RISK ASSESSMENT OF SITE CONDITIONS AT THE PORT RADIUM MINE SITE, NWT

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ABSTRACT

The Port Radium mine site located on the eastern shore line of Great Bear Lake, Northwest Territories, was mined for radium, uranium and silver between 1932 and 1982. At closure, all surface facilities were demolished and the site was remediated to standards prevalent at that time. The community of Déline, is located approximately 265 west of the mine site. To address concerns expressed by Déline residents about the environmental impacts of the site, site investigations were carried out between 2001 and 2004 to delineate current site conditions. Surface water, ground water, soils, tailings, vegetation and small game samples were collected for chemical and radiological characterization. In addition, a gamma survey was carried out across the entire site. The results of these investigations were used to assess the risks to aquatic and terrestrial species in the vicinity of the site and to people using the site.

The ecological risk assessment considered aquatic biota from all trophic levels. Metal levels in water in the Great Bear Lake near the mine site were shown to below levels that could adversely affect aquatic plants, benthic invertebrates, zooplankton, bottom feeding fish and predator fish. Not surprisingly, the concentrations of some metals in the tailings basin were greater than the toxicity benchmarks for some aquatic species. However, as there is no outflow from the basin, the effects on aquatic biota, if any, are restricted to the water body.

The ecological risk assessment also considered a range of terrestrial species including bear, caribou, ducks (mallard, merganser and scaup), fox, grouse, hare and moose. Arsenic, cobalt and uranium were identified as potential issues for some animals in localized areas with elevated levels in soils, surface drainage and/or vegetation. Radiation exposures from internal and external doses were shown not to be a concern for any of the ecological species.

As there are no permanent residents at the Port Radium site, four hypothetical groups were identified for consideration in the human health risk assessment. The time spent on-site was assumed to range from a low of 1 day per year (an inspector) to 3 months per year (adult and child campers). Exposure pathways considered for these groups included consumption of: drinking water and fish obtained from Great Bear Lake; berries gathered from across the site; ducks obtained from the on-site tailings basin; small game (hare, grouse) that inhabit the site; and, large game (caribou, moose) that traverse the site. The results of the risk assessment showed that radionuclides and metals present in environmental media on-site do not a pose a risk of adverse effects to people who may use the site. Also, radiation exposures for all individuals were estimated to be below the incremental dose limit of 1 millisievert per year to members of the public.

INTRODUCTION

The Port Radium site is located in the Northwest Territories at Echo Bay on the eastern shores of Great Bear Lake, one of North America's largest fresh water lakes (see Figure 1). The 110-hectare site is about 440 km north of the City of Yellowknife and about 265 km east of the Dene community of Déline at the edge of the Arctic Circle. Predominant access to the site is by water, although an airstrip is located about 6 km from the site. Mining and milling operations for radium, uranium and silver were undertaken at the site almost continuously from 1932 to 1982.

A rocky and rugged relief that features rock outcrops and sheer cliffs that rise rapidly from the lake's shoreline characterizes the area of the Port Radium site. Peak elevations in the region around the site rise to more than 456 m, approximately 300 m above Great Bear Lake, while peak elevations at the site itself are in the order of 220 m, or about 60 m above Great Bear Lake water level. Natural flat lying land is, for the most part, non-existent in the area of the site and the surrounding areas.

Figure 1 – Location of Port Radium Site

Following discovery of a pitchblende seam at the Port Radium site in 1930, some manner of mining and milling activity was undertaken almost continuously between 1932 and 1982. Radium, uranium, and silver ores were mined and milled at various times throughout the history of the operation by its owners. Eldorado Mining and Refining processed ore for radium and uranium recovery from initial development until 1960. Portions of the townsite and milling facilities were re-activated in association with the development and operation of the nearby Echo Bay mine from 1964 to 1975. From 1976 to 1982 Echo Bay Mines Ltd. mined the Port Radium Mine for silver. Upon depletion of the reserves in 1982 the site was decommissioned.

Records indicate that during its life, Eldorado and Echo Bay mining and milling operations combined produced some 37 million ounces of silver, 10.5 million pounds of copper and 13.7 million pounds of U_3O_8 before final shutdown and closure in August 1982. While detailed records are not available, the amount of gangue material (tailings) produced from the processing of uranium ore with an average head grade of 0.75% $U_3O_{8,}$, has been estimated to be in the order of 910,000 tons, most of which was deposited in Great Bear Lake. It is estimated that a total of about 800,000 tons of tailings were generated from the silver operations, most of which were discharged to the McDonough (Garbage Lake) Tailings Basin.

