PUBLIC HEALTH EVALUATION OF EXPOSURE
OF KIVALINA AND NOATAK RESIDENTS
TO HEAVY METALS FROM RED DOG MINE

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Environmental Public Health Program
Section of Epidemiology
Alaska Division of Public Health

EXECUTIVE SUMMARY

Purpose

The Section of Epidemiology, Alaska Division of Public Health (ADPH) conducted an investigation to determine if mining operations at the Red Dog Mine were exposing local residents to any public health threats that could adversely affect their health. Here, we summarize our findings.

Background

The Red Dog Mine is located in the northwestern Brooks Range in an area with high levels of naturally occurring metals. The mine primarily produces lead and zinc ore concentrate with other metals in much smaller quantities. The mine consists of the mine site, port facility, and a 52-mile haul road that connects them. Mining began in 1989. At the mine, ore is processed to concentrate the lead and zinc which is trucked to the port facility and loaded on barges for transportation to smelters in British Columbia, Europe, Korea, Japan, and Australia. The port is about 15 miles from the village of Kivalina (377 residents). The mine is located about 60 miles from Kivalina and about 40 miles from Noatak (428 residents).

Since the early stages of planning and development of the mine, government agencies have been monitoring the environment to determine impacts of mining operations. The Section of Epidemiology reviewed available monitoring data from State and federal agencies, and Teck Cominco Incorporated, the mine owner.

What we know from past studies of lead exposure in the area

In 1990, a large amount of water and tailings leaked from the mine's holding pond, discoloring the Red Dog Creek and the Ikalukrok Creek. Because residents of Kivalina and Noatak were concerned about possible lead exposure, the ADPH in collaboration with the Maniilaq Association and the villages, conducted voluntary blood testing to measure lead levels of all residents. In Kivalina, 90% of the residents were tested, including 125 children and 94 adults. In Noatak, 91% of the residents were tested, including 128 children and 158 adults. Community blood lead levels were low and of no public health concern. The results documented that the communities had not been exposed to lead as a result of the mining operations.

In 1992 the ADPH investigated an infectious disease outbreak in Pt. Hope. During the investigation, we offered blood lead testing to children. Of the 6 children tested, all had very low blood lead levels.

In 1993-1994, the ADPH conducted blood lead testing of children in selected villages throughout Alaska as part of a special blood lead screening project. Of the 21 children from Kivalina who were tested, all had very low blood lead levels.

The results of these investigations of blood lead levels in Kivalina, Noatak, and Point Hope provided evidence that the communities had not been exposed to lead from mining operations.

What we know from past studies of lead and zinc mining in Alaska

For many decades up to the mid-1980s, lead ore concentrate from a mine in the Yukon Territory, Canada, was transported by train and later by truck from the mine to the port of Skagway, Alaska. The ore concentrate escaped from the train cars and trucks, extensively contaminating the community, including main streets and the port area. Levels of ore in the town were measured at levels far exceeding the levels measured along the Red Dog haul road by the National Park Service.

In the 1980s the ADPH, in collaboration with the National Centers for Disease Control and Prevention (CDC), conducted extensive investigations into the public health consequences of the lead ore contamination of Skagway. Blood lead testing was offered to all children and many adults in Skagway. All blood lead testing results showed that children and adults in the community had blood lead levels that were of no public health concern. An extensive environmental clean up was performed under the oversight of DEC and EPA.

As part of the investigation, extensive testing was done of the lead ore concentrate. The National Toxicology Program (NTP) conducted animal feeding experiments to determine the bioavailability of the lead ore concentrate. These experiments documented that the lead ore concentrate from the mine in the Yukon Territory was of low bioavailability. This finding helped explain how persons could be exposed to the lead ore in the environment, yet not have elevated levels of lead in their blood.

Because the lead ore in the Yukon Territory was thought to be similar to the lead ore at the Red Dog Mine, the ADPH recommended that the Red Dog Mine ore also be tested for bioavailability by the NTP. This testing was done by the NTP, and the lead ore from the Red Dog Mine was found to be very similar to the ore from Skagway. It, too, was of low bioavailability.

What we know from the ongoing monitoring that has been done

Drinking water: Overall, the levels of heavy metals in the drinking water are very low and do not pose a health threat.

Soil: Concentrations of lead and zinc are elevated at the mine, near the port, and along the haul road. Because of the low bioavailability of the ore, the presence of the ore will not pose a health threat to wildlife or people. Public access to the mine and port areas is limited for safety reasons, so potential for exposure is also limited.

Sediments: People do not come into contact with sediments at the port. In addition, lead and zinc levels in the sediments are low, so they do not pose a public health threat.

Fish: The concentrations of metals found in fish from the Red Dog Mine area and watershed are low. Eating fish from rivers in the mine area does not pose a public health threat.

Caribou: The average concentrations of metals found in caribou harvested near the Red Dog Mine and haul road were low. Eating caribou from the Western Arctic Caribou Herd does not pose a public health threat.

Salmonberries: The concentrations of metals in all berry samples were low. Eating berries from the areas sampled does not pose a public health threat.

Recommendations

- Residents of Kivalina, Noatak, and Pt. Hope should continue to eat their traditional foods without restriction.
- Water samples from Kivalina show no evidence of contamination from mine operations. Water samples from the drinking water system should routinely be collected and analyzed in accordance with state drinking water regulations.
- Teck Cominco Incorporated should implement their planned use of new technology and procedures to reduce ore contamination at the mine, along the road, and at the port.
- State and federal regulatory agencies should review all current monitoring programs, seek input from local residents about their adequacy, and develop a consensus future monitoring plan. All monitoring data should be routinely evaluated and interpreted involving local residents and reporting to the communities.
- There are no identified exposure pathways from Red Dog Mine to the residents of Noatak and Kivalina. Exposure monitoring by blood lead testing is not medically indicated at this time.

