# SUPPLEMENTARY INFORMATION

## Do Arctic local sources of pollution influence the exposure of ringed seals (*Pusa hispida*) analyzed in contaminants monitoring programs?

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**Table S1**. Infrastructures and potential local sources of contamination in regions where ringed seals are collected for long-term contaminants monitoring A) Canada, B) Greenland, C) Norway. NA= Not Applicable.

| **A) Canada** | | | | | |
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| | **Nain, Labrador** | **Arviat, Nunavut** | **Resolute Bay, Nunavut** | **Sachs Harbour, Northwest Territories** | **Reference** |
| **Human population size**<br>2010<br>2015<br>2020 | <br><br>1,168<br>1,267<br>1,373 | <br><br>2,213<br>2,374<br>2,547 | <br><br>210<br>226<br>243 | <br><br>112<br>111<br>111 | NASA Socioeconomic Data and Applications Center (SEDAC) population estimator |
| **Mine** | Mine closest to Nain<br>**Company**: Voisey's Bay (Vale Newfoundland and Labrador Limited)<br>**Commodity**: Nickel, copper, cobalt<br>**Type**: Open-pit, underground, concentrator.<br>**Years of operation:** 2005-present<br><br>**Distance to mine:** 34 km | Closest mine is in Rankin Inlet<br>**Company**: Meliadine (Agnico Eagle Mines Limited)<br>**Commodity**: Gold<br><br>**Type**: Open-pit, underground, concentrator<br>**Years of operation:** 2019-present<br>**Distance to mine:** 215 km | No current mine.<br><br>**Company:** Polaris, decommissioned in 2003-2004.<br><br>**Commodity:** Zinc, lead<br><br>**Type:** Underground<br><br>**Years of operation:** 1981-2002<br><br>**Distance to mine:** 96 km | Closest mine is in the Yukon<br>**Company**: Dublin Gulch<br><br><br>**Commodity:** Gold<br><br>**Type:** Open-pit, concentrator<br><br>**Years of operation**: 2019-present<br><br>**Distance to mine:** 981 km | The Atlas of Canada - Minerals and Mining. |
| **Power source** | **Company:** Newfoundland and Labrador Hydro | **Company:** Quiliq Energy Corporation | **Company:** Quiliq Energy Corporation | **Company:** NWT Power Corporation | The Atlas of Canada - Remote Communities Energy Database |

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| | **Type**:<br>Diesel<br>9377 MWh/yr | **Type**:<br>Diesel<br>8661 MWh/yr | **Type**:<br>Diesel<br>4607 MWh/yr | **Type**:<br>Diesel<br>954 MWh/yr | |
| **Airport** | **Number of flights per year**: 900<br><br>Current airport has three foot of buffer from the water. On-going feasibility study for a new airport. | **Number of flights per year**: 876 | **Number of flights per year**: 1296 | **Number of flights per year**: 156 | Department of Economic Development and Transportation, Airports Division, 2023.<br><br>Jugol Faruque, 2022<br><br>Flightradar24 https://www.flightradar24.com |
| **Distant Early Warning (DEW) line sie** | **Name**: Cape Kiglapait (LAB-3)<br><br>**Distance**: 74.5 km<br><br>**Name**: Big Bay (LAB-4)<br><br>**Distance**: 117 km | **Name**: Bird, Manitoba BIR-X<br><br>**Distance**: 502 km | **Name**: Matheson point (CAM-C)<br><br>**Distance**: 619 km | **Name**: Horton River (Malloch Hills; BAR-E)<br>**Distance**: 229 km | Government of Canada, 2013.<br><br>GoogleEarth for distance measurements |
| **Wastewaters** | **Flow**: 306 $m^3$/day | **Flow**: 251 $m^3$/day<br><br>Wastewater is transported to a sewage lagoon (close to ocean), and the lagoon slowly feeds the wastewater into a treatment wetland of 0.78 $km^2$. | **Flow**: 917 $m^3$/day<br><br>Wastewater flows into Resolute Bay. A new wastewater system is in progress and should be implemented by 2024. Airport has a sewage lagoon that will be closed | **Flow**: 10.63 $m^3$/day<br><br>Wastewater is transported to a natural lake. It is unknown where this lake drains. | Bagnall et al. 2015.<br><br>George, 2020.<br><br>Wootton et al., 2008.<br><br>Nunavut Water Board, nwb-oen.ca<br>Inuvialuit Water Board, inuvwb.ca<br><br>GoogleEarth for |