Figure 2 provides an overview of the site, which is bounded by Great Bear Lake to the west, Cobalt Channel to the south and Labine Bay on the east. The McDonough Tailings Basin is located to the north west of the former mill site area. Drainage from the site was found during site visits to be limited to intermittent flowing surface seeps. Two seeps, which originated from under waste rock covering the former access road to the West Adit, flowed towards Cobalt Channel. A third surface seep, observed below the Echo Bay Adit, discharged to Inner Labine Bay of Great Bear Lake.

Due to the nature and extent of past mining operations, community concerns exist with respect to potential contamination of the environment and with respect to potential exposure of Déline residents, as traditional land users in the area. To address these concerns, the Canada-Déline Uranium Table (CDUT) via the Department of Indian Affairs and Northern Development (DIAND) initiated a program to assess site conditions and potential impacts on human health and the environment.

Figure 2 – Overview of Port Radium Site

OVERVIEW

In keeping with the program objectives, a preliminary assessment of the environmental conditions at the site was carried out in early winter and spring of 2001. The initial program confirmed that:

- contamination is present at the site in concentrations exceeding established guidelines (CCME);
- the site has areas of potential environmental concern, e.g., potential exposure pathways exist for contaminants to come into contact with potential receptors; and
- further investigation is required prior to proceeding with a Remediation or Risk Management Strategy.

Subsequently, a program was developed to carry out further testing to define the boundaries of identified contamination, site conditions and contaminant pathways potentially relevant to risk assessment and/or site remediation planning. Thus, subsequent investigations were carried out at the Port Radium site in the fall of 2001 and 2003.

This paper discusses the results of the monitoring program and the HHERA based on these results.

MONITORING PROGRAM

The sampling/monitoring/analysis initiatives included: inspecting physical conditions at the site; characterizing air, water, tailings, waste rock, soil and vegetation at the site and in background areas; measuring and monitoring terrestrial radiation across the site and at off site locations; and, collecting small game (hare and grouse) specimens for chemical and radiological analyses. Great Bear Lake activities included collection and analysis of sediments, tailings, benthics, and fish samples, as well as lakebed bathymetry, delineation, and characterization. Using the above information, and the outcomes from human health and ecological risk assessments, the existing physical, chemical, and radiological conditions of the site were evaluated, and potential actions and decommissioning scenarios were developed for consideration by the CDUT, the community of Déline, and regulatory agencies.

In summary, fieldwork and studies carried out to 2002 showed that with the exception of a surface opening on Labine Point, the site does not pose an immediate risk to human health or the environment and that off-site impacts on Great Bear Lake are minimal. Site inspections found that the site was generally neat, clean, and safe due to past efforts to: cover tailings present in surface depressions near the former mill site with waste rock (i.e. the Murphy, Radium North and Radium South tailings areas shown on Figure 3); demolish, burn, and remove surface structures; dispose and bury scrap metal; and to grade the site area. Some of the remaining issues identified included:

- the status of closed mine openings;
- miscellaneous scrap at the site;
- areas of elevated gamma radiation levels on Silver Point Causeway, parts of Lower and Upper Mill site, near the West Adit, and some road areas;
- elevated metal levels measured in local surface seeps;
- elevated metal levels measured in vegetation collected in the vicinity of spilled tailings and surface seep near West Adit; and
- elevated metals levels measured in lake sediments (characteristic of tailings).