Introduction

During June 2001, the National Park Service (NPS) released a study "Heavy Metals in Mosses and Soils on Six Transects Along the Red Dog Mine Haul Road Alaska" (National Park Service 2001). The report generated a great deal of local community, government agency, and media attention.

Following the release of the NPS report, the Trustees for Alaska, a public-interest environmental law firm, petitioned Governor Knowles for an emergency closure of the DeLong Mountain Transportation System Road. After reviewing all available data and in consultation with the Alaska Department of Health and Social Services, the Alaska Department of Environmental Conservation (ADEC) denied the petition. ADEC Commissioner Michele Brown stated that the issue of heavy metals deposition along the road required the combined efforts of all stakeholders, including state and local agencies, involved communities, and representatives for the mine, to determine the best way to protect against further contamination of the transportation corridor.

The Division of Public Health, Environmental Public Health Program (EPHP) began working with ADEC, the Alaska Native Health Board (ANHB) and the Maniilaq Regional Health Corporation to develop a coordinated response to health-related concerns related to mining activities at Red Dog. The purpose of this report is to review, analyze, and evaluate all data currently available to determine the potential for human exposure to heavy metals from Red Dog Mine and Port Facility activities, and to assess the potential for harm from heavy metals to residents of communities located in the vicinity of the mine.

Background

The Red Dog Mine is located in Northwestern Alaska, 55 miles east of the Chukchi Sea in the DeLong Mountains, at the western end of the Brooks Range (Exponent 2001). (Figure 1) The Northwestern Brooks Range is a highly mineralized area, with a number of zinc-lead-silver deposits consisting of layers rich in sulfide minerals that are dispersed in black shale and chert. The dominant minerals are sphalerite (zinc sulfide), silver-rich galena (lead sulfide), pyrite (iron sulfide) and marcasite (iron sulfide) (USGS 1995). Water quality data collected prior to mining activities from streams draining the Red Dog deposit indicate that the waters were acidic and contained levels of cadmium, lead, and zinc that exceeded State of Alaska drinking water standards and were in a range considered toxic to aquatic life (USGS 1995).

The Red Dog Mine is currently operated by Teck Cominco Alaska, Incorporated, following a merger in July 2001 of the mining companies Teck and the Cominco Alaska parent company Cominco, Ltd. Subsequent name changes were approved in September 2001, with Cominco Alaska Incorporated becoming Teck Cominco Alaska Incorporated (Teck Cominco). Therefore, in this document we will refer to both Cominco Alaska Incorporated (Cominco) and to Teck Cominco (for references after September 10, 2001).

The Red Dog Mine is the largest zinc/lead mine in the world, producing approximately 1.2 million tons of lead and zinc ore concentrates per year. The mine is connected to a port facility via a 52-mile long, 30-foot wide gravel road. Together, the port facility and road make up the DeLong Mountain Transportation System (DMTS) (Exponent 2001). The mine is located approximately 90 miles northeast of Kotzebue (pop. 3,082), and the port facility is located on the Chukchi Sea approximately 15 miles south of the village of Kivalina (pop. 377). The next nearest village is Noatak (pop. 428), which is located 55 miles north of Kotzebue (AK Department of Community and Economic Development, http://www.dced.state.ak.us). Both the port and mine are located within the Northwest Arctic Borough, on land owned by the Northwest Arctic Native Association. The DMTS road traverses 24 miles of National Park Service lands in Cape Krusenstern National Monument. A detailed history of the Red Dog Mine is available on the Internet (Alaska's Red Dog Mine – Beating the Odds, http://imcg.wr.usgs.gov/usbmak/mt1.html).

The mine, which began operations in 1989, processes ore through a series of crushing, grinding, flotation, and dewatering steps. Contaminated water from all sources is collected in the tailings impoundment. The water treatment process uses lime to precipitate zinc, lead, and iron as hydroxides, and sodium sulfide to precipitate cadmium. The majority of precipitates are removed by settling, then the water is transported through two sand filters to remove suspended solids. Treated water is discharged into the Red Dog Creek at rates up to 14,000 gallons per minute when Red Dog Creek is flowing (approximately mid-March until mid-October) (Werniuk 2001).

The resulting lead and zinc ore concentrates are in a powder form, and are transported from the mine to the port facility via large, tandem tractor-trailer trucks. Until September 2001, ore was transported in 72-ton payload trucks covered with tarps. At the port, the ore was dumped into a hopper unit by tilting and vibrating the complete tractor-trailer unit. Teck Cominco is in the process of replacing these trucks with a fleet of nine new trucks with hydraulically sealed tops and a side-dumping feature. In response to concerns over fugitive dust emissions from the trucks, Cominco installed truck-washing stations at the port and at the mine. The truck-washing stations currently only operate during summer months (Cominco, 2001a).

At the port, ore is stored in large concentrate storage buildings (CSB). The port facility receives ore year round; however, the port is open to shipping -- i.e., ice-free -- only 100 days per year (approximately July through early October). Concentrate is moved from CSBs to barges via conveyors; the barges then transport the concentrate to deepwater ships anchored approximately 5 km offshore (Werniuk 2001). No smelting of mined ores occurs in Alaska.

Public Health Background

Lead is a naturally occurring element in the earth's crust. However, exposure to unsafe levels of lead can adversely affect mental and physical growth in children. From 1985 to 1991, the Centers for Disease Control and Prevention (CDC) defined a blood lead level (BLL) of ≥25 µg/dl in a child as the "intervention level," or the level at which the CDC recommended individual case management. In October 1991, based on the availability of new data, CDC revised its guidelines and policies, identifying blood lead levels of ≥10 µg/dl in children and ≥25 µg/dl in adults as "elevated". CDC guidelines do not recommend interventions for individual children with blood lead levels less than 15 µg/dl (CDC 1991). The American Academy of Pediatrics recommends that parents of children with confirmed BLLs between 10 and 14 µg/dl be provided with general education on measures to reduce lead exposure. Individualized case management and treatment begins at BLLs of ≥20 µg/dl.

