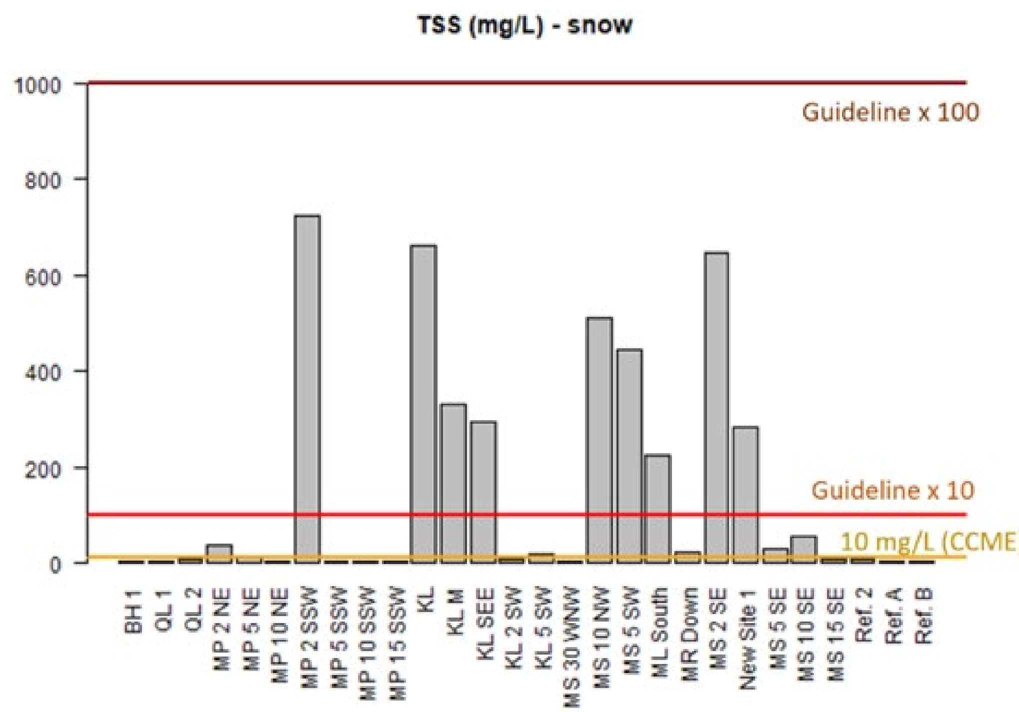

Figure 6: *Total Suspended Solids (TSS) concentrations measured in snow sampled near the project area at spring 2024. The orange line represents the Canadian Council of Ministers of the Environment (CCME) guideline for the protection of aquatic life. The red line exceeds ten times the CCME guideline value.*

Total dissolved solids (TDS) were low in the snow covering terrestrial areas but significantly higher in the snow covering the sea ice (e.g., MP 2 NE, MP 5 NE, MP 10 NE, BH 1, Ref B; Figure 7). This suggest that TDS is sensitive to seawater influence and reflects its ions enriched composition (e.g. notably high concentrations of calcium, magnesium, potassium, sodium, and sulfur in snow samples covering the sea ice vs snow samples collected on the land (Tables 2 and 3).

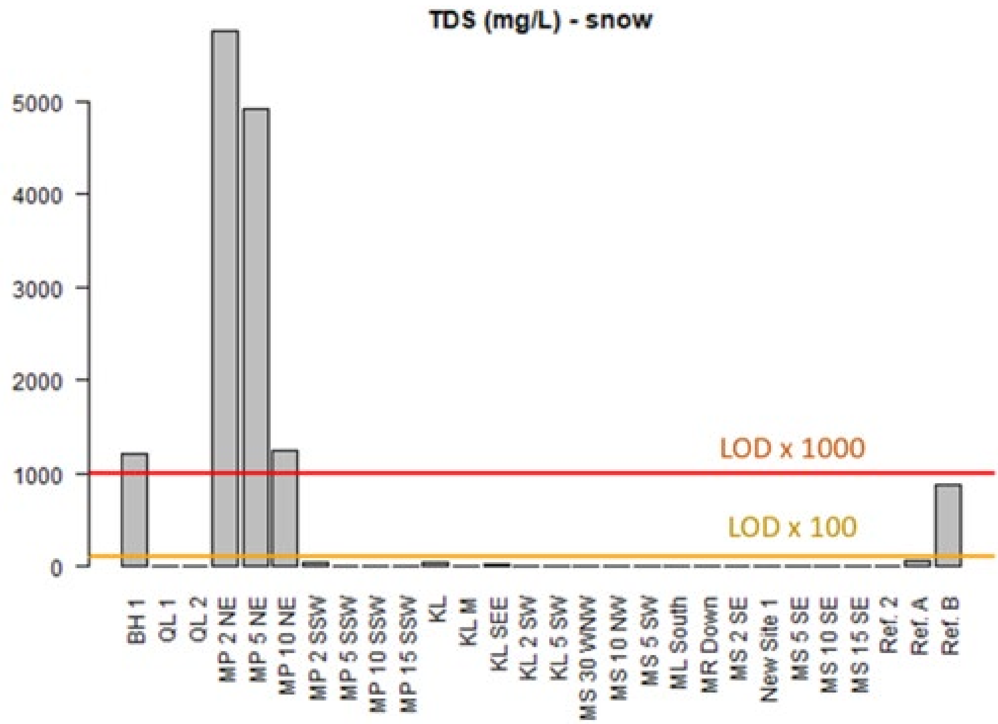

Figure 7: *Total Dissolved Solids (TDS) concentration measured in snow sampled at spring 2024. The orange line and red line represent 100 and 1,000 times the limit of detection (LOD), respectively.*

3.1.3 Trace Metals

Concentrations of trace metals in snow sampled from 28 stations are summarized in Tables 2 and 3. 39 metal species were tested. At 18 of the 28 stations (including reference stations), at least one metal exceeded the CCME guideline for the protection of aquatic life. Aluminum (Al), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), cadmium (Cd), chromium (Cr), and mercury (Hg) exceeded the guideline for the protection of aquatic life for at least one station. It is important to note that for16 metal species, CCME has not yet established any guidelines for the protection of aquatic life.

Trace metal concentrations in snow were related to the distance of the sampling station to the project area: mine infrastructures, transport infrastructures and stock piling (Figure 9). For example, in snow sample collected at station MP 2 SSW located close to the Milne Port infrastructure, six metal species exceeded the CCME guideline for the protection of aquatic life, whereas concentrations were relatively low at stations located farther away from the port (e.g., BH 1, QL 1, MP 15 SSW, MP 10 SSW).

Snow samples collected at stations located along the Tote Road near Katiktuk Lake had up to six metal species exceeding the CCME guideline for the protection of aquatic life, whereas contamination was noticeably lower at stations located off the road (KL 2 SW, KL 5 SW, MS 30 WNW).

In snow samples collected at stations located close to the mine site, up to six metal species exceeded CCME guideline for the protection of aquatic life, whereas concentrations were low at other stations located farther from the mine (MS 30 WNW, MS15SE).