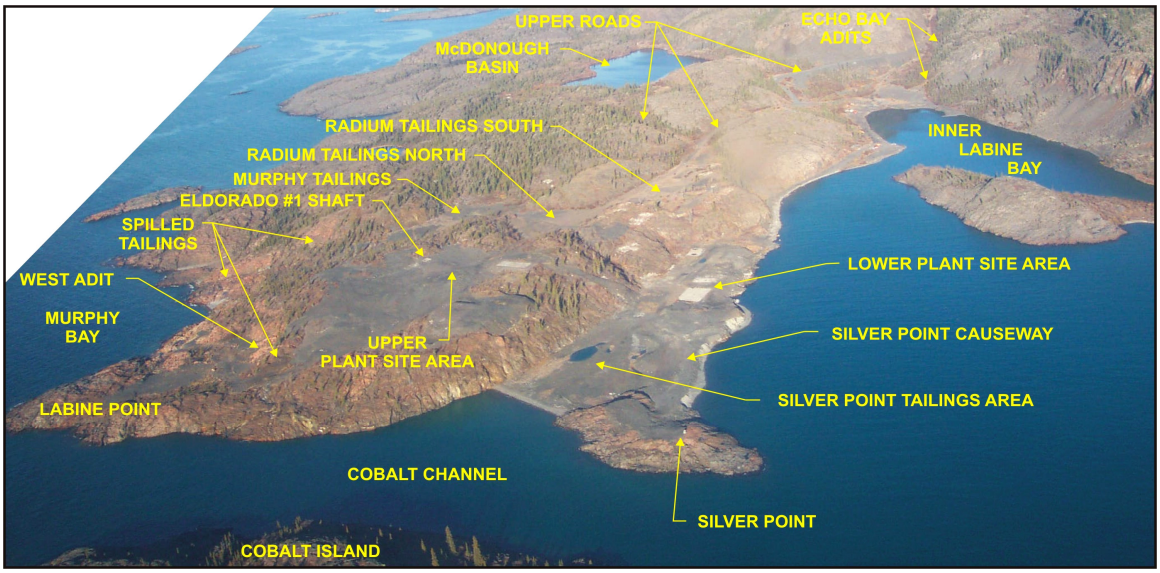

Figure 3 – Port Radium Mine Site Features

Based on analytical results from the sampling campaigns prior to 2002 and the 2002 Human Health and Ecological Risk Assessment (HHERA), the following recommendations were presented to DIAND/CDUT with respect to addressing the questions raised by the stakeholders as part of the Three Year Action Plan:

1. assess geotechnical stability of surface opening on Labine Point and address as appropriate;
2. collect additional vegetation samples for chemical analyses from across the site;
3. collect additional water and sediment samples for chemical analyses;
4. continue radiation monitoring (gamma and radon) at the site and at background locations;
5. refine the risk assessment to incorporate additional information from above and incorporate traditional knowledge into assessment; and
6. refine decommissioning concepts as appropriate.

Thus in 2003, field programs were carried out to: collect additional vegetation and soil samples for chemical analyses from across the site; collect additional water and sediment samples for chemical analyses; and continue radiation monitoring (gamma and radon) at the site and at background locations.

RESULTS OF MONITORING PROGRAM

Water Quality

The results of the monitoring data indicate that water quality in the nearshore zone of Great Bear Lake adjacent to the Port Radium site is affected by past activities at the site. The measured levels of some metals in these waters were found to exceed the CCME guidelines for protection of aquatic life. It is also noted that some of the samples collected at the bottom of the water column had higher concentrations that those collected at the top of the water column.

Analytical results of fish tissue samples show that concentrations of radionuclides and metals in fish caught near the Port Radium site are no different and in some cases are lower, than from background areas in Great Bear Lake.

In McDonough Lake Tailings Basin, water quality data exceeded CCME guidelines for the protection of aquatic life for some metals. For example, arsenic and copper levels measured 122 µg/L and 11 µg/L respectively. This finding is not surprising, as the basin was used for disposal of tailings during the period when silver was mined and milled at the site.

Sediment Quality

Sediments collected from the nearshore waters of Labine Bay, Cobalt Channel and Murphy Bay in the vicinity of the Port Radium site were found to consist mainly of tailings, which were deposited in the lake during the periods when uranium and radium were mined and milled at the site. Not surprisingly the metals content of the sediments were higher than sediment quality guidelines for several of the metals. The average arsenic and copper content of tailings samples collected from Cobalt Channel equalled 1,533 µg/g and 2647 µg/g, respectively.

Benthic Invertebrate Populations

Benthic samples collected at a reference background site and in the vicinity of the mine were found to have low density. The species diversity in the benthic samples collected near the mine site was lower than that of the background sample. However, the substrates at the sites were quite different (i.e. sandy near the Port Radium site and gravelly at the reference sampling station location). As sandy substrates do not provide an ideal habitat for productive benthic communities, it is likely that this factor has a greater influence on the diversity and density of benthic organisms than the elevated metal and radionuclide levels in the sediments/tailings.

Surface Seeps and Ponded Water

Water samples collected from surface seeps and ponded water on the site areas were found to contain elevated metals. The maximum measured arsenic and copper levels in surface seepage equalled 389 µg/L and 473 µg/L, respectively.

Terrestrial Soils and Vegetation

The results of the sampling program show elevated metal levels in soil (tailings) and vegetation in former site impacted areas such as Cobalt Seep near the West Adit, Murphy Tailings and the tailings spill near Murphy Bay. A range of vegetation species were samples including berries, birch and willow browse, horsetail, rosehips, Labrador tea, lichen, mushrooms and water sedge.