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| | | | when new wastewater system is working. | | distance measurements |
| **Solid waste disposal** | **Distance from landfill to coastline:** 0.04 km<br><br>The landfill is located close to the ocean without a lining or leachate remediation measures. | **Distance from landfill to coastline:** 0.36 km<br><br>Open landfill next to the sewage lagoon. | **Distance from landfill to coastline:** 1.17 km<br><br>Landfill is at capacity. It is close to the water and lacks fencing. | **Distance from landfill to coastline:** 0.70 km<br><br>General waste goes into an active landfill cell and larger items are segregated and stored in a fenced off area. The site is within the Mary Sachs River watershed and is in close proximity to water bodies. The site drains into a creek. | Brown, 2021.<br><br>Consultation Report-Infrastructure for a Sustainable Resolute Bay, 2011. http://toolkit. |
| **Other** | | | Military training facility<br><br>Weather station<br><br>Polar Continental Shelf Program accommodation and lab facilities. | | Integrated Community Sustainability Plan (ICPS) Toolkit-Resolute Bay, Government of Nunavut. Template - Government of Nunavut (buildingnunavut.com) |

| B) Greenland | | | | |
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| | **Ittoqqortoormiit** | **Qeqertarsuaq** | **Avanersuaq/ Qaanaaq** | **Reference** |
| **Human population size** 2020 | 442 | 828 | 646 | NASA Socioeconomic Data and Applications Center (SEDAC) population estimator |
| **Mine** | **Name:** Mestersvig<br><br>**Commodity:** Lead and zinc, 1956-1963<br><br>**Remarks:** Situated >200 km from Ittoqqortoormiit and only local pollution with lead and zinc detected (within approx. 10-15 km from mine site). | **Name:** Maarmorilik<br><br>**Commodity:** Lead, zinc and silver, 1973-1990<br><br>**Remarks:** Situated >200 km from Qeqertarsuaq and only local pollution with lead, zinc, mercury and other metals detected (currently within approx. 10-15 km from mine site).<br><br>**Name:** Qullissat<br><br>**Commodity:** Coal, 1924-1972<br><br>**Remarks:** Situated approx. 100 km from Qeqertarsuaq. No significant pollution detected in the only | | Søndergaard and Mosbech, 2022 |

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| | | | | environmental study from 2015. | | | | |
| **C) Norway** | **Power source** | | NA | | NA | | NA | |
| | **Airport** | **Svalbard (whole island)** | Airport | **Kongsfjorden** | Airport | **Isfjorden** | Airport | **Van Mijenfjorden** | **Reference** |
| **Human population size** 2024 | **Boats/Ferry/ Cruises** | ~3100 | NA | 50 | NA | Longyearbyen: ~2600 | NA | | NASA Socioeconomic Data and Applications Center (SEDAC) population estimator |
| | **Distant Early Warning (DEW) line sites** | | NA | | NA | Barentsburg: 415<br><br>Pyramiden (old Russian settlement): 6 | NA | | |
| | **Wastewater** | | Untreated greywater is released to the environment. | | Untreated greywater is released to the environment. | | Untreated greywater is released to the environment. | | |
| **Mine** | | **Type:** Coal extraction is the main source of mining. | Open waste burning year-round. Dangerous waste is shipped to Denmark. | Ny-Alesund was a mining settlement that closed in 1963. Now its used as a research facility. Some PAH background concentration reported from coal dust. | Open waste burning year-round. Dangerous waste is shipped to Denmark. Some waste is exported to incinerator in nearby Ilulissat. | **Type:** Coal released to the environment.<br><br>The local coal plant closed in 2023.<br><br>Currently active mine (Mine 7) is located 15 km southeast of Longyearbyen and is to be closed in 2025.<br><br>There is also an active mine in Barentsburg, 36 km southeast of Longyearbyen. | Open waste burning year-round. Dangerous waste is shipped to Denmark. | | Nilsen, T. 2022<br><br>Granberg, et al. 2017 |
| | **Solid waste disposal** | | | | | | | | |
| | **Types of pollution associated with coal mining**: Heavy metals (Fe, Cu, Mn, Cd, As, Ni and Hg), polycyclic aromatic hydrocarbon (PAH), acid drainage from coal, pyrite, siderite, and ankerite. | | | | | | | | |
| | **Recorded Spills** | | NA | | NA | | NA | | |
| **Power source** | | The main source is burning diesel. | | | | Longyearbyen switched from coal to diesel burning in 2023. | | | |