Table 2: *Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Trace metals concentration in snow sampled at spring 2024 near Milne Inlet and Katiktuk Lake. Colors highlight stations exceeding the CCME's guidelines for the protection of aquatic life. LOD stands for Limit of Detection. See Figure 1 for the geographic location of the stations.*

Analyte in SNOW	Units	LOD	Canadian Guidelines			Bruce Head	Qurluqtuuq Lake		Milne Port							Katiktuk Lake				
			CCME Aquatic Life[A]	CDWQS[B]	CCME Livestock[A]	BH 1*	QL 1	QL 2	MP 2 NE*	MP 5 NE*	MP 10 NE*	MP 2 SSW	MP 5 SSW	MP 10 SSW	MP 15 SSW	KL	KL M	KL SEE	KL 2 SW	KL 5 SW
Hardness	mg/L	0,5				244	1,38	1,32	977	847	266	11,4	2,44	0,5	1,58	12,6	11,6	12,8	0,89	1,64
TDS	mg/L	10				1200	10	10	5760	4920	1250	50	10	10	10	35	12	21	10	10
TSS	mg/L	3	10[1]			3,8	3,4	7,1	35,7	13	4,2	726	3	3	3	663	332	295	9,3	17
pH	pH	0,1				7,85	6,64	6,47	8,41	8,03	6,59	7,38	6,65	5,88	7,28	8,83	8,16	8,2	6,3	6,87
Aluminum	µg/L	3	100[2]	2900	5000	40,4	32,8	108	300	139	60,6	8390	30,8	19,5	49	7340	3450	4520	112	202
Copper	µg/L	0,5	2[3]	2000	1000	5	0,56	0,5	5	5	5	8,55	0,5	0,5	0,5	3,67	3,07	3,75	0,5	0,5
Iron	µg/L	10		*300[7]*		100	65	139	1060	345	100	11000	26	12	22	6340	3720	4270	94	196
Lead	µg/L	0,05	1[3]	5	100	0,5	0,126	0,133	0,5	0,5	0,5	13,8	0,05	0,05	0,092	8,41	3,97	5,04	0,125	0,23
Manganese	µg/L	0,1		120		1,45	1,96	5,2	20,5	8,9	3,33	417	1,19	0,49	0,96	174	93,5	114	2,91	5,41
Nickel	µg/L	0,5	25[3]		1000	5	0,5	0,5	5	5	5	11,5	0,5	0,5	0,5	2,53	1,96	1,76	0,5	0,5
Uranium	µg/L	0,01	15	20	200	0,142	0,01	0,068	0,58	0,457	0,145	9,96	0,011	0,01	0,01	5,81	2,14	2,64	0,042	0,096
Zinc	µg/L	1			50000	30	3	3	30	30	30	28,1	3	3	3	36,8	35,1	25,2	3	3
Arsenic	µg/L	0,1	5	10	25	1	0,1	0,1	1	1	1	1,5	0,1	0,1	0,1	0,53	0,38	0,37	0,1	0,1
Cadmium	µg/L	0,005	0,04[6]	7	80	0,05	0,005	0,005	0,05	0,05	0,05	0,0269	0,005	0,005	0,0058	0,02	0,0115	0,01	0,005	0,005
Chromium	µg/L	0,5	1[4]	50	50[5]	5	0,5	0,5	5	5	5	10,6	0,5	0,5	0,5	4,55	3,18	3,06	0,5	0,5
Mercury	µg/L	0,005	0,026	1	3	0,005	0,005	0,005	0,0404	0,0199	0,005	0,0155	0,005	0,005	0,005	0,005	0,005	0,0103	0,005	0,005
Selenium	µg/L	0,05	1	50	50	0,5	0,05	0,05	0,5	0,5	0,5	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Silver	µg/L	0,01	0,25			0,1	0,01	0,01	0,1	0,1	0,1	0,052	0,01	0,01	0,01	0,028	0,014	0,016	0,01	0,01
Barium	µg/L	0,1		2000		1	1,44	0,95	4,23	2,72	1,17	48,9	0,34	0,17	0,33	78,9	52,8	50,5	1,54	3,28
Beryllium	µg/L	0,02			100	0,2	0,02	0,02	0,2	0,2	0,2	0,42	0,02	0,02	0,02	0,295	0,136	0,156	0,02	0,02
Bismuth	µg/L	0,05				0,5	0,05	0,05	0,5	0,5	0,5	0,116	0,05	0,05	0,05	0,064	0,05	0,05	0,05	0,05
Boron	µg/L	10	1500	5000	5000	162	10	10	671	605	190	10	10	10	10	10	10	10	10	10
Calcium	µg/L	50			1000000	20200	445	454	66000	57100	17000	6760	748	105	689	18400	12100	13500	501	739
Cesium	µg/L	0,01				0,1	0,01	0,014	0,1	0,1	0,1	1,72	0,01	0,01	0,01	1,59	0,74	1,04	0,022	0,041
Cobalt	µg/L	0,1			1000	1	0,1	0,12	1	1	1	8,88	0,1	0,1	0,1	2,07	1,3	1,21	0,1	0,1
Lithium	µg/L	1				10	1	1	22,8	22,2	10	24,6	1	1	1	20,7	8,9	13,6	1	1
Magnesium	µg/L	5				50400	204	159	202000	185000	59500	4920	305	48,6	188	8920	4870	5980	230	303
Molybdenum	µg/L	0,05	73		500	0,5	0,05	0,05	1,82	1,58	0,5	0,29	0,05	0,05	0,05	0,599	0,42	0,448	0,05	0,05
Phosphorus	µg/L	50				500	50	50	500	500	500	194	50	50	50	94	66	63	50	50
Potassium	µg/L	50				13800	112	54	56400	54100	16100	2730	70	50	50	2740	1420	2020	50	95
Rubidium	µg/L	0,2				4,24	0,2	0,23	16,1	14,7	4,62	21,6	0,2	0,2	0,2	23	11,9	16,4	0,38	0,74
Silicon	µg/L	100				1000	100	200	1000	1000	1000	12600	100	100	100	10900	5650	7140	190	350
Sodium	µg/L	50				342000	706	403	1570000	1340000	361000	5650	1500	178	453	1780	919	1200	134	199
Strontium	µg/L	0,2		7000		307	0,99	0,86	1140	1040	334	24	1,6	0,27	0,92	27,8	17,7	22,6	0,63	1,17
Sulfur	µg/L	500				48700	500	500	184000	100000	10200	560	500	500	500	500	500	500	500	500
Tellurium	µg/L	0,2				2	0,2	0,2	2	2	2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Thallium	µg/L	0,01	0,8			0,1	0,01	0,01	0,1	0,1	0,1	0,153	0,01	0,01	0,01	0,144	0,077	0,102	0,01	0,01
Thorium	µg/L	0,1				1	0,1	0,1	1	1	1	5,08	0,1	0,1	0,1	4,21	2,13	2,47	0,1	0,1
Tin	µg/L	0,1				1	0,1	0,1	1	1	1	0,45	0,1	0,1	0,1	0,59	0,31	0,39	0,1	0,1
Titanium	µg/L	0,3				3	0,76	2,15	7	4	3	210	0,79	0,37	0,78	228	127	184	3,43	6,64
Tungsten	µg/L	0,1				1	0,1	0,1	1	1	1	0,1	0,1	0,1	0,1	2,86	1,01	0,75	0,1	0,1
Vanadium	µg/L	0,5			100	5	0,5	0,5	5	5	5	4,04	0,5	0,5	0,5	4,31	2,38	3,27	0,5	0,5
Zirconium	µg/L	0,2				2	0,2	0,2	2	2	2	0,87	0,2	0,2	0,2	0,93	0,6	0,68	0,2	0,2

[A] *Guideline from the Canadian Council of Ministers of the Environment [Consulted online on 2024-10-01] – short-time guideline*

[B] *Canadian Drinking Water Quality Guideline from the Health Canada website [Consulted online on 2024-10-01]*

* *Station under marine influence - Detection Limit Raised: Dilution required due to high concentration of test analyte(s).*

1 – The average increase should not exceed 5 mg/L above background levels (5 mg/kg at reference stations) for long term exposure (24h to 30 days)

2 - If pH ≥ 6.5 (long-term exposure)

3 - For waters hardness between 0 and 60 mg $CaCO_3 \cdot L^{-1}$ (right except for snow on ice sheet)

4 - Guideline for Cr(iV), the principal species found in surface waters and aerobic soils

5 - Interim guideline

6 - For waters hardness between 0 and 17 mg $CaCO_3 \cdot L^{-1}$

7 - Guideline for iron is an Aesthetic Objective (AO) of less than or equal to 0.3 milligrams per liter (mg/L). If Aesthetic Objective is exceeded the water could taste bad but it remains safe for drinking.