Gamma Survey

Gamma survey data (SENES 2002) indicate that there are elevated gamma levels in the former mine impacted areas on the site. The gamma level from measurements across 63 ha of site area averaged approximately 50 µR/h as compared to a background level of 26 µR/h. Of the total area surveyed approximately 2 ha had a gamma level above 250 µR/h.

The findings from the monitoring program as well as the monitoring results were considered in the risk assessment process.

RISK ASSESSMENT

The overall objectives of the human health and ecological risk assessment of the Port Radium site were to assess risks associated with chemical and radiological exposures to people and wildlife that may use the site. The assessment was undertaken to address concerns of the local Dene community of Déline with respect to the status of site, and to provide input into the evaluation of possible actions should follow up work be required to address residual concerns.

As noted above, several planned initiatives have been carried out through the Action Plan to define site conditions. These efforts have included consolidation of previously available information and gathering additional background and site specific data to fill information gaps (SENES 2004a). This paper discusses the HHERA which incorporates all previously relevant site information including the 2003 data sets, particularly the site wide soil and vegetation information. Details of the HHERA are presented in SENES (2004b).

The site characterization database developed through the various initiatives was used to identify contaminants of potential concern. Measured maximums and averages were used in the risk assessment calculations as appropriate to evaluate the risks to representative ecological species and people for various exposure scenarios as discussed below.

SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN

A selection process was performed to identify contaminants of potential concern (COPC) at the various sites based on human health considerations. The procedure followed for selection of COPC for human health is illustrated in Figure 4 and described below. COPC were selected by comparing measured concentrations in water and soil/tailings to the Canadian Council of Ministers of the Environment (CCME) guidelines. It is recognized that comparing tailings to soil guidelines is not necessarily appropriate as the guidelines were not developed for application to this type of material; however, for the purpose of identifying COPC at a site (e.g. in wind blown dust and site drainage) it was felt to represent a reasonable approach.

All contaminants with concentrations below the respective guidelines were dropped from the assessment. Typically, if no guidelines were available, then the contaminants were compared to baseline concentrations. If measured concentrations were found to be below baseline concentrations then those contaminants were also dropped from further consideration. Only contaminants which exceeded guidelines or baseline levels (when no guidelines were available) were selected for further consideration. The final step in the selection of COPC involved determining whether toxicity benchmarks for human health are available for the contaminants selected for further assessment. Only contaminants for which toxicity benchmarks exist were retained on the COPC list.

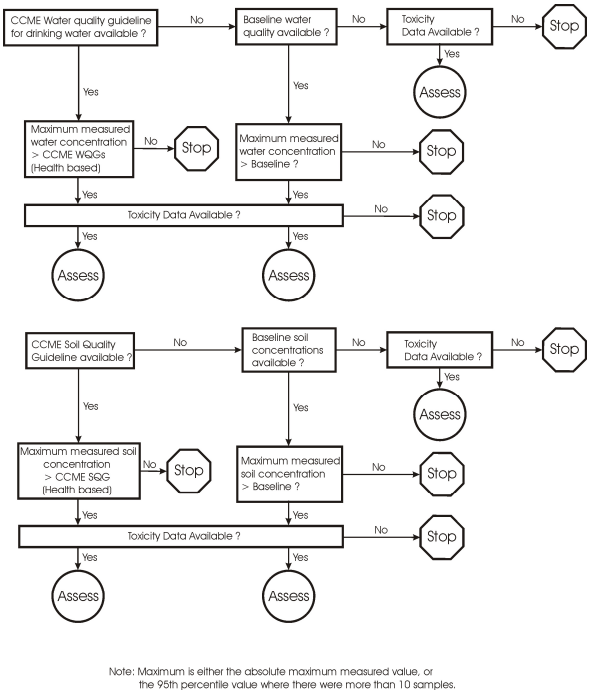

Figure 4 – Selection Procedure for Contaminants of Potential Concern

The twenty-five non-radionuclide contaminants that were included in the selection process were: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, bromide, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, tin, titanium, uranium, vanadium and zinc.

The non-radionuclide COPC identified through the selection process were: aluminum (aquatic environment only), antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, uranium and zinc. The COPC discussed above were carried through the quantitative risk assessment process to evaluate the potential risks to humans and the environment associated with the measured concentrations in the existing environment.