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| | Svalbard wants to be zero emissions in the future through a combination of solar panels, windmills, bioenergy, geothermal, and battery mega-packs. | | Barentsburg has an active coal power plant. | | |
| **Airport** | | Airport in Ny-Alesund. | Airport in Longyearbyen.<br><br>There has been an extensive cleaning in Longyearbyen airport in 2023 with the removal of 17800 $m^3$ of contaminated soil. The estimated amount of PFAS was 32 kg.<br><br>Barentsburg and Pyramiden have heliports. | | |
| **Boats/Ferry/ Cruises** | NA | NA | NA | NA | |
| **Distant Early Warning (DEW) line sites** | NA | NA | NA | NA | |
| **Wastewater** | Small treatment plant at the Polish research station in Hornsund and a | | Evidence of heavy metals in the water system because of wastewater. | | Kalinowska et al. 2020 |

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| | system installed in 2015 in Ny-Alesund.<br><br>Up to November 2022, untreated sewage from Longyearbyen was discharged into the fjord (2 km off the coast). Mechanical water treatment was installed in 2022. | | | | |
| **Solid waste disposal** | Most of the garbage and waste from Longyearbyen is sent to mainland Norway for incineration.<br><br>There is a dumpsite in Adventdalen. It receives inert materials and some solid waste and ash for the coal power station.<br><br>Heavy metal concentrations above the limit have been found at the dumpsite by | The old dumpsite at Thiisbukta is one of the more extensive contamination sources in Ny-Alesund. High levels of Hg, pesticides, PAH, PCB have been detected there. | | | Granberg et al. 2017. Local contamination<br><br>Løtveit SV. 2012 |

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| | Lotveit (2012). | | | | |

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**Table S2**. Chemicals included for each contaminant class used in the five distance-based redundancy analyses done using Canadian data, and ringed seal tissues analyzed.

| Class of contaminants | Analyzed compounds | Tissue type |
|---|---|---|
| Organochlorine pesticides (OCPs) | *p-p'*-DDD, *p-p'*-DDE, *p-p'*-DDT, *o,p*-DDT, *o,p'*-DDE, α-HCH, γ-HCH, dieldrin, γ-chlordane, α-chlordane, trans-nonachlor, cis-nonachlor | Blubber |
| Polychlorinated biphenyls (PCBs) | Sum tri PCB, Sum tetra PCB, Sum penta PCB, Sum hexa PCB, Sum hepta PCB, Sum octa PCB, Sum nona PCB | Blubber |
| Polybrominated diphenyl ethers (PBDEs) | BDE 49, BDE 47, BDE 99, BDE 100, BDE 153, BDE 183, BDE 209 | Blubber |
| Per-, polyfluoroalkyl substances (PFAS) | PFHxS, PFHpS, PFOS, PFHpA, PFOA, PFNA, PFDA, PFUnA, PFDoA, PFTriA, PFOSA | Liver |
| Trace elements | aluminum, arsenic, cadmium, copper, lead, lithium, manganese, mercury, tin, silver, zinc | Liver |

DDT: dichlorodiphenyltrichloroethane; *p,p'*-DDE: dichlorodiphenyldichloroethylene; *p,p'*-DDD: dichlorodiphenyldichloroethane; HCB: hexachlorobenzene; PFHpS: perfluoroheptane sulfonic acid; PFHxS: perfluorohexane sulfonic acid; PFOS: perfluorooctane sulfonic acid; PFHpA: perfluoroheptanoic acid; PFOA: perfluorooctanoic acid; PFNA: perfluorononanoic acid; PFDA: perfluorodecanoic acid; PFUnA: perfluoroundecanoic acid; PFDoA: perfluorododecanoic acid; PFTriA: perfluorotridecanoic acid; PFOSA: perfluorooctane sulfonamide.