Table 3: *Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Trace metals concentration in snow sampled at spring 2024 near the Mary River Mine Site and at Reference stations. Colors highlight stations exceeding the CCME's guidelines for the protection of aquatic life. LOD stands for Limit of Detection. See Figure 1 for the geographic location of the stations.*

Analyte in SNOW	Units	LOD	Canadian Guidelines			Mine Site										Reference		
			CCME Aquatic Life[A]	CDWQS[B]	CCME Livestock[A]	MS 30 WNW	MS 10 NW	MS 5 SW	ML South	MR Down	MS 2 SE	New Site 1	MS 5 SE	MS 10 SE	MS 15 SE	Ref. 2	Ref. A	Ref. B*
Hardness	mg/L	0,5				1,19	4,86	2,61	1,82	0,96	4,08	2,1	0,52	0,89	2,56	4,94	12,4	174
TDS	mg/L	10				10	11	10	10	11	10	10	10	10	10	10	65	874
TSS	mg/L	3	10[1]			3,8	512	446	225	22,8	649	284	28,7	55,8	6,3	6,9	3	3
pH	pH	0,1				6,56	7,28	7,44	6,34	6,16	6,64	6,35	5,92	6,57	6,59	7,16	5,92	6,71
Aluminum	µg/L	3	100[2]	2900	5000	60,6	7660	5530	2980	1210	8970	6000	392	327	79,9	79,6	12,8	59,5
Copper	µg/L	0,5	2[3]	2000	1000	0,5	6,6	12	4,88	1,97	15,4	8,19	0,7	0,91	0,8	0,5	1,2	0,5
Iron	µg/L	10		*300[7]*		49	8430	8450	5000	2860	27600	12800	797	690	86	91	10	59
Lead	µg/L	0,05	1[3]	5	100	0,073	7,05	9,94	2,23	0,626	3,86	2,76	0,226	0,325	0,139	0,139	0,192	0,132
Manganese	µg/L	0,1		120		1,98	211	203	145	59,2	657	268	24	17,1	4,06	3,95	0,21	1,42
Nickel	µg/L	0,5	25[3]		1000	0,5	7,35	16,6	12,2	3,5	39,1	20,6	1,09	1,56	0,5	0,5	0,5	0,5
Uranium	µg/L	0,01	15	20	200	0,013	3,38	1,08	0,446	0,157	0,915	0,563	0,047	0,035	0,064	0,014	0,01	0,083
Zinc	µg/L	1			50000	3	43,9	21,9	11,7	4,9	24,5	17	3	3	3	3	3	3
Arsenic	µg/L	0,1	5	10	25	0,1	0,6	1,36	0,68	0,36	2,46	1,25	0,16	0,12	0,1	0,1	0,1	0,1
Cadmium	µg/L	0,005	0,04[6]	7	80	0,005	0,0293	0,0628	0,0221	0,0092	0,103	0,0321	0,005	0,005	0,005	0,005	0,005	0,005
Chromium	µg/L	0,5	1[4]	50	50[5]	0,5	8,16	12,3	8,94	3,05	24,9	18,3	1,06	1,34	0,5	0,5	0,5	0,5
Mercury	µg/L	0,005	0,026	1	3	0,005	0,005	0,005	0,005	0,005	0,0052	0,005	0,005	0,005	0,005	0,005	0,005	0,0152
Selenium	µg/L	0,05	1	50	50	0,05	0,05	0,058	0,065	0,05	0,073	0,065	0,05	0,05	0,05	0,05	0,05	0,05
Silver	µg/L	0,01	0,25			0,01	0,033	0,073	0,022	0,01	0,05	0,036	0,01	0,01	0,01	0,01	0,01	0,01
Barium	µg/L	0,1		2000		0,61	80,5	41,4	24,7	7,7	28,2	27,6	3,1	1,64	0,77	1,18	0,12	0,77
Beryllium	µg/L	0,02			100	0,02	0,27	0,247	0,129	0,05	0,42	0,251	0,02	0,02	0,02	0,02	0,02	0,02
Bismuth	µg/L	0,05				0,05	0,142	0,204	0,054	0,05	0,158	0,129	0,05	0,05	0,05	0,05	0,05	0,05
Boron	µg/L	10	1500	5000	5000	10	10	10	10	10	10	10	10	10	10	10	10	122
Calcium	µg/L	50			1000000	645	4870	10000	1030	318	1260	951	203	399	509	2570	803	11500
Cesium	µg/L	0,01				0,01	1,16	0,675	0,299	0,084	0,299	0,388	0,034	0,021	0,01	0,01	0,01	0,012
Cobalt	µg/L	0,1			1000	0,1	3,92	5,22	4,52	1,73	25,9	8,59	0,59	0,6	0,1	0,1	0,1	0,1
Lithium	µg/L	1				1	14,7	7,2	4,7	1,6	18,5	9,5	1	1	1	1	1	4,4
Magnesium	µg/L	5				151	4690	9200	3100	1050	7700	5640	361	455	423	606	2600	35100
Molybdenum	µg/L	0,05	73		500	0,05	0,668	0,507	0,163	0,116	0,259	0,207	0,063	0,091	0,05	0,05	0,05	0,284
Phosphorus	µg/L	50				50	188	417	170	53	302	171	50	50	50	50	50	50
Potassium	µg/L	50				50	3300	2420	944	386	1240	1390	179	126	92	98	678	9010
Rubidium	µg/L	0,2				0,2	23,3	18,3	7,11	2,21	7,51	8,52	1,05	0,49	0,28	0,23	0,21	2,63
Silicon	µg/L	100				130	11100	8710	4620	1820	10200	8130	580	550	150	150	100	130
Sodium	µg/L	50				96	1410	467	504	210	505	468	165	199	297	1170	18300	266000
Strontium	µg/L	0,2		7000		0,6	20,4	9,89	4,1	1,21	4,36	2,91	0,44	0,56	0,58	5,32	14,3	195
Sulfur	µg/L	500				500	500	500	500	500	810	500	500	500	500	500	680	26600
Tellurium	µg/L	0,2				0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Thallium	µg/L	0,01	0,8			0,01	0,14	0,121	0,052	0,015	0,075	0,067	0,01	0,01	0,01	0,01	0,01	0,01
Thorium	µg/L	0,1				0,1	3,43	3,11	0,96	0,31	2,1	1,35	0,1	0,1	0,1	0,1	0,1	0,1
Tin	µg/L	0,1				0,1	0,44	0,3	0,15	0,1	0,2	0,17	0,1	0,1	0,1	0,1	0,1	0,1
Titanium	µg/L	0,3				1,91	291	285	143	39,8	160	194	15,1	10,7	3,58	2,36	0,38	3
Tungsten	µg/L	0,1				0,1	1,28	0,38	0,83	0,1	0,1	0,12	0,1	0,1	0,1	0,1	0,1	0,1
Vanadium	µg/L	0,5			100	0,5	6,68	11,2	4,61	1,42	5,38	6,58	0,56	0,5	0,5	0,5	0,5	0,5
Zirconium	µg/L	0,2				0,2	0,84	1,15	0,42	0,2	0,5	0,33	0,2	0,2	0,2	0,2	0,2	0,2