Radionuclides were not selected through a screening process. For the assessment, contributions from the following three decay series were considered: uranium-238 (U-238), uranium-235 (U-235) and thorium-232 (Th-232). While radionuclides from both the uranium-238 decay series and the thorium-232 decay series have been measured in the various environmental media, the focus of this screening level assessment was on the uranium-238 decay series radionuclides. The ore commonly found in the Northwest Territories is rich in U-238, and it was therefore expected that Th-232 and related products would be present at very low levels. This was confirmed by the measured data; also, the Th-232 decay series was found to have a negligible impact on the dose calculations. Therefore, the Th-232 decay series was not considered further in the assessment. The U-235 series is directly associated with the U-238 series and impacts from the decay products of U-235 were accounted for in the dose calculations. The principal radioactive elements considered in the uranium-238 decay series were uranium-238 and uranium–235 (U-238, U-235), thorium-230 (Th-230), radium-226 (Ra-226), lead-210 (Pb-210) and polonium-210 (Po-210).

ECOLOGICAL RISK ASSESSMENT

The selection of the various ecological (aquatic and terrestrial) biota for inclusion in the ERA was based on scientific and community input with respect to species associated with the site. It should be noted that the ERA evaluates the effects on populations rather than individual species. For the aquatic environment, the species covered the entire food chain starting from aquatic plants and animals, through to fish. For the terrestrial environment the species considered ranged from small local mammals (e.g. fox, hare) through to large broad ranging mammals (e.g. bear, caribou, moose), as well as water fowl (e.g. ducks) and terrestrial birds (e.g. grouse).

Exposure pathways included intake of COPC through the consumption of water, sediment, vegetation, soil or flesh at various stages of the food chain (see Figure 5).

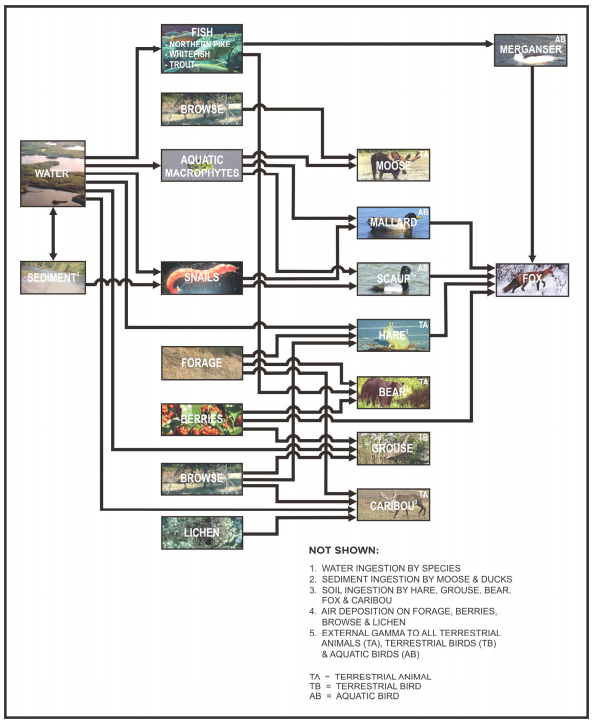

Figure 5 – Pathways of Exposure Considered for Ecological Risk Assessment

Depending on the size of the home range for the species under consideration, the analysis was based on contaminant levels measured at specific locations on the site or on site-wide averages. The analysis also considered the length of time the various species would be present on the Port Radium site (see Figure 6).]