Due to imprecision in the testing methods, BLL testing has inherent variability. The same lab testing the same blood sample may get different results each time the sample is tested. As a result, the CDC blood lead proficiency program, a national quality assurance program for laboratories testing blood lead levels, allows an internal lab error rate of ±4 µg/dl. It is best to use the same lab when doing repeat BLL testing; otherwise there is a great potential for introducing inter-lab variability.

In all investigations and BLL testing done by the Alaska Division of Public Health (DPH), ESA Laboratories, Bedford, Massachusetts, has been used as the sole laboratory. ESA Laboratories is the reference (i.e., standard-setting) laboratory for the CDC blood lead proficiency program.

During the past two decades, the DPH, Lead Poisoning Prevention Program has evaluated blood lead levels in many Alaska communities following detection of elevated lead levels in drinking water supplies. In addition, several Alaska communities have been evaluated for possible exposure to lead ore in response to community concerns over mining activities.

Blood lead levels for a group of people (e.g., a certain age group) are frequently reported as the geometric mean. Geometric means are calculated to help account for a skewed distribution of the data (i.e., more results at lower BLLs) in order to be more precise. However, often the arithmetic mean and geometric mean do not differ greatly.

Previous Key Investigations of Lead Exposure in Alaska by the DPH

Kivalina and Noatak – 1990

In 1990, in response to concerns from village residents, and with support from the Maniilaq Association and the Kivalina and Noatak IRA Councils, DPH Section of Epidemiology (Epi) conducted a study to measure the blood lead levels of residents of Kivalina and Noatak (DPH 1991). Participation was voluntary; the goal was to test every resident in each village.

In Kivalina, 219 of 241 (90%) residents were tested; 125 were children less than 19 years of age, and 94 were adults. Only one child tested had a blood lead level higher than 10 µg/dl. Only 3 adults tested higher than 15 µg/dl. The adult who had the highest blood lead level (35 µg/dl) was employed at the Red Dog Mine and his level was below the Mining Safety and Health Administration (MSHA) intervention level of 40 µg/dl. Overall, the geometric mean BLL was 2.5 µg/dl in children aged 0 to 5 years, and 2.2 µg/dl in children aged 6 to 18 years.

In Noatak, 286 of 313 (91%) residents were tested; 128 were children less than 19 years of age, and 158 were adults. Only 7 children tested higher than 10 µg/dl; 2 children, brothers aged 9 and 12 years, tested above 15 µg/dl. Their levels were 20 µg/dl and 21 µg/dl, respectively. An extensive investigation with the children and their families failed to uncover a source of lead exposure that could account for their high levels. Of the adults tested, 17 had blood lead levels higher than 15 µg/dl, and only two had levels higher than 25 µg/dl. No risk factors or lead exposure sources were identified for the two adults. Overall, the geometric mean BLL was 3.7 µg/dl in children aged 0 to 5 years, and 4.3 µg/dl in children aged 6 to 18 years.

Blood Lead Screening of Medicaid-eligible Children – 1993

During a statewide project to assess BLL in Alaska children who were eligible for Medicaid during 1993-94, 21 children from Kivalina were tested (Robin et al. 1997, DPH 1994). The geometric mean BLL for these 21 children was 1.6 µg/dl.

For comparison, during the period 1991 to 1994, the CDC estimated that the national geometric mean BLL was 2.7 µg/dl for children aged 1 to 5 years. The data from Kivalina and Noatak compared very favorably to the national estimates from CDC, and provided no evidence of lead exposure in Kivalina or Noatak.

Point Hope, Alaska – 1992

In 1992, while Epi was investigating an infectious disease outbreak, the village of Point Hope made arrangements for a small number of children to be tested for blood lead levels. BLLs were determined for six children (age range 16 months to 12 years). All six children had BLLs <5 µg/dl (DPH 1992).

The results of these investigations are shown in Figure 2.

Red Dog Mine, Cominco workers – 1992

In 1992, Epi was consulted by ADEC and Cominco to evaluate the potential for increased exposure to lead dust of workers at Red Dog Mine from lead concentrations in the ambient air. Specifically, the

proximity of the personnel accommodation complex (PAC) to the mill and mine site raised concerns because ambient air quality standards for total suspended particulate (TSP) and lead had been exceeded (DPH 1993).

As part of the response, Cominco developed and conducted a BLL study of workers at the PAC, testing their BLL upon arrival at the mine and upon completion of their work shift. All blood lead samples were sent to ESA Laboratories for testing. Cominco provided BLL results to Epi for review and consultation.

In the study, 507 blood lead tests, representing 75 people, were done. Mean BLLs were 5.3 µg/dl upon arrival and 5.4 µg/dl upon departure. The highest BLL reported was 29 µg/dl in a mill worker. There was no correlation between BLL and ambient air monitoring results for TSP or lead.

Ongoing surveillance

The EPHP maintains a statewide blood lead surveillance database. The database utilizes the information gained from mandatory reporting regulations: Alaska statute requires reporting of blood lead test results of greater than or equal to 10 µg/dl for any person tested in Alaska. Excluding persons who work for Red Dog Mine, no reports of blood lead levels ≥10 µg/dl have been received for any resident of Northwest Alaska.

Skagway, Alaska

In 1988 and 1989, Epi investigated exposure of the residents of Skagway, AK to high concentrations of lead in soil resulting from years of transportation of lead ore concentrate through the center of town (DPH 1988 a-c, 1989). Between 1967 and 1982, lead ore was transported from a lead mine located in the Yukon Territory to Skagway via railway freight cars. Beginning in 1985, ore was transported by trucks that arrived in Skagway every 30 minutes, 24 hours per day, 362 days per year. The lead ore concentrate contained approximately 62% lead, primarily as lead sulfide.