ALUMINUM (AL)

At 17 stations, the concentration of Al in snow exceeded the CCME guideline for the protection of aquatic life (0.1 mg/L). Among these stations, 9 of them exceeded the guideline for drinking water quality (2.9 mg/L) and 6 of them (MP 2 SSW, KL, MS 10 NW, MS 5 SW, MS 2 SE and New Site 1) exceeded the guideline for the protection of livestock (5 mg/L, Table 3, Figure 8a). The guideline for the protection of livestock addresses concentrations that are susceptible to be toxic for animals . Concentrations of dissolved aluminum (readily assimilable by organism) exceeded the CCME guideline for the protection of aquatic life at one stations (KL SEE) and were elevated in the other Kitiktuk lake samples in general.

Table 4: *Dissolved aluminum, manganese and zinc concentration in snow sampled near the project area at spring 2024. Colors highlight stations exceeding the Canadian Council of Ministers of the Environment (CCME)'s guideline for the protection of aquatic life. LOD stands for Limit of Detection. See Figure 1 for the geographic location of the stations.*

Analyte in SNOW (dissolved)	Units	LOD	Canadian Guidelines			Stations								
			CCME Aquatic Life[A]	CDWQS[B]	CCME Livestock[A]	KL	KL M	KL SEE	KL 5 SW	MS 2 SE	MS 10 NW	MS 30 NW	MP 2 SSW	MP 5 SSW
Aluminum	µg/L	1	100[1]	2900	5000	83	56	104	56	3	45	1,5	16	1,6
Manganese	µg/L	0,1	110[2]	120		4.0	4.0	2.2	1.5	75	14	0.8	74	0.7
Zinc	µg/L	1	30[3]		50000	1	1	1	1	1	1	1	1	1

1 - Guidelines are for total concentrations
2 - Guidelines are for dissolved concentrations

COPPER (CU)

At 9 stations, the concentration of Cu in snow exceeded the guideline for the protection of aquatic life (2 µg/L) (Figure 8b):

LEAD (PB)

At 9 stations, the concentration of Pb in snow exceeded the guideline for the protection of aquatic life (1 µg/L). Among these stations, 5 of them (MP 2 SSW, KL, KL SEE, MS 10 NW, MS 5 SW) exceeded the guideline for drinking water quality (5 µg/L) (Figure 8c).

IRON (FE)

At 14 sites, the concentration of Fe exceeded Aesthetic Objective of 0.3 mg/L of the CDWQS (Figure 8d). There is currently no human health-based guideline value for Fe. If the Aesthetic Objective is exceeded the water may have a bad taste but remains safe for drinking. However, at station MS 2 SE (27.6 mg/L), the Fe concentrations in snow were 100 times the Aesthetic Objective. Nine other stations have concentrations 10 to 100 times the aesthetic objective.

MANGANESE (MN)

At 7 stations (MP 2 SSW, KL, MS 10 NW, MS 5 SW, ML South, MS 2 SE, New Site 1), the concentration of Mn in snow exceeded the guideline for drinking water quality (120 µg/L) (Figure 8e).

CHROMIUM (CR)

At 12 sites, the concentration of Cr in snow exceeded the guideline for the protection of aquatic life (1 µg/L) (Figure 8g).

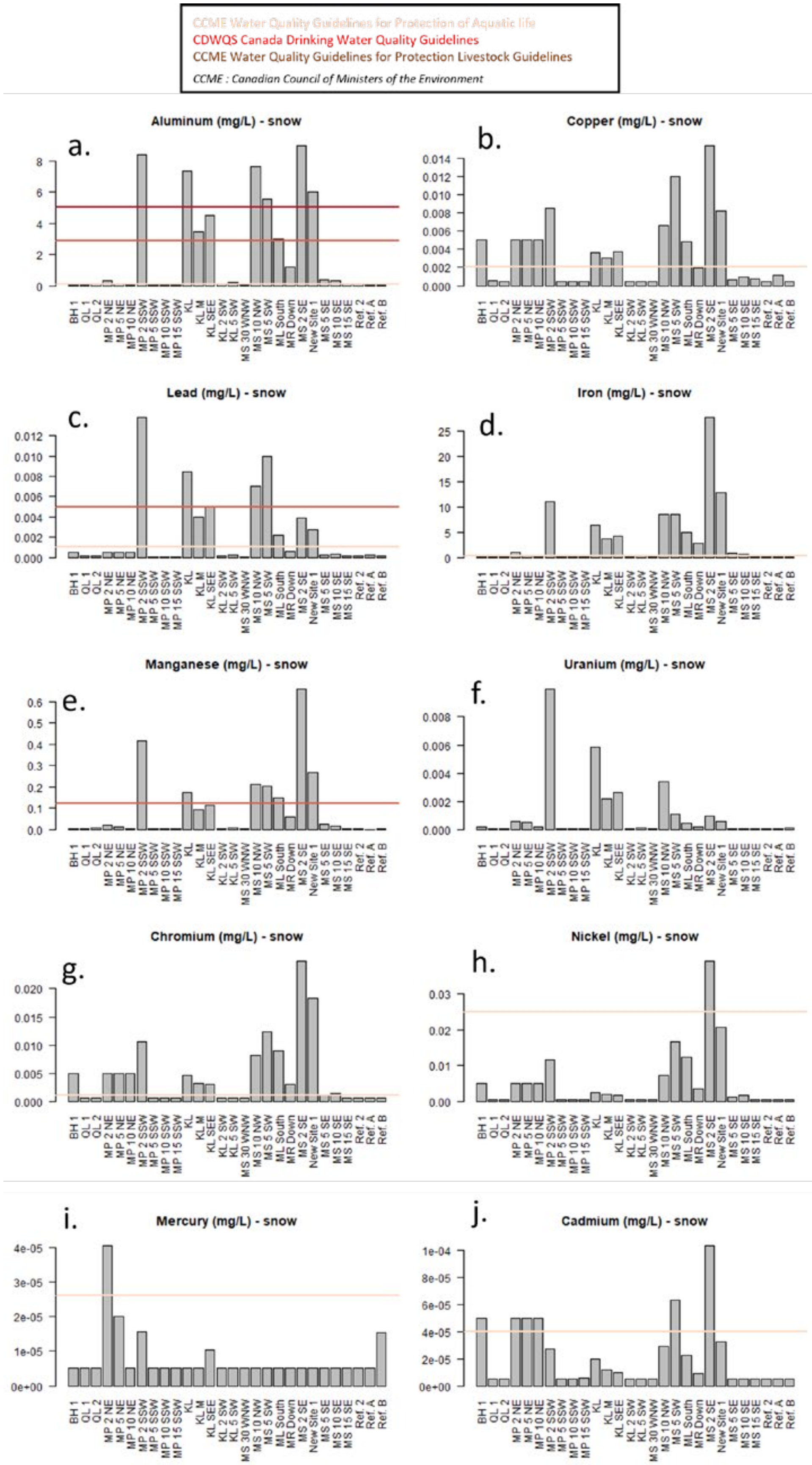

Figure 8: *Trace metals concentration measured in snow samples in spring 2024. Colored bars represent the different Canadian guidelines (see legend)*

MERCURY (HG)

One station (MP 2 NE) exhibit concentration of Hg over the guideline for protection of aquatic life (26 ng/L for long-term exposure) (Figure 8i).