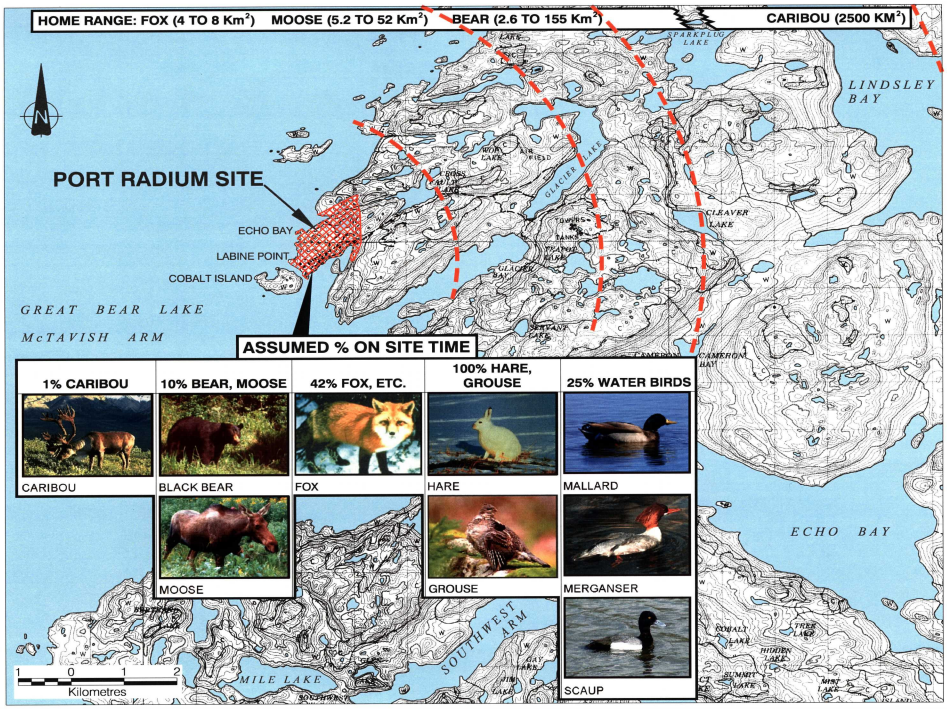

Figure 6 – Location and Range of Terrestrial Receptors

The assessment of risks to ecological species was based on comparison of estimates intakes of metals from all pathways to toxicity benchmarks. These benchmarks were based on data from reputable databases used in ecological risk assessments. Metals found to exceed toxicity benchmarks for the respective species assessed in the ecological risk assessment are identified in Table 1 and Table 2 for aquatic and terrestrial receptors, respectively.

Table 1 – Risk Assessment Results for Aquatic Biota

Aquatic Biota	Metals Exceeding Toxicity Benchmarks	
	McDonough Tailings Basin	Great Bear Lake
Pond Weed	None	None
Primary Producers	Arsenic, Copper, Uranium	None
Benthic Invertebrates	None	None
Zooplankton	Uranium	None
Predator Fish	Copper	None
Bottom Feeder Fish	None	None

Table 2 – Risk Assessment Results for Terrestrial Biota

Terrestrial Biota	Metals Exceeding Toxicity Benchmarks
Bear	None
Caribou	None
Ducks - Mallard	None
- Merganser	None
- Scaup	Arsenic
Fox	Arsenic
Grouse	Uranium
Hare	Arsenic, Cobalt, Uranium
Moose	None

The major conclusions drawn from the ecological risk assessment are as follows:

- The metal levels in Great Bear Lake near shore waters are below levels that could adversely affect aquatic biota.
- Not surprisingly, arsenic, copper and uranium levels in water overlying tailings in the McDonough Tailings Basin are greater than the toxicity benchmarks for some aquatic receptors.

It should be note that it is not known if fish are present or absent in the McDonough Tailings Basin as it was used for tailings disposal. Also, as there is no outflow from this water body, the effects on aquatic biota; if any, are restricted to the water body.

- Arsenic was identified as a potential issue for three of the terrestrial biota (fox, grouse and hare). The primary exposure pathways were attributed to consumption of vegetation and associated soil, mainly from localized areas around the Cobalt Seep, Murphy Tailings, and the spilled tailings near Murphy Bay. The removal of the influence of these localized elevated concentrations results in no predicted effects to the fox.

- Elevated concentrations of cobalt and uranium in the localized areas of the Cobalt Seep, Murphy Tailings, and the spilled tailings near Murphy Bay are a cause for potential concern for local species such as the hare. Notwithstanding this finding, it is noted that a large, apparently healthy, arctic hare was collected during the 2001 sampling campaign near Cobalt Seep.

The ecological risk assessment for radiation exposures from internal and external doses found that the radionuclides present at the Port Radium Mine site are not a cause for concern from an ecological perspective. While it is likely that caribou would only be present at the site for a minimal time period, caribou were included in the assessment as they are important source of food for the Dene. The assessment determined that there are no adverse impacts to caribou using the site.

HUMAN HEALTH RISK ASSESSMENT

As there are no residences at the Port Radium site at this time, scenarios were developed for hypothetical use situations to facilitate the assessment of potential risks to people from Déline, or others, who may visit the site. To this end, the following hypothetical receptors were considered:

- Dene campers (adult and child) on site for 3 months per year;
- Inspectors present on site 2 days per year;
- Fisherman/hunter at the site for 1 week per year; and
- Fishing lodge worker on site for 2 months per year.

It was assumed that the individuals with casual access to the site would spend their time near Inner Labine Bay and Echo Bay and that the family campers and proposed fishing lodge worker would be located further inland around the Radium Tailings area. These areas are identified on Figure 3.