**Table S3**. Explanatory variables selected through forward selection for each distance based redundancy analysis (db-RDA) for trace metals, per-and polyfluoroalkyl substances (PFAS), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs). Variables that were considered are: human population size, distance to mines, power source, flights per year at airport, distance to closest miliatry DEW line site, solide waste, wasterwater, seal age, seal sex, seal size (length), and nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopes.

| **Contaminant group** | **Selected local source variables** | **Selected biological variables** |
|---|---|---|
| Trace elements | Power, mine, wastewater, airport, military site (dewline) | Age, sex, size, $\delta^{15}N$, $\delta^{13}C$ |
| PFAS | Power, wastewater, military site (DEW line sites) | $\delta^{15}N$, $\delta^{13}C$ |
| PBDEs | Power | $\delta^{15}N$, $\delta^{13}C$ |
| OCPs | Power, mine, airport | $\delta^{15}N$, $\delta^{13}C$ |
| PCBs | Mine, wastewater, solid waste, power | Size, $\delta^{15}N$, $\delta^{13}C$, age |

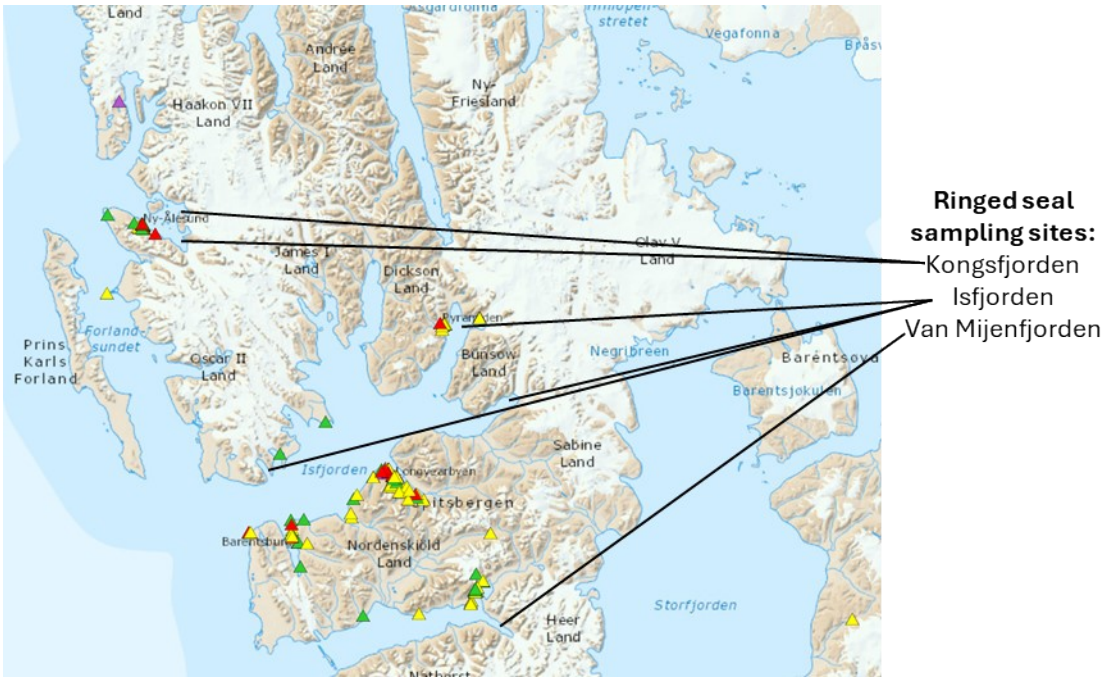


**Figure S1**. Sites of ringed seal sampling and contaminated ground (triangles) in Svalbard, Norway. The colors of the triangles refer to following: green, very little or no contamination; yellow, contamination level is currently acceptable; red, contamination level is not acceptable, actions needed; purple, situation unclear. Source: Norwegian Environmental Agency https://grunnforurensning.miljodirektoratet.no/