ERs were less than 1 for all VECs and all COCs (Tables II-8 to II-11). ERs were calculated for exposure to maximum concentrations metals in food, water and soil from the LLCF. Since all ERs were less than 1, no risks to individual animals are predicted. Since no risks to individuals are predicted, there would be not risks to populations. The very low ERs provide confidence that no effects on wildlife will occur, even when overall exposure to all metals of concern is considered. Most of exposure was due to the soil pathway, followed by the plant ingestion pathway. Water ingestion contributed very little to the overall exposure (Appendix II, Section 4.5).

4.6 Uncertainty

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. This assumption accounts for the potential variability in concentrations in soil, water and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the LLCF were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (i.e., 365 days per year) from caribou that were exposed to maximum metals concentrations from the LLCF for 6 months per year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals from the study area is uncertain. Therefore, TRVs for wildlife were based on studies where only subtle health effects (e.g., reduced growth) were observed. If such a study was not available, then studies where no observed health effects were selected. This large margin of safety ensures that doses less than the toxicity benchmarks are safe and that minor exceedances of these benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that exposure to metals from the LLCF has not been underestimated.

5. HUMAN HEALTH RISK ASSESSMENT

5.1 Problem Formulation

5.1.1 Human Receptor Screening

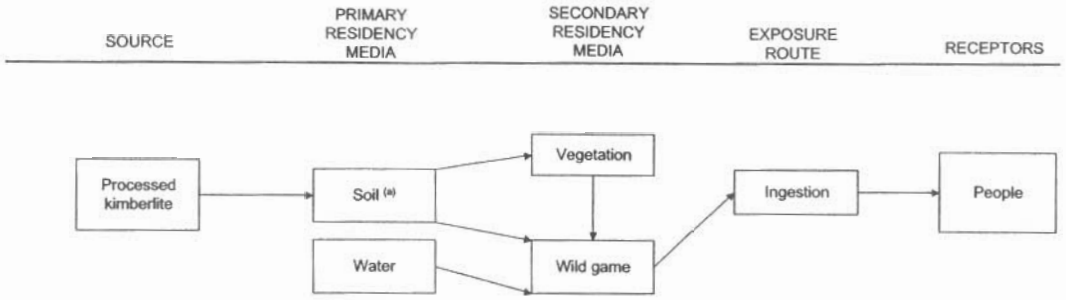
Consistent with risk assessment guidance (Health Canada 1994, [unpublished] 1995, 2003), the toddler life phase (i.e., seven months to four years) was chosen as the most susceptible child lifestage for evaluation of non-carcinogenic metals. The toddler phase is the most susceptible childhood phase due to their smaller body size to ingestion rate ratio. Therefore, the risk assessment estimated exposures that a hypothetical child may have after ingesting meat tissue from caribou that are exposed to metals from the LLCF. A hypothetical adult receptor was also evaluated for exposure to metals in caribou meat since adults eat greater amounts of meat for a longer period of time.

5.1.2 Human Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors. They are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The purpose of the exposure pathway screening process is to determine the ways in which people may come into contact with metals from the LLCF. The results of the exposure pathway screening are summarized in the Conceptual Exposure Model, which details the source of the metal, the release mechanisms, environmental transport and residency media, exposure routes and receptors (Figure II-6).

No other exposure pathways are applicable for human health because the closest community is Wekweti, a Dogrib community approximately 180 km southwest of the EKATI Diamond Mine. It is unlikely that the general public would be in close proximity to the LLCF for significant periods of time. Therefore, they would not inadvertently ingest soil or drink water from the LLCF. In addition, the plants used to stabilize the processed kimberlite on the LLCF are not traditional plants and therefore, would not be consumed by people.

Figure II-6
Human Exposure Pathways



(a) Soil is soil-amended processed kimberlite.

Ingestion of Wild Game

The only potential exposure pathway between the LLCF and the general public is via ingestion of caribou meat from caribou that have grazed on vegetation grown on the LLCF, or have been exposed via inadvertent ingestion of processed kimberlite while grazing and drinking standing water in the LLCF. People would not be directly exposed to vegetation or processed kimberlite since they are not expected to be within the area of the LLCF for extended periods.

5.2 Exposure Assessment

5.2.1 Spatial and Temporal Boundaries

Vegetation of the LLCF is part of BHPB's reclamation plan. Therefore, it was assumed that people would eat caribou that have been exposed to metals from the LLCF, every day for their entire lives. This is a very conservative assumption since not all caribou would pass through the EKATI Diamond Mine or spend significant periods of time near the LLCF.

5.2.2 Exposure Estimate Equations

The exposure estimate equation used for meat ingestion in the human health exposure assessment is presented in Table II-12. Meat tissue concentrations were calculated using bioconcentration factors from water, soil and food ingestion to meat tissue. The concentrations and calculations

are presented in Appendix I. Although humans may consume other meat tissue such as muskoxen, the concentration in meat tissue in other organisms would be similar to caribou because the meat concentration is based on metal-specific bioconcentration factors.