Exposure pathways considered in the analysis for the Dene campers are shown on Figure 7. The pathways include drinking water and eating fish from Great Bear Lake; eating berries from across the site, eating hare exposed to soils and vegetation with elevated contaminant levels; eating ducks exposed to contaminants in McDonough Tailings Basin; and, eating larger animals (caribou and moose) that traverse the site as part of their range, and forage and drink from various areas of the site. With the exception of caribou, duck and moose, the HHRA was based on measured contaminant levels in all other food and water sources. To facilitate the HHRA, a simple pathways model was used to predict contaminant levels in caribou, duck and moose flesh.

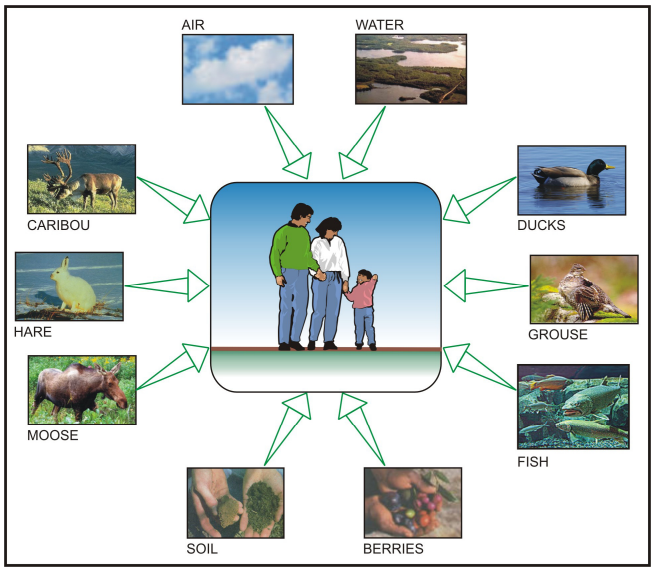

Figure 7 – Pathways of Exposure Considered in the Human Health Risk Assessment

The linking of some of the food components to McDonough Tailings Basin (e.g. ducks) represents a cautious assumption which potentially leads to an over-estimate of exposure.

In addition to the dietary intake, the camper exposure scenario also considered direct exposure to gamma radiation while on site. Dietary intake values were obtained from a food survey for an indigenous population in the area of the Port Radium Mine site (Receveur *et al.* 1996). The Sahtu community encompasses this area and these dietary habits were assumed to be representative of the Déline people.

Similar calculations of dose were also carried out for the other hypothetical human receptors based on specific assumptions for each receptor about sources of food and water, where the person spent their time on site and duration of stay on site.

Intakes were compared to toxicity benchmarks from Health Canada or the U.S. EPA. Predicted radiation doses were compared to an incremental dose limit of 1 mSv/y for members of the public (CNSC 2000).

The HHRA results show that:

- gamma radiation was the primary contributor to the radiological dose to all hypothetical human receptors. A conservative estimate of the radiation dose to the potentially most exposed seasonal camper was less than the 1 mSv/y (1000 µSv/y) incremental limit established by the Canadian Nuclear Safety Commission (CNSC) for the protection of human health (see Figure 8);

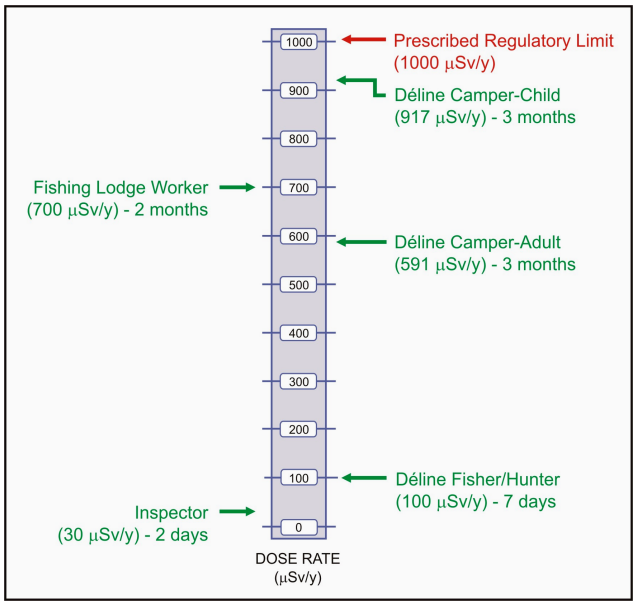

Figure 8 – Summary of Results for the Radiological Risk Assessment

- for metals, the predicted intakes were below the acceptable intake levels for all non-carcinogenic contaminants of potential concern (see Figure 9);