CADMIUM (CD)

As Hg, Cd is toxic at very low concentrations. Six stations exhibit concentration over the guideline for protection of aquatic life (40 ng/L for long-term exposure). The highest level was observed at station MS 2 SE (Figure 8j).

NICKEL (NI)

The concentration of Ni exceeded the guideline for the protection of aquatic life (25 µg/L for acute exposure) at MS 2 SE (Figure 8h).

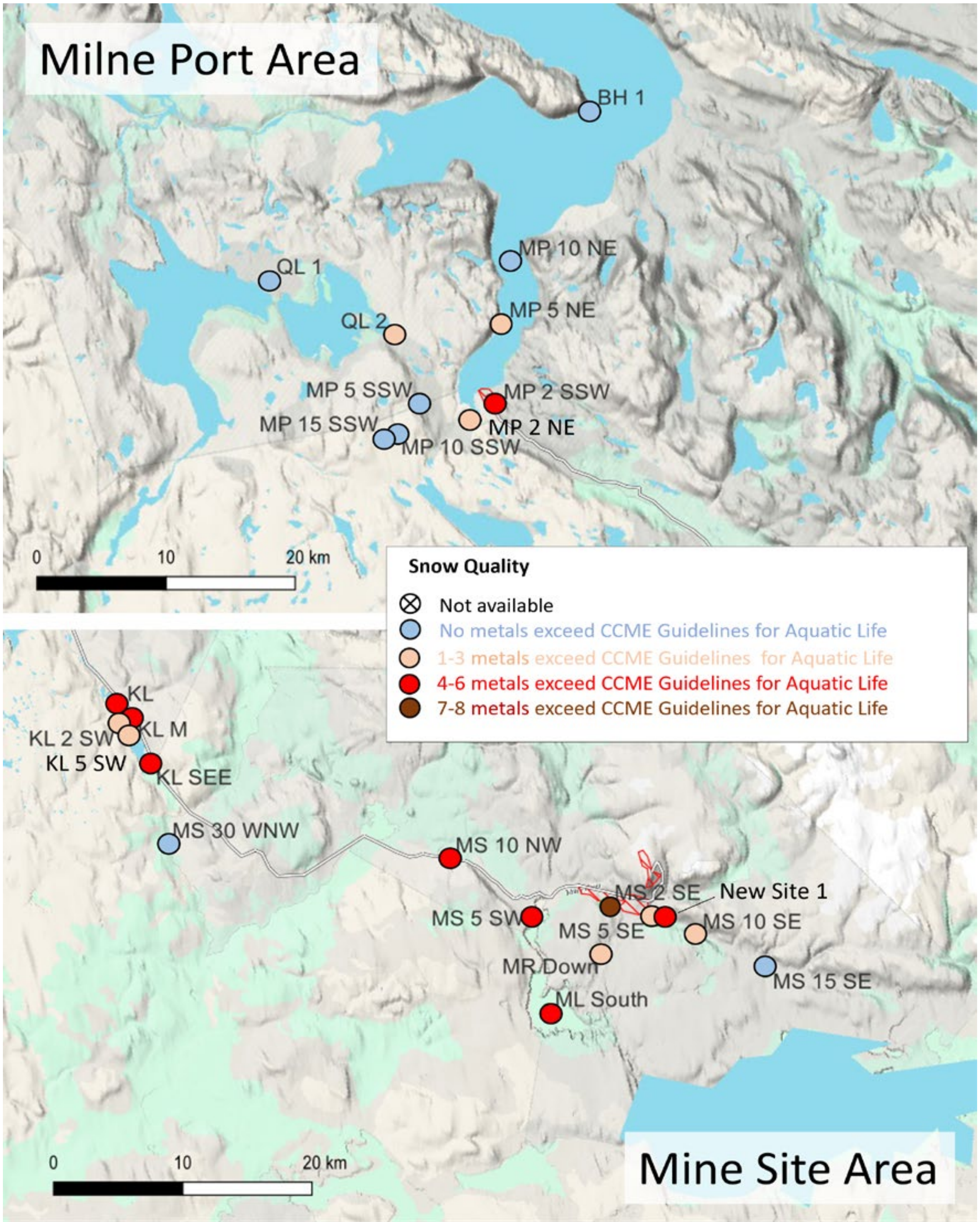

Figure 9: *Map showing stations where different trace metals in snow exceeded the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life.*

3.2 Lichen

3.2.1 Trace Metals

The concentration of trace metals in lichen varied significantly across the 18 sampled stations. The levels of trace metals measured at each location were compared to those in lichen from uncontaminated reference stations (Ref B and Ref 2) (Table 5). Notably, lichen sampled at MS 10 NW, along the tote road, exhibited exceptionally high trace metal concentrations compared to the reference levels. The concentrations of Al (8,390 mg/kg dw), Cr (13.2 mg/kg dw), Fe (13,300 mg/kg dw), and U (3.04 mg/kg dw) were more than 20 times the values of the reference stations. Levels of Pb (7.48 mg/kg dw) and Ni (10.4 mg/kg dw) in lichen were 10 to 20 times the reference stations.

Lichen samples from stations along the Tote Road near Katiktuk Lake (KL M, KL SEE) showed elevated trace metal concentrations compared to the reference stations, especially Al, U and Pb.

Stations within a 5 km radius of the Mine Site showed elevated levels of Al, Cr, Ni, and Fe ranging from five to twenty times the values of the reference stations.

In contrast, lichen samples from stations farther from Milne Port (e.g., MP 10 SSW, QL 1), the Mine Site (e.g., MS 30 WNW, MS 10 SE, MS 15 SE) or the Tote Road generally exhibited trace metal concentrations that were within the range of or only slightly higher than those observed at the reference stations.

Table 5: *Trace metals concentration (dry weight) in lichen samples collected near the project area at spring 2024. LOD stands for Limit of Detection. See Figure 2 for the geographic location of the stations. The numbers in color indicate levels that are 5, 10, and 20 times higher than those in lichen from the reference stations.*