Table II-12
Exposure Equations

Pathway	Equation and Equation Parameters
Meat ingestion	$EDI_{meat} = \frac{IR \times C_{meat}}{BW}$
	EDI_{meat} = exposure due to ingestion of meat (mg metal/kg body weight-day) IR = ingestion rate (kg/day) C_{meat} = metal concentration in caribou meat (mg/kg) BW = receptor body weight (kg)

5.2.3 Human Exposure Parameters

Details on the body weights and food ingestion rates for humans are presented in Table II-13.

Table II-13
Exposure Parameters Used in the Human Health Risk Assessment

Parameter	Receptor	
	Toddler (6 months to 4 yrs)	Adult (20+ years)
Body weight (kg)[(a)]	16.5	70.7
Meat ingestion rate (kg wet wt/day)[(a)]	0.085	0.28

[(a)] Richardson 1997.

5.3 Bioavailability

As described in Section 4.3, bioavailability is typically not adjusted in a risk assessment unless one of the following occurs:

- if the medium of exposure is different than the medium on which the toxicity reference value is based (e.g., exposure is from soil, but the toxicity reference value is based on exposure from water);

- if the route of exposure is different than the route of exposures in the study used to derive the toxicity reference value (e.g., oral route of exposure, but based on an inhalation study); and
- the toxicity reference value derived by the regulatory agency has been adjusted for bioavailability.

In the human health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body) and because bioavailability information was not available. However, bioavailability was incorporated into the exposure assessment for nickel because the nickel TRV is based on exposure through drinking water (Health Canada 2003), a very soluble and bioavailable form of nickel, whereas the form of nickel in food is much less bioavailable (ATSDR 1997). In humans, ingested nickel is poorly absorbed. In a study reviewed in ATSDR (1997), nickel administered in drinking water was absorbed much more readily than when administered in food (27% absorption in water versus 0.7% absorption in food). For the purpose of this assessment, bioavailability of via food ingestion was assumed to be 3% relative to bioavailability via water ingestion (ATSDR 1997).

5.4 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of metals and determination of the amount of metals that can be taken into the body without experiencing adverse health effects. The toxicity assessment provides the basis for determining an acceptable exposure and what level of exposure may adversely affect people's health. The toxicity assessment is based on chronic exposure and not acute exposure.

5.4.1 Toxicity Reference Values

Toxicity reference values (TRVs) are safe exposures below which there is minimal risk of adverse health effects. The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2003) and the U.S. EPA's Integrated Risk Information Service Database (IRIS 2003). The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional

information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented.

Animal studies provide dose-response information that can be extrapolated to humans by applying safety factors. In most cases safety factors of 100 to 1,000 are applied to laboratory derived No-Observed-Adverse-Effect Level (NOAEL; the highest concentration in a toxicity test where no chronic health effects were observed or measured) to account for interspecies extrapolation and protection of the most susceptible in a population (i.e., children and elderly). Therefore, TRVs have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

The TRVs used in this assessment are presented as reference doses (RfDs) for non-carcinogenic chemicals. None of the chemicals of concern identified in this assessment were listed as carcinogens via the ingestion pathway. The RfDs defined as the amount of metal per unit body weight that can be taken into the body each day with no risk of adverse health effects (RfD). The RfDs used in the risk assessment are presented in Table II-14 and a brief summary of the toxicity studies on which the RfDs are based is presented below.

Table II-14
Reference Doses Used for the Human Health Risk Assessment

Metal	Reference Dose (RfD) (mg/kg-day)	Summary of Health Effect	Reference
Chromium	1.5	Reduced liver and spleen weight	IRIS 2003
Cobalt	0.001	Increased total blood cell mass	ATSDR 2001
Manganese	0.14	Central nervous system effects	IRIS 2003
Molybdenum	0.005	Gout-like symptoms	IRIS 2003
Nickel	0.0013	Decreased maternal weight gain and rat pup survival	Health Canada 2003
Strontium	0.6	Changes in bone mineralization	IRIS 2003

5.4.1.1 Chromium

An oral RfD of 1.5 mg/kg-day for chromium was based on a chronic toxicity study conducted by Ivankovic and Preussman (1975 in IRIS 2003). Groups of rats (12 to 19 rats/group) were exposed to 0, 2% or 5% chromic oxide in bread for 5 days per week for 18 weeks. Food consumption and body weight were monitored. Toxicological endpoints included serum protein, urine analysis, organ weights and microscopic examination. The only effects observed were reductions (12% to 37%) in liver and spleen weights of animals in the high-dose group. The NOAEL was 1,468 mg/kg-day.

An uncertainty factor of 1,000 was applied to the NOAEL; 10 for interspecies extrapolation, 10 for protection of the most susceptible receptor and 10 for a lack of chronic and reproductive toxicity studies (IRIS 2003).

5.4.1.2 Cobalt

An oral RfD of 0.001 mg/kg-day for cobalt is based on a subchronic toxicity study by Davis and Fields (1958 in ATSDR 2001). Six male volunteers were exposed to 1 mg/kg-day of cobalt chloride for up to 22 days. In all six individuals, exposure to cobalt resulted in an increased total blood cell mass or polycythemia, in some cases an increase as high as 20% above pre-treatment levels was noted. Polycythemic conditions returned to normal 9 to 15 days after termination of cobalt exposure. The LOAEL for the study was 1 mg/kg-day.