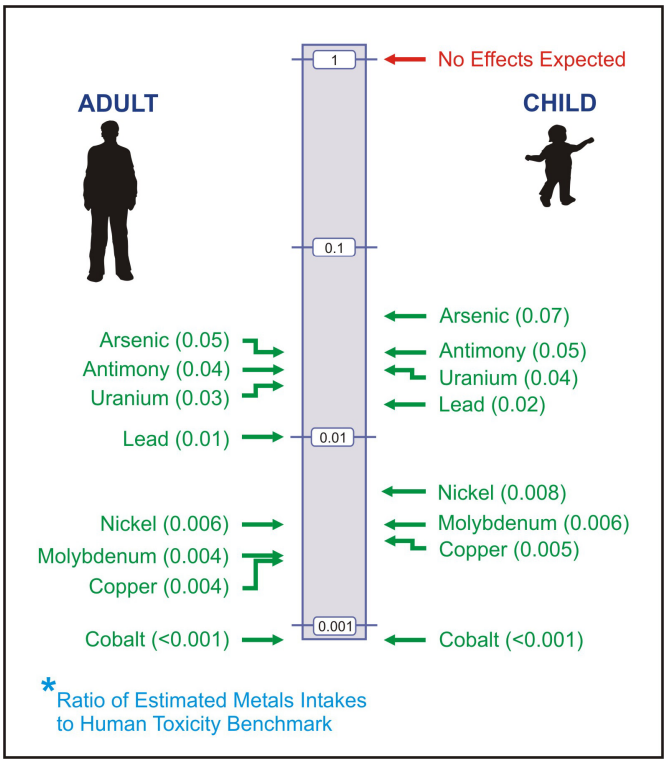

Figure 9 – Summary of Results for the Non-Radiological Risk Assessment

- risk levels associated with the carcinogenic properties of arsenic are below risk levels from background exposure in Canada, which for an adult ranges between 7 in 10,000 to 1 in 1,000 (see Figure 10).

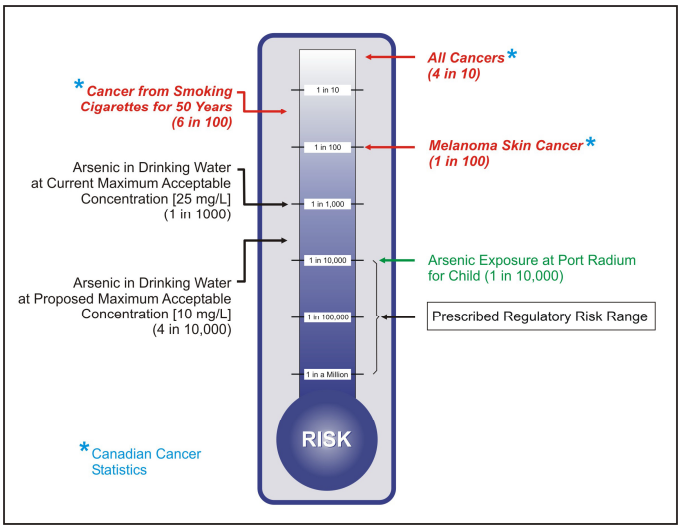

Figure 10 - Comparison of Risks of Incidence of Skin Cancer from Exposure at Port Radium Mine Site to Incidence of Cancer in the General Canadian Population

In summary, the presence of radionuclides and metals at the Port Radium Mine site are not a cause for concern under the exposure scenarios described above for Dene campers or fishermen, or others, who might occasionally visit the site. It should be noted that residual physical site hazards that may pose risk to human health, including mine openings and miscellaneous scrap, have been identified as part of the site characterization program.

SUMMARY

The results of the overall assessment indicate that members of the Dene community or other individuals can be present at the site over the summer season (3 months) and not experience adverse health effects.

From an ecological perspective, there are localized areas in the vicinity of the West Adit (Cobalt Seep), Murphy Tailings, and the spilled tailings near Murphy Bay that potentially may result in adverse effects on a limited number of small terrestrial animals (e.g. hare) in these areas. Large animals such as bear, moose, and caribou are not expected to be adversely affected by the existing site conditions.

The site assessment programs have been used to develop remediation options that are being considered by the CDUT to address physical hazards, residual issues identified by the risk assessment and Dene concerns with regard to current site conditions. Looking forward, a preferred closure plan will be developed by the CDUT for future implementation at Port Radium.

ACKNOWLEDGEMENTS

This project was funded by the Canadian Déline Uranium Table (CDUT). We would also like to thank David Kennedy from the Department for Indian Affairs and Northern Development for his advice and support over the course of the project.

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