Metals LICHEN	Abbr.	LOD	Units	Qurluqtuuq Lake		Milne Port		Katiktuk Lake			Mine Site										Reference	
				QL 1	QL 2	MP 5 SSW	MP 10 SSW	KL 5 SW	KL M	KL SEE	MS 30 WNW	MS 10 NW	MS 5 SW	ML South	MR Down	MS 2 SE	New Site 1	MS 5 SE	MS 10 SE	MS 15 SE	Ref. B	Ref. 2
Aluminum	Al	2.0	mg/kg dw	893	1380	1500	200	1330	4420	3510	550	8390	1190	1010	1470	2150	2370	2240	741	979	190	329
Arsenic	As	0.020	mg/kg dw	0.243	0.276	0.334	0.048	0.282	0.506	0.366	0.080	0.321	0.141	0.133	0.274	0.576	0.481	0.351	0.144	0.131	0.066	0.083
Cadmium	Cd	0.0050	mg/kg dw	0.030	0.0382	0.0612	0.0141	0.0285	0.0451	0.0498	0.0393	0.0808	0.0100	0.0107	0.0731	0.0352	0.0763	0.0357	0.0445	0.0446	0.044	0.030
Chromium	Cr	0.050	mg/kg dw	1.71	2.68	1.47	0.400	2.65	8.41	4.57	1.15	13.2	4.34	5.73	3.45	5.12	6.49	5.91	1.75	1.75	0.36	0.70
Copper	Cu	0.10	mg/kg dw	2.54	3.57	2.95	1.10	3.56	6.37	4.78	1.72	11.4	2.04	3.97	4.62	4.86	5.77	3.37	3.74	2.30	2.43	2.04
Iron	Fe	3.0	mg/kg dw	1280	2030	1560	290	2180	7960	5200	929	13300	2220	2010	6000	9810	9000	5460	2590	1530	347	507
Lead	Pb	0.020	mg/kg dw	1.05	1.78	2.06	0.246	1.20	4.24	3.66	0.672	7.48	1.38	1.01	0.977	2.57	2.36	2.81	0.625	1.36	0.433	1.11
Manganese	Mn	0.050	mg/kg dw	38.2	62.4	45.5	9.14	65.0	160	98.3	31.0	222	36.9	33.9	47.8	107	121	71.7	35.9	79.5	40.2	17.3
Mercury	Hg	0.0050	mg/kg dw	0.0323	0.0789	0.0527	0.0913	0.0900	0.0575	0.0983	0.133	0.0382	<0.0050	0.0078	0.0343	0.0344	0.109	0.0755	0.0793	**0.183**	0.112	0.0654
Nickel	Ni	0.20	mg/kg dw	1.38	1.93	2.58	0.28	1.57	5.05	3.34	0.83	10.4	5.56	9.61	3.69	5.24	8.15	6.57	1.70	1.77	0.53	0.58
Selenium	Se	0.050	mg/kg dw	<0.10	0.065	0.064	<0.050	0.078	0.074	0.136	0.078	0.069	<0.050	<0.050	0.063	0.070	0.129	0.078	0.071	0.145	<0.10	<0.10
Uranium	U	0.0020	mg/kg dw	0.0892	0.266	0.565	0.0254	0.290	1.79	1.67	0.166	3.04	0.266	0.295	0.305	0.473	1.12	0.538	0.151	0.286	0.169	0.117
Zinc	Zn	0.50	mg/kg dw	11.0	24.4	15.6	12.6	24.8	27.0	17.1	20.7	38.7	6.39	5.78	29.3	14.4	25.4	13.9	25.4	13.6	11.5	15.2
Antimony	Sb	0.010	mg/kg dw	0.010	0.011	<0.010	<0.010	0.011	0.018	0.011	<0.010	0.016	<0.010	<0.010	0.012	0.014	0.019	0.013	<0.010	<0.010	<0.010	<0.010
Barium	Ba	0.050	mg/kg dw	6.99	7.02	12.0	1.52	8.48	29.8	33.0	10.3	56.5	6.68	7.13	38.1	11.0	30.0	15.0	10.1	18.8	117	11.8
Beryllium	Be	0.010	mg/kg dw	0.051	0.089	0.155	0.010	0.066	0.186	0.152	0.025	0.297	0.065	0.050	0.057	0.133	0.107	0.102	0.030	0.065	<0.010	0.015
Bismuth	Bi	0.010	mg/kg dw	0.010	0.025	0.025	<0.010	0.016	0.088	0.062	0.011	0.316	0.017	0.015	0.034	0.050	0.054	0.039	0.017	0.014	<0.010	<0.010
Boron	B	1.0	mg/kg dw	10.6	15.3	10.8	5.8	19.2	17.9	9.2	3.0	10.1	4.8	3.4	9.8	4.1	5.7	3.9	8.1	2.4	3.6	6.0
Calcium	Ca	20	mg/kg dw	35300	36300	27900	19100	32500	39200	16000	15000	15600	4140	2590	17200	7060	24700	7440	18100	2600	11500	27600
Cesium	Ce	0.0050	mg/kg dw	0.100	0.225	0.151	0.0178	0.196	0.718	0.634	0.0999	1.02	0.132	0.141	0.104	0.151	0.208	0.202	0.0620	0.0965	0.266	0.0375
Cobalt	Co	0.020	mg/kg dw	0.491	0.782	0.533	0.078	0.601	2.16	1.50	0.290	4.06	1.02	1.03	1.09	2.20	1.87	1.58	0.543	0.526	0.201	0.221
Lithium	Li	0.50	mg/kg dw	2.50	3.87	5.69	<0.50	6.04	14.7	8.85	1.05	13.4	2.55	1.98	1.71	3.23	2.46	3.96	0.84	1.03	<0.50	0.59
Magnesium	Mg	2.0	mg/kg dw	2300	4340	2330	1390	6980	14400	7410	1430	7050	2080	1750	3580	1980	3040	2020	2100	1460	1630	1010
Molybdenum	Mo	0.020	mg/kg dw	0.100	0.102	0.107	0.028	0.250	1.17	0.831	0.140	2.68	0.152	0.060	0.532	0.517	0.830	0.373	0.235	0.211	0.095	0.141
Phosphorus	P	10	mg/kg dw	289	331	347	1310	543	396	905	1040	512	347	263	377	320	637	427	739	1100	1230	267
Potassium	K	20	mg/kg dw	827	802	900	1500	1150	1930	2500	1840	3890	641	439	1420	759	1710	929	1340	1880	2270	801
Rubidium	Rb	0.050	mg/kg dw	2.43	3.56	2.54	0.548	4.34	13.6	13.9	3.42	27.4	3.54	2.84	3.09	4.59	7.39	5.94	2.34	4.54	15.0	1.17
Sodium	Na	20	mg/kg dw	125	78	52	231	32	96	108	288	208	21	<20	58	<20	110	68	121	150	1500	168
Strontium	Sr	0.050	mg/kg dw	22.5	21.7	15.8	11.3	14.8	25.7	15.6	11.1	32.4	3.72	3.53	18.6	4.78	10.9	4.94	7.69	3.83	36.1	56.4
Tellurium	Te	0.020	mg/kg dw	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Thallium	Tl	0.0020	mg/kg dw	0.0166	0.0262	0.0187	0.0036	0.0261	0.0893	0.0995	0.0131	0.167	0.0216	0.0203	0.0201	0.0346	0.0455	0.0426	0.0147	0.0134	0.0123	0.0073
Tin	Sn	0.10	mg/kg dw	<0.10	<0.10	<0.10	<0.10	<0.10	0.30	0.20	<0.10	0.50	<0.10	<0.10	<0.10	0.10	0.12	0.14	<0.10	<0.10	<0.10	<0.10
Vanadium	V	0.10	mg/kg dw	2.13	3.19	2.18	0.48	2.66	7.23	4.87	0.99	13.7	3.41	2.56	2.15	3.92	3.77	4.60	1.17	1.76	0.61	0.85
Zirconium	Zr	0.20	mg/kg dw	1.41	2.27	1.44	0.30	1.58	6.46	4.88	0.66	9.76	2.46	1.98	1.41	2.66	2.49	2.74	0.71	0.94	<0.60	<0.80

LOD	< Ref * 5	> Ref * 5	> Ref *10	> Ref * 20

Due to the lack of guidelines available and for comparison purpose, we compared our results to trace metal levels measured in lichen in other industrialized environment of the alpine tundra (Turkey (Uluozlu et al., 2007), Italy (Loppi et al., 2000) and in Nepal (Pandey et al., 2002) and Arctic tundra (Alaskan region (Ford et al. 1995) (Figure 10).