Environmental sampling found concentrations of up to 60,000 mg/kg lead in the immediate vicinity of the lead warehouse. Elevated lead levels were found along the railroad tracks and State Street, the principle routes used to transport ore through Skagway. Samples from street gutters along State Street measured as high as 28,000 mg/kg, however, 60% of soil samples collected 5 feet from the road contained <1,000 mg/kg lead. Most soil samples taken on residential property contained less than 500-mg/kg lead.

Epi evaluated the exposure of Skagway residents to lead in September 1988. During November 1988 and September 1989, Skagway residents participated in voluntary BLL testing. During 1989, 13 children aged 0 to 5 years (geometric mean BLL = 8.3 µg/dl) and 35 children aged 6 to 18 years (geometric mean BLL = 7.2 µg/dl) were tested. Blood lead testing occurred twice more, after differing periods following extensive environmental cleanup. No children or adults were found to have elevated blood lead levels from non-occupational environmental exposure.

The results of the testing in Skagway were compared to data from CDC for 9,933 people tested in the National Health and Nutrition Examination Survey (NHANES) II (1976-1980):
- Nationally, only 22.1% of people in the NHANES II study had BLLs <10 µg/dl, compared to 78.4% of Skagway residents.
- Nationally, 85% of those tested had BLLs <20 µg/dl compared to 97.4% of Skagway residents.
- Except for ore terminal workers, all Skagway residents had BLLs of 20 µg/dl or less.

In addition to the human sampling that occurred, a medical epidemiologist from CDC obtained blood samples in Skagway from five dogs, two cows, and nine horses to test for lead. Preliminary results showed dogs, horses, and cows had mean BLLs of 3.0 μg/dl, 21.3 μg/dl and 11.0 μg/dl, respectively. Grazing animals are generally considered to have greater dietary exposure to lead than carnivores. Horses are known to be comparatively more sensitive to effects of lead; however, no signs or symptoms of adverse health were reported or observed in any Skagway animals (DPH 1988c).

The extensive scientific investigation at Skagway established several critical facts:
- Despite high levels of lead ore concentrate in the immediate environment and their homes, Skagway residents, including children, did not have blood lead levels of public health concern;
- The lead ore concentrate was tested and shown to have low bioavailability;
- The low bioavailability of the lead ore was critical in evaluating the health risk; and
- There was a need for environmental stewardship and clean-up.

Bioavailability studies

Bioavailability is a measure of the extent to which a chemical can be absorbed by a living organism following exposure (usually ingestion or inhalation). Lead sulfide, or galena, is the chemical form of lead in the ore from both Skagway and Red Dog Mine, and is very insoluble.

Ore from Skagway and the Red Dog Mine were rigorously tested by the National Institute of Environmental Health Sciences, National Toxicology Program in several rat feeding studies. These studies were designed and performed with lead ore from Skagway and Red Dog Mine and other types of lead to compare relative bioavailability.

In 1993, the National Toxicology Program published results in the *Journal of Toxicology and Environmental Health* that documented the low bioavailability of lead from Skagway ore (Dieter et al. 1993). Also in 1993, the National Toxicology Program conducted a study of lead ore concentrate from the Red Dog Mine. The study of the Red Dog ore was completed; however, the National Toxicology Program had not officially reviewed the contractor's report.

EPHP reviewed the National Toxicology Program contractor's report, and the results of the Red Dog ore study were directly comparable to the Skagway ore concentrate bioavailability study (DPH 2001). Both studies had similar methods, and a variety of assays were performed (e.g., blood, bone, kidney, liver, and brain lead concentrations, and the levels of enzymes and intermediates involved with heme synthesis) to determine the bioavailability of different types of lead in the rat model. Both studies found that body lead burdens (concentrations) in rats fed lead sulfide from Skagway and Red Dog were much lower than those in rats fed more bioavailable forms of lead such as lead acetate (DPH 2001).

EPHP asked the National Toxicology Program to evaluate the studies of the bioavailability of Red Dog Mine ore. The National Toxicology Program affirmed that the Red Dog ore is very similar to the Skagway ore (Eastin 2001). Therefore, the findings from the investigation in Skagway are very useful for evaluating the potential public health impact of lead ore from the Red Dog Mine.

Current Investigation

As part of the current investigation and evaluation of potential health risks associated with possible exposure to heavy metals derived from activities at the Red Dog Mine, EPHP reviewed available environmental data as well as data from the worker blood lead testing program at the mine. Data sources

included the Alaska Department of Fish and Game, the Alaska Department of Environmental Conservation, Cominco, Teck Cominco, the Alaska Division of Public Health, the North Slope Borough, and the Alaska Industrial Development and Export Authority.

Worker Blood Lead Testing

EPHP reviewed data from Cominco's blood lead testing program for Red Dog mine workers. Cominco provided data on initial blood lead levels for recently hired residents of Kivalina and, for comparison purposes, Noorvik. In addition, Cominco provided a database of blood lead levels of employees and contractors (Cominco, 2001b).

Blood Lead Levels -- Recent hires from Kivalina and Noorvik

Persons from Kivalina and Noorvik recently hired by Cominco were identified and Cominco provided their blood lead levels at time of hire to EPHP. BLL results were available for 20 persons from Kivalina and 15 persons from Noorvik. *Kivalina*: The range of BLL was 0 to 15 μg/dl, with an arithmetic mean BLL of 4.7 μg/dl. An estimated geometric mean, obtained by excluding the one 0 value, was 3.7 μg/dl. *Noorvik*: The range of BLL was 1 to 20 μg/dl, with an arithmetic mean BLL of 4.7 μg/dl and a geometric mean of 3.4 μg/dl.