An uncertainty factor of 1,000 was applied to the LOAEL; 10 for protection of the most susceptible receptor, 10 for using a LOAEL instead of a NOAEL value and 10 for using a subchronic study (ATSDR 2001).

5.4.1.3 Manganese

An oral RfD of 0.14 mg/kg-day for manganese was based on a safe daily intake from diets high in whole-grain cereals, nuts, green leafy vegetable and tea (IRIS 2003). Manganese is ubiquitous in nature and is an essential nutrient for enzymatic reactions. Ingested manganese has rarely been associated with toxicity.

An uncertainty factor of 1 was applied to the NOAEL since many large populations consume manganese in normal diets over an extended period of time without adverse health effects. When ingested, manganese is considered to be among the least toxic of the trace elements (IRIS 2003).

5.4.1.4 Molybdenum

The oral RfD of 0.005 mg/kg-day for molybdenum was based on an epidemiological study conducted by Koval'skiy et al. (1961 in IRIS 2003). The incidence of gout-like symptoms (i.e., pain, swelling, inflammation and deformities of joints and elevated uric acid in the blood) was determined in the two villages. One of the villages had high molybdenum content in soil and plants (38 and 190 times that of the control area). The average adult in the study region was exposed to 0.14 to 0.21 mg molybdenum/kg-day compared to 0.01 to 0.03 mg molybdenum/kg-day in the control region. Gout-like symptoms were observed in 31% of the study population compared to 17.9% in the control population. The LOAEL was 0.14 mg/kg-day.

An uncertainty factor of 30 was applied to the LOAEL; 3 for protection of the most susceptible receptor and 10 to extrapolate from LOAEL to NOAEL (IRIS 2003).

5.4.1.5 Nickel

An oral RfD of 0.0013 mg/kg-day for nickel was based on a 11-week toxicity study conducted by Smith et al. (1993 in Health Canada 2003; TERA 2003). Groups of female rats were exposed to 0, 10, 50 or 250 mg/kg nickel chloride in drinking water for 11 weeks before mating and then throughout two successive periods of mating, gestation and lactation. Maternal weight gain was reduced in rats exposed to 50 and 250 mg/kg. The proportion of dead pups per litter was significantly elevated at the 50 and 250 mg/kg exposure levels. The LOAEL was 1.3 mg/kg-day based on decreased weight gain and pup survival.

An uncertainty factor of 1,000 was applied to the LOAEL; 10 for interspecies extrapolation, 10 for protection of the most susceptible receptor and 10 for use of a LOAEL rather than a NOAEL (IRIS 2003).

5.4.1.6 Strontium

An oral RfD of 0.6 mg/kg-day for strontium was based on a chronic toxicity study conducted by Storey (1961 in IRIS 2003). Groups of young and adult rats (3 rats/group) were fed strontium as strontium carbonate at dietary levels of 190, 380, 750, 1,000 or 3, 000 mg/kg-day. Rats were examined for changes in bone mineralization and cartilage defects. Bone and cartilage changes were evident in young rats exposed to 380 mg/kg-day. In adults, bone changes were evident in the 750 mg/kg-day exposure group. The NOAEL for this study was 190 mg/kg-day, based on the affects observed in young rats.

An uncertainty factor of 300 was applied to the NOAEL; 10 for interspecies extrapolation, 3 for protection of the most susceptible receptor and 10 for a lack of reproductive toxicity studies (IRIS 2003).

5.5 Risk Characterization

In the risk characterization step, ERs were calculated as the ratio of the estimated exposure to the toxicity benchmark value, according to the following equation:

ER = estimated exposure ÷ toxicity benchmark value

For non-carcinogenic chemicals, an ER value of less than 0.2 (considered to be the appropriate threshold for this assessment) represents exposure that does not pose a significant health risk to receptors (Health Canada 2003). As stated in Section 2.1.4, an ER value of 0.2 is considered appropriate because only one exposure pathway was evaluated for human health.

When the ER is greater than 0.2, the scenarios pose a potential concern and require further scrutiny. It is important to note that ER values greater than 0.2 do not necessarily indicate that adverse health effects will occur due to the layers of safety employed in their estimation (e.g., the toxicity reference values are protective of human health).

5.5.1 Results

ERs for the human health risk assessment are presented in Table II-15.

Table II-15
Human Health ER Values for Exposure to Metals

Parameter	ER	
	Toddler	Adult
Chromium	0.0003	0.0003
Cobalt	0.001	0.001
Manganese	0.002	0.001
Molybdenum	0.007	0.005
Nickel	0.03	0.02
Strontium	0.004	0.003

All of the ERs are much less than 0.2 for both toddlers and adults (Table 3). ERs were calculated for exposure to metals via consumption of caribou meat from caribou that have been exposed to maximum concentrations of metals in food, water and soil from the LLCF. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the LLCF.

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