Concentrations of Al and Fe in lichen near the project area, at most stations monitored, exceeded levels observed in polluted areas, such as an incinerator site in Italy and roadside locations in Turkey (Figure 10). Cr and Ni levels in lichen collected near the mine site and Katiktuk Lake were also within the range of levels observed in lichen from roadside locations in Turkey (Figure 10).

Hg levels in some lichen samples (e.g., MS 30 WNW, New Site 1, and MS 15 SE) were higher than those measured in lichen collected just 50 meters from a solid waste incinerator in Italy (Figure 10). In contrast, the concentrations of other trace metals, such as Pb, Mn, and Zn, were lower than those reported in the scientific literature.

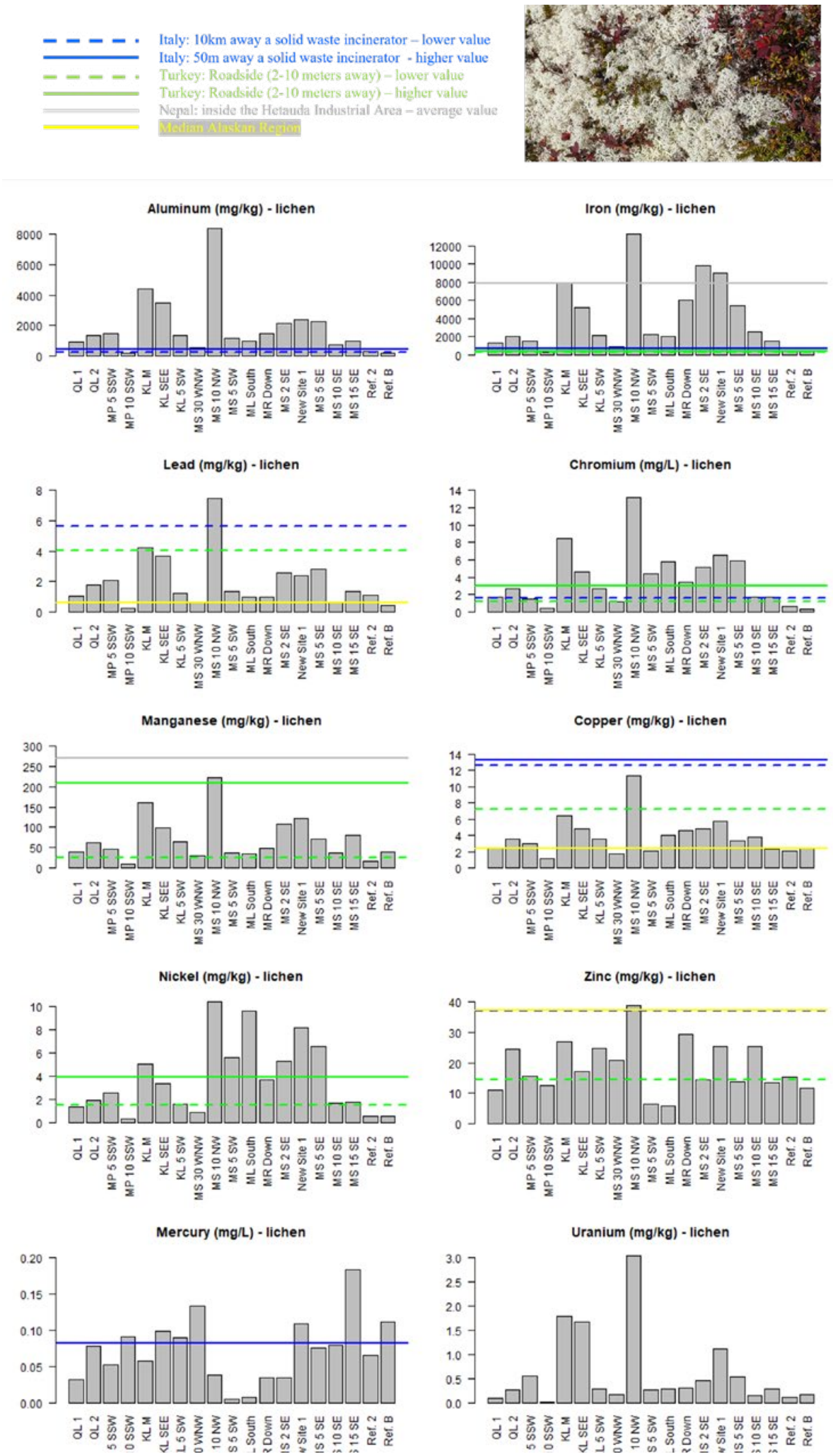

Figure 10: *Trace metals concentration (grey bars) in lichen samples collected in spring 2024 compared with lichen sampled from other industrialized areas of North America, Europe and Asia.*

4 - Discussion

4.1 Summary of the results

The objective of this study was to assess the potential persistence of fugitive dust contamination observed in 2023 around the Mary River Project Area (Coupel & L'Hérault, 2023). Following the recommendations of the 2023 report, we adapted our sampling design to better estimate the extent of dust deposition on snow and lichen by investigating gradients of dust deposition around previously identified hotspots of contamination; Mary River mine, Katiktuk lake (tote road) and Milne Inlet Port.

Concentrations of trace metals in snow and lichen showed significant geographical variability, with the highest contamination levels observed near the industrial infrastructures (Figure 9). At 18 of the 28 snow stations, at least one metal exceeded the guidelines for the protection of aquatic life defined by the CCME. Elevated trace metals concentrations correlated closely with high TSS levels, trace metals concentration in lichens and visual observations of snow discoloration at the stations. In snow samples, Al, Pb and Mn exceeded the drinking water guideline at 9 snow stations (Figure 8, Tables 2 and 3). The guideline for the protection of livestock, a more constraining guideline, was also exceeded for 6 of these sites.

MARY RIVER SITE

Within the stations sampled near the Mine Site, 50 % of them exceeded the CCME (aquatic life guideline) and the CDWQS (drinking water guideline) for Al and Mn. Al levels were even found above the guideline for the protection of livestock, Pb levels were over the drinking water guideline for MS 10 NW and MS 5 SW, and Ni levels exceeded the guideline for the protection of aquatic life at one station (MS 2 SE). Similarly, lichens at MS 10 NW showed exceptionally high levels of Al (8,390 mg/kg dw), Fe (13,300 mg/kg dw), Cr (13.2 mg/kg dw), and Ni (10.4 mg/kg dw).

KATIKTUK LAKE

Snow sampled at Katiktuk Lake stations, located along the Tote Road, (KL, KL M, KL SEE) were heavily contaminated. TSS levels were up to 100 times above the CCME guideline for the protection of aquatic life and elevated metal concentrations were found in both snow and lichen. 60% of the stations exceeded the drinking water guideline for Al and Pb concentrations. Lichens near Katiktuk lake accumulated Al, Cr, and Pb levels comparable to those found in polluted roadside environments in Europe (Uluozlu et al., 2007). Off-road stations (KL 2 SW, KL 5 SW) exhibited lower TSS levels, minimal discoloration, and trace metal concentrations closer to reference values, highlighting the localized impact of the fugitive iron dust released from the carrier trucks.

MILNE INLET PORT

Near Milne Port, MP 2 SSW exhibited the highest metal contamination in the area, with Pb and Cu exceeding drinking water and aquatic life guidelines, alongside visible snow discoloration and elevated TSS levels. Hg levels at MP 2 NE exceeded long-term aquatic life thresholds , possibly linked to seawater influence. Aluminum concentrations at Qurluktuuq 2 and MP 5NE exceeded the guideline for the protection of aquatic life. In contrast, farther stations such as MP 10 SSW and MP 15 SSW had clean snow, low TSS levels, and trace metal concentrations near reference levels, demonstrating reduced contamination with increasing distance.

OTHER SITES

Interestingly, Hg levels in lichen at some remote stations (e.g., MS 30 WNW, MS 15 SE), exceed values reported near industrial incinerators in other studies, despite the low TSS levels and minimal snow discoloration observed in this area. These results suggest that Hg deposition may originate from broader atmospheric sources rather than direct local industrial activities.

MULTIANNUAL OBSERVATIONS

In general, 2024 results are coherent with the 2023 report. Similar to 2023 snow results, and yet accounting a different sampling design, over 50% of the snow samples exceeded the CCME guideline for the protection of aquatic life for TSS levels. In line with the 2023 data, highest levels of trace metals in the 2024 snow samples were observed within a 10 km radius of the Mary River mine and along the tote road near Katiktuk lake. Similar to 2023, Al, Pb, Fe and Cr were elevated in snow and lichen sampled in 2024. A deeper look at Katiktuk Lake area in 2024 revealed the highest levels of trace metals found in the project area, with total Aluminum exceeding the guideline for the protection of aquatic life by 10 to 100 times. Gradient analyses rhighlighted a progressive decrease in trace metal levels with distance to infrastructures (divided by a factor of 100 from 2 to 10 km).

The 2024 results extend previous observations made in 2023, and highlight the persistence of contamination near the project area further confirmed through visual evidence of snow disclororation and testimonies of local land users. It points out to potential threat to aquatic and terrestrial ecosystems.

4.2 Potential impacts

The elevated TSS levels and trace metal concentrations observed in snow and lichen throughout the study area present significant risks to the local environment and Inuit communities who rely on these resources for subsistence and cultural practices. Near industrial sites, such as the Mine Site, along the Tote Road at Katiktuk Lake, high concentrations of Al, Mn, Pb, Ni, and other metals in snow and lichen highlight the potential for contamination to enter aquatic and terrestrial food webs. These metals pose direct health risks if introduced into drinking water sources, as melting snow is often used for drinking by Inuit communities. It is especially the case for Al, Pb and Mn levels in the snow (sometimes far) exceeding the limits of the Canadian Drinking Water Quality Guidelines (Figure 8, Tables 2 and 3).

For instance, elevated Al levels, which were well above the livestock protection guideline in snow and particularly high in lichen compared to reference areas, could lead to neurological, urinary tract, and toxicological effects in humans (Health Canada, 2019). Pb concentrations exceeding drinking water guidelines could impair the central nervous system, while Mn could affect neurological development, memory, and motor skills, particularly in children (Health Canada, 2019).

Contamination of aquatic ecosystems could also lead to bioaccumulation throughout the food chain, affecting animals commonly consumed by Inuit communities (e.g. lake trout, land-locked chars). These contaminants may compromise the safety of traditional fishing practices in lakes and streams, where the deposition of fine sediments (high TSS) could also reduce fish populations by impairing egg and larval survival (Erman and Erman 1984; Noel et al. 1986; Valiela et al. 1987; Culp 1996). The connection between the land watershed and the marine ecosystem, particularly through the water carried from Philips Creek down to Milne Inlet, raises serious consideration for the contamination of the marine ecosystem. Dust accumulation and contamination of the snow near the Milne port is evident, and extend far to the sea ice and the waters of Milne Inlet with potential consequences on the benthic and pelagic invertebrates, fish and marine wildlife.

Furthermore, elevated trace metal levels in lichen, the main food source for caribou, may impact the health of caribou populations and, consequently, the food security of Inuit communities relying on caribou as a traditional food. Metals such as Ni, Cr, and Pb found at high levels near the Mine Site and Tote Road could accumulate in the tissues of caribou, raising concerns for human health.

These findings underscore the need for ongoing monitoring of snow, water, and biota, alongside mitigation efforts to reduce fugitive dust and industrial emissions, to protect both the environment and the health and well-being of Inuit communities.

4.3 Limits of the study

Although multiple lines of evidence indicate snow contamination by ore dust near the project area, the impacts on aquatic, terrestrial, and marine ecosystems remain uncertain. Melted snow samples were analyzed and compared to Canadian guidelines; however, these results do not directly reflect conditions within aquatic ecosystems. The mass melting of snow during spring releases sediments and trace metals into aquatic and terrestrial environments, potentially degrading water quality and posing risks to species, humans, and wildlife.

5 - Recommendations

5.1 Snow monitoring

This report confirms elevated contamination levels in snow samples collected near the project area. To further assess the extent of contamination, snow sampling could be conducted along a four-directional gradient extending up to 30 km outward from the mining infrastructure and along perpendicular transects near Katiktuk lake. Certain metals, such as Hg, exhibit elevated levels in areas located far from industrial infrastructure. These findings underscore the importance of sampling in regions distant from industrial activities to identify metals originating from sources other than local industry. Additional sampling along the tote road is recommended to determine whether the elevated contamination at Katiktuk Lake is representative of broader patterns observed along the entire length of the tote road.

5.2 Terrestrial ecosystems

We recommend the continuation of lichen sampling as it serves as an effective indicator of trace metal accumulation into terrestrial vegetation and potential uptake by wildlife (Budzyńska-Lipka et al., 2022). Similar to snow sampling, an outward gradient approach should be implemented to identify areas where lichen is impacted by dust pollution.

5.3 Seasonal and Spatial Monitoring

To gain deeper insight into the influence of snow contamination on aquatic ecosystems, future sampling during the summer is recommended. Analyzing trace metals in rivers and at the estuary in Milne Inlet could effectively indicate the transfer of metals from contaminated snow to aquatic systems. Additionally, sampling benthic organisms at the river mouth near Milne Port would offer insights into the transfer of trace metals from dust deposition into the aquatic food web. Sampling lichen later in the year would provide valuable information on the residence time of metals in lichen and help assess potential seasonal variations in contaminant accumulation. In the future, additional sampling of animals of interest (e.g. lake trout, land-locked char, small game, or caribou) should be considered to address potential bioaccumulation patterns of trace metals and potential risks to the health of Inuit communities.

5.4 Identify the source of contaminants

A quantitative analysis of the mineral and geochemical composition of iron ore dust released by mining activities, compared with the trace metal signatures found in snow and lichen, would help to identify a cause-effect relationship and assess the origin of the contaminants. For example, the studying the isotopic signature of the source iron dust or running geochemical fingerprinting of this source would allow to discriminate its contribution in the trace metals measured in snow and lichen vs the contribution of naturally occurring metals mobilized through erosion or weathering processes.

5.5 Inuit Qaujimajatuqangit

We recommend incorporating the observations and knowledge shared by local land users and Elders as a guiding framework. Their long-term insights into the state of ecosystems, fish habitats, caribou, and marine mammals are invaluable and can inform the development of scientifically testable hypotheses. For example, their knowledge of local winds, rivers or wildlife migratory routes could help identify the main pollutant transport routes and avoid long-term accumulation.

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