Blood Lead Levels -- Employees and Contractors

Cominco provided EPHP with data from 10,685 blood test results from 1,805 regular and contract employees during the time frame of January 1992 to 2001. The data was provided by individual, with multiple test results reported for most individuals during the time frame. Aggregate data was summarized and analyzed for two time frames: January 1992 to 2001 and January 1, 1995 to 2001. The geometric mean of all BLL results was 9.02 μg/dl (range 1 – 74 μg/dl). Results are provided in Table 1 and Table 2. Over the entire timeframe, only 11% of the BLLs were ≥25 μg/dl, and 1% were ≥40 μg/dl (Figure 3). Since 1995, only 8.7% of tests were ≥ 25 μg/dl, and 0.9% were ≥ 40 μg/dl (Figure 4). When only the most recent tests are considered, only 2 of 1,367 persons (0.15%) tested ≥ 40 μg/dl. No correlation was noted between length of time between the initial test and the final test and an individual's blood lead level (Figure 5).

Cominco employees

Results were reported for 1,142 Cominco employees (Figure 6). The geometric mean BLL for the 7,955 tests run was 9.7 μg/dl (range 1 – 74 μg/dl). Only 88 (1%) of tests were ≥40 μg/dl. BLL test results were considered separately by department. Particular attention was focused on workers in the mine and mill areas, and at the port facility, who were hypothesized as having the greatest occupational exposure to lead. For these departments, results were reported for 6,754 tests representing 936 persons. The geometric mean BLL for all tests for mill workers was 11.7 μg/dl (range 1 – 60 μg/dl) and was 10.1 μg/dl (range 1 – 74 μg/dl) for mine workers. Port workers had a geometric mean BLL of 8.8 μg/dl (range 1 – 44 μg/dl) for all tests. When only the most recent test for an individual was considered, the geometric mean BLL was 10.7 μg/dl for mill workers, 9.5 μg/dl for mine workers, 8.0 μg/dl for port workers, and 8.9 μg/dl for truck drivers. Geometric mean blood lead levels for persons in Finance (n = 119) and Human Resources (n = 161) were 3.5 μg/dl (Figure 7).
Contract employees

Results were reported for 663 contract employees (Figure 8). Of the 2,730 tests run, the geometric mean BLL was 7.2 µg/dl (range 1 – 63 µg/dl). When only the most recent tests were considered (n = 444), the geometric mean BLL was 6.1 µg/dl.

The results from Cominco's blood lead monitoring program indicate that the lead can be absorbed by workers who are heavily exposed to lead ore concentrate. However, workers in occupations that do not involve routine, heavy exposure to lead ore have low blood lead levels, comparable to those of the general population, and overall blood lead levels in workers at Red Dog are well below the level of concern for adults (25 µg/dl).

Environmental Assessment

Description of the Potential Exposure Pathways and Available Sources of Data

Estimating an individual's exposure to chemicals requires a determination of whether or not an exposure pathway exists. Therefore, in order to fully assess if chemicals in the environment derived from mining activities at Red Dog pose a public health threat to village residents, EPHP carefully reviewed all currently available data and evaluated them for potential exposure pathways.

An exposure pathway contains the following five elements:
- a source of contaminants;
- an environmental medium such as air or water that contains or moves the contamination;
- a point where people contact contaminated media such as a river;
- an exposure route, such as eating contaminated berries or drinking contaminated water; and
- people who can come in contact with the contaminants.

An exposure pathway is not complete if at least one of the five elements of a pathway is missing and is not expected to occur. If no exposure pathway exists, then no impact to health is expected. The potential exposure pathways evaluated in this health consultation are outlined below:
- Ingestion of water from the Wulik River;
- Skin contact with, inhalation of, and ingestion of contaminated surface soils located at the port or along the DMTS road;
- Exposure to sediments at the port;
- Ingestion of fish from the Wulik River or other streams;
- Ingestion of caribou harvested in the area; and
- Ingestion of salmonberries harvested in the area.

Methods for Analyzing the Data

EPHP first screened the chemical concentrations against risk-based screening concentrations. Chemicals that exceeded screening concentrations were then further evaluated. It must be emphasized that screening concentrations are not thresholds of toxicity. Although concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any concentration that exceeds a screening value would be expected to produce adverse health effects. The principle purpose behind protective health-based standards and guidelines is to enable health professionals to quickly recognize and resolve potential public health hazards. Any concentration that exceeds its screening value is then carefully evaluated. The probability that health effects will actually occur does not depend on environmental concentrations alone, but on a unique combination of site-specific conditions and individual lifestyle and genetic factors that affect the route, magnitude, and duration of actual exposure.

Water and soil concentrations were screened using Agency for Toxic Substances and Disease Registry (ATSDR) health-based comparison values (ATSDR 2001), United States Environmental Protection Agency Region 9 Preliminary Remediation Goals (USEPA 2000), and ADEC drinking water maximum contaminant levels (MCL), action levels, and soil residential clean up values (ADEC 2000).

Caribou, fish, and berry risk-based screening concentrations were derived using the mean ingestion rates for Kivalina presented in the Alaska Department of Fish and Game Division of Subsistence Community Profile Database (ADF&G 2001a). This database estimates ingestion rates from harvest information. Note that the ingestion rates are only rough estimates. Ingestion rates may be higher or lower based on a number of factors (ADF&G 1996). The estimated ingestion rates were combined with the U.S. Environmental Protection Agency's (EPA) published oral reference dose (RfD) for non-carcinogens or EPA's slope factor for carcinogens. RfDs are estimates of daily exposure of a person to a chemical for a specified exposure duration that is likely to result in no appreciable non-cancer health risk. The slope factor for a chemical is a number used to estimate its ability to cause cancer in humans. The probability that something will cause cancer is termed risk. Cancer risk is usually estimated as how many extra cancers may appear in a group of people who are exposed to a particular substance at a given concentration, in a particular pathway, and for a specified period of time. The overall lifetime risk of developing cancer is quite high: one in four people in the U.S. are expected to develop cancer sometime during their lives (American Cancer Society 1998). Risk assessments often find that a chemical in the environment may add a very small hypothetical risk, e.g., on the order of 0.0001%, to this background incidence rate.

An oral reference dose for lead has not been derived by regulatory agencies. Therefore, lead concentrations in caribou, fish, and berries were evaluated using the standard USEPA Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (USEPA 2001). In addition, to determine if lead concentrations in these subsistence resources are elevated over normal background levels, comparisons were made to concentrations detected in the same species elsewhere.

Drinking water

Kivalina village water

The source for the village of Kivalina's drinking water system is the Wulik River. It is a Class A community water system with two service connections at the washeteria and the school. A Class A system is defined as serving more than 25 people for six months of the year. Treatment includes pressure sand and cartridge filtration and chlorination. Water can be "made" (i.e., treated and stored) from June until August; most of the water is "made" during August. There are two storage tanks with a total capacity of approximately 1,250,000 gallons. The most recent testing of city water occurred during April 2001. Five samples were collected (one from the water tank and four from the washeteria) and analyzed for lead and copper. Lead was not detected (method reporting limit = 0.004 mg/L) and copper was detected in each sample below the State of Alaska action level. Testing for other heavy metals occurred in 1995 (antimony, arsenic, barium, beryllium, cadmium, chromium, cyanide, fluoride, mercury, nickel, nitrate, selenium, and thallium) and 1996 (antimony, beryllium, cyanide, nickel, and thallium). All detections were well below their respective MCLs:

1995:
    Barium 0.16 mg/L (MCL 2.0 mg/L)
    Cadmium 0.0002 mg/L (MCL 0.005 mg/L)
    Selenium 0.003 mg/L (MCL 0.05 mg/L)

1996:
    Beryllium 0.0009 mg/L (MCL 0.004 mg/L)

All results were also well below the EPA risk-based screening concentrations. No other analytes were detected.

Kivalina school and clinic

Cominco collected 27 water samples from the school in 1991, 1992, 1993, 1997, and 1998. One water sample was collected from the clinic in July 1997. The samples were analyzed for total dissolved solids (TDS), aluminum, cadmium, copper, iron, lead, and zinc. There was only one instance where an analyte was detected above a MCL or risk-based screening level. Aluminum was detected in January 1998 at 63 mg/kg, compared to the EPA risk-based screening level of 36 mg/kg. In the next sampling event (March 1998), the concentration was 30 mg/kg. The average concentration of lead was 0.002 mg/L for the 27 samples.

Wulik River Station 1

Cominco has collected water samples from the Wulik River at Station 1 since 1990. Station 1 is located where Kivalina residents collect fresh water for treatment and storage. For this report, EPHP evaluated the 24 water samples collected during the time frame 1998 to 2001. Based on their potential for health effects, EPHP evaluated data for aluminum, cadmium, chromium, copper, iron, manganese, nickel, lead, selenium, and zinc (Figures 9-1 to 9-10).

During this sampling period, lead was detected (0.02 mg/L) only once above the Alaska drinking water action level (0.015 mg/L). Cadmium was detected (0.0034 mg/L) once above the ASTDR child screening level (0.002 mg/L), but not above the EPA screening value of 0.018 mg/L. No other heavy metals were detected above the risk-based screening levels.

Wulik River Station 2

Cominco has collected water samples from the Wulik River at Station 2 since 1990. Station 2 is located upstream of Tutak Creek, approximately 20 miles upstream from Kivalina on the Wulik River.

For this report, EPHP evaluated 34 water samples collected from 1998 through 2001. Based on their potential for health effects, EPHP evaluated the aluminum, cadmium, chromium, copper, cyanide, iron, manganese, nickel, lead, selenium, silver, and zinc data (Figures 10-1 to 10-11).

During this sampling period, in only one instance was any chemical detected above the risk-based screening concentration. Lead was detected (0.12 mg/L) once above the Alaska drinking water action level (0.015 mg/L). Cadmium was detected twice (0.0024 mg/L and 0.0028 mg/L) slightly above the ATSDR child screening level (0.002 mg/L), but not above the state drinking water MCL (0.005 mg/L) or the EPA risk-based screening level (0.018 mg/L). Nickel was detected once above the MCL, but not above the ATSDR or the EPA risk-based screening level.

Water data collected near the port

As part of the Port Site Monitoring Program conducted by Cominco, water samples were collected near the Port facilities beginning June 1990 (baseline studies) until 1996 and analyzed for lead and zinc (RWJ Consulting 1997). In 1996, 244 water samples were collected from the four lagoons located near the port, tundra surface water (random samples), and marine water. Due to the nature of these water sources, it is very unlikely anyone would ingest water from any of these sources. However, as an indication of potential impacts to drinking water sources near the port such as nearby creeks, the results of the 22 water

samples collected from the four lagoons were compared to MCLs and risk-based screening levels. Lead and zinc were not detected above MCLs or risk-based screening concentrations in any sample.

Drinking water summary

The heavy metals detected in these water samples do not indicate any health threat. Most concentrations were well below established National and State risk-based screening concentrations. Lead was detected above the State and National action limit one time in samples from the Wulik River at Station 1 and Station 2; however, the mean concentrations over that period were 0.0034 mg/L for Station 1 and 0.0059 mg/L for Station 2, well below the action level (0.015 mg/L). The concentrations of heavy metals in the most recent sampling from the Kivalina Village water supply were well below National and State standards. EPHP recommends that Kivalina residents consume water from the village water supply since the water is chlorinated to kill microbial pathogens, and the water is treated with a sand filtration system that will remove particles.

Soil

National Park Service road data

The National Park Service collected moss and soil samples along six transects (three south and three north) of the DMTS road in the Cape Krusenstern National Monument (National Park Service 2001). Samples of moss (*Hylocomium splendens*) were collected along the transects at distances of 3 meters, 50 meters, 100 meters, 250 meters, 1000 meters, and 1600 meters from the road. Samples were analyzed for aluminum, cadmium, calcium, iron, lead, magnesium, silver, and zinc. The concentrations of all the analytes decreased significantly within 250 meters distance from the road. There was no difference in the concentrations of heavy metals detected on the moss for samples collected at 1000 meters and 1600 meters from the road. The concentration of lead slightly exceeded the ADEC and EPA screening concentration in four of six samples collected 3 meters from the road (maximum concentration detected was 458 mg/kg; ADEC residential clean-up standard is 400 mg/kg). One sample collected 50 meters from the road contained lead exceeding the risk-based screening concentration. No other heavy metals exceeded the screening concentration except for iron, which was detected above the EPA risk-based screening concentration (23,000 mg/kg) in two samples collected 3 meters from the road.

Soil samples were collected at distances of 3 meters and 1000 meters from the road along the transects and analyzed for aluminum, cadmium, calcium, iron, lead, magnesium, silver, and zinc. None of the concentrations exceeded the risk-based screening concentrations except iron. High levels of iron are naturally occurring in the area (USGS 1995).

DMTS Road spills

Thirty truck roll-over spills of zinc or lead ore have occurred on the Red Dog DMTS Road from 1990 to present. To date, 9 of the 30 sites have had spill site clean-up and closure conducted. Standard procedures for spill site closure include removing soil until target clean-up concentrations are achieved (1000 mg/kg for zinc and 500 mg/kg for lead). These concentrations are below the industrial clean up levels of 767,000 mg/kg for zinc in the Arctic climate zone and 1000 mg/kg for lead. Teck Cominco is in the process of identifying the remaining spill sites and conducting closeout procedures.

Port soil data

Soil samples were collected at the Port facilities from June 1990 (baseline studies) to 1996 as part of the Port Site Monitoring Program conducted by Cominco (RWJ Consulting 1997). In 1996, 498 soil samples

were collected around Port structures and analyzed for lead and zinc. Samples were collected around the concentrate storage building (CSB), the conveyor area, the dock, the roadway, the concentrate unloading area, and the fuel storage area. The highest lead (36,000 mg/kg) and zinc (180,000 mg/kg) concentrations were detected in the unloading area. Maximum and median concentrations for each structure are listed in Table 3. Maximum concentrations detected at the control sites were used as a comparison (lead = 52.8 mg/kg and zinc = 181 mg/kg).

Each area had lead and zinc concentrations exceeding ADEC and EPA residential or industrial screening concentrations. The number of samples detected over background concentrations decreased significantly between 50 and 500 feet from the port facilities indicating the majority of dust generated from port operations does not travel off site.

Soil summary

Although the concentrations of lead and zinc are elevated near the port and to some extent along the DMTS road, the general public will have limited exposure to soils in these areas since there are no residences near the mine, DMTS road or the port. Furthermore, NANA currently restricts public access to the port, DMTS road, and mine.

Although recent soil samples have not been collected outside of NANA property, available data indicate that the majority of dust generated from port and road activities will not travel off NANA property.

If the general public does access the port and road areas, any exposure to soils containing high concentrations of lead or zinc would be short in duration since these areas will likely be used only to access other areas. Additionally, uptake of lead would be limited because of the low bioavailability of the ore concentrate.

Thus, the concentrations of lead and zinc detected at the port and near the road do not pose a public health threat to the general public. As detailed earlier in this report, Cominco's mandatory worker blood lead monitoring program ensures that workers are not exposed to hazardous levels of lead.

Sediment

Nearshore marine sediment

As part of the Port Site Monitoring Program conducted by Cominco, sediment samples were collected at the Port from June 1990 (baseline studies) to 1996 (RWJ Consulting 1997). In 1996, 81 marine sediment samples were collected at varying distances up to 1,500 feet from the offshore loading facilities. The maximum concentrations of lead and zinc were 74 mg/kg and 260 mg/kg, respectively.

Lagoons sediment

In 1996, 22 sediment samples were collected from the three lagoons near the port and a control lagoon located 1 mile southeast of the port (RWJ Consulting 1997). The maximum concentration detected was 140 mg/kg for lead and 1,200 mg/kg for zinc.

Sediment summary

Exposure to the sediments of the nearshore marine environment and the port lagoons does not pose a public health concern because individuals will have very limited or no contact with the sediments at either location. In addition, lead and zinc were below State and Federal human health risk-based screening concentrations for soil exposure.

Fish

Dolly Varden

Since 1990, the Alaska Department of Fish and Game (ADF&G) has sampled adult Dolly Varden from the Wulik River and measured concentrations of aluminum, cadmium, copper, lead, and zinc in muscle, gill, liver, and kidney tissue. Beginning in 1996, tissue samples also were analyzed for selenium. One of the goals of the ADF&G adult Dolly Varden sampling is to identify any changes in tissue concentrations that may be related to mining operations. Metals do not tend to accumulate in the muscle, but tend to concentrate in specific tissues: aluminum, selenium, zinc are most prevalent in gill tissue, cadmium and copper in liver, selenium in reproductive tissues, and lead in both liver and kidney (ADF&G 2001b). Fish were collected twice yearly: once in the fall before freeze-up and once in the spring after break-up.

The concentrations of metals in Wulik River Dolly Varden tissues do not appear to correlate with the age of fish, nor do older fish appear to be accumulating higher concentrations of metals. In addition, metals are not bioconcentrated up the food chain. In general, ADF&G reported the concentration of heavy metals detected in Dolly Varden collected from the Wulik River has been relatively constant since 1990, with the exception of some fluctuations in concentrations of heavy metals that were corrected by engineering design at the mine (ADF&G 2001b).

To determine the potential health impacts of heavy metals detected in the tissues of Dolly Varden, EPHP compared calculated intake concentrations with calculated risk-based screening concentrations (Table 4). The ADF&G data provided in dry weight were converted to wet weight and average tissue concentrations were calculated for sampling results reported for 1990 through 2000. One-half the detection limit was used for non-detects (ADF&G 2001b). Intake concentrations were calculated assuming individuals could potentially eat all fish tissues. The average concentration of each tissue was multiplied by the tissue percent weight and the result for each tissue was added together to derive the total. The percent weight for each tissue is based on an average of three fish: 2.3 % for the liver, 0.99% for the kidney, 1.2% for the gills, and 0.39% for the reproductive organs (based only on one fish) (Scannell 2001).

The adult risk-based screening concentrations were calculated using the mean per-capita ingestion rate for char (252 g/day) presented in the ADF&G database (ADF&G 2001a) and a body weight of 70 kg. The child risk-based screening concentrations were calculated similarly using an estimated child ingestion rate and a body weight of 15 kg. The estimated child ingestion rate was calculated by multiplying the adult ingestion rate by a correction factor of 0.54. This value was calculated from the ratio of the child fish intake rate (five and under) to the average of the adult male and female (20 years and older) fish intake rate presented in Table 10-46 in USEPA's Exposure Factors Handbook (USEPA 1997).

The calculated intake concentrations for all heavy metals detected in Dolly Varden were below the calculated adult and child risk-based screening concentrations. The potential health effects of lead in Dolly Varden were evaluated together with the lead concentrations from all other potential exposure media using the standard USEPA Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children as described below.

Grayling

In the spring of 1999, the ADF&G also collected six arctic grayling females from the North Fork of Red Dog Creek and analyzed their livers and ovaries for selenium. The reported selenium concentrations were converted to wet weight and compared to calculated risk-based screening concentrations derived using the mean per capita ingestion rate (3.89 g/day) for grayling reported in the ADF&G database. The

concentrations of selenium detected in the liver and the ovaries were over 800 times lower than the calculated risk-based screening concentration.

Fish summary

The concentrations of heavy metals measured in fish collected from streams and rivers in the Red Dog Mine area are well below any risk-based screening level and do not pose a public health concern.

Caribou

In response to concerns about the potential accumulation of heavy metals in caribou, ADF&G harvested 15 caribou along the DMTS road in 1996 (North Slope Borough 2001). Liver, kidney and muscle tissues were analyzed for arsenic, cadmium, copper, iron, lead, and zinc. Results for these animals were compared to those for caribou collected by the North Slope Borough and ADF&G from the vicinity of Anaktuvuk Pass (10), Barrow (6), Chariot (18), Point Hope (6), and Teshekpuk Lake (9) as part of an investigation of caribou mortality around Cape Thompson (Figures 11-1 through 11-18). Intake concentrations were calculated assuming individuals eat caribou liver, kidney, and muscle. To calculate the intake concentration, the average concentration of each tissue was multiplied by the tissue percent weight and the result for each tissue was added together to derive the total. It was assumed that muscle contributed 96% of caribou ingestion and liver and kidney contributed 2% each. The value of 2% for caribou liver and kidney was estimated based on the percent weight of reindeer liver reported by Stimmelmayr (1994). The adult risk-based screening concentrations were calculated using the mean per-capita ingestion rate for caribou (177 g/day) presented in the ADF&G database (ADF&G 2001a) and a body weight of 70 kg. The child risk-based screening concentrations were calculated similarly using an estimated child ingestion rate and a body weight of 15 kg. The estimated child ingestion rate was calculated by multiplying the adult ingestion rate by a correction factor of 0.41. This value was derived from the ratio of the toddler (1 to 6 years) beef intake rate to the adult (20 to 45 years) beef intake rate presented in Table 11-18 in USEPA's Exposure Factors Handbook (USEPA 1997). The potential health effects of the lead concentrations detected in the tissue of caribou were evaluated together with the lead concentrations from all other potential exposure media using the standard USEPA IEUBK for lead in children as described below.

The calculated intake concentration of each analyte was below the risk-based screening concentration except for arsenic (Table 5). Comparing the arsenic muscle, liver and kidney tissue concentrations to arsenic concentrations detected in the caribou collected from the other Alaskan sampling areas, indicates only the muscle arsenic concentration is elevated above arsenic concentrations detected in other areas (Figures 11-1, 11-7, and 11-13).

The analytical results for arsenic in the caribou tissues represent total arsenic. It is well known that arsenic in food exists in organic and inorganic forms. The organic forms of arsenic are considered relatively non-toxic because they pass through the digestive system without being absorbed (ATSDR 2000). Therefore, it is difficult to put these caribou arsenic levels in context regarding the potential for adverse health effects. Arsenic in seafood is estimated to mostly (80-99%) be present as non-toxic organic forms (ATSDR 2000). Environment Canada uses a standard value of 37% for all food to estimate inorganic arsenic concentrations (ATSDR 2000). There have not been any studies determining the inorganic and organic concentrations of arsenic in muscle, kidney and liver of caribou; however, the inorganic arsenic concentration is probably much less than 100% for muscle tissue.

The World Health Organization (WHO) provisional tolerable daily intake (PTDI) for arsenic is 2 μg/kg/day. Based on the concentrations of arsenic detected in caribou near Red Dog Mine, the daily

intake of arsenic would be 1.4 µg/kg/day. This assumes an ingestion rate of 177 g/day (ADF&G 2001a) and a body weight of 70 kg. If the Environment Canada value of 37% inorganic arsenic is applied to the arsenic concentrations detected in the caribou tissues, then the daily intake of inorganic arsenic (the toxic form of arsenic) would be 0.52 µg/kg/day. To calculate an individual's total arsenic daily intake, the daily intake of arsenic from ingestion of caribou would be added to the daily intake of arsenic from other food and water sources. Water samples collected in 1995 from Kivalina's water supply did not detect arsenic. At this time, no other arsenic data is available.

Caribou summary

The concentrations of heavy metals detected in caribou collected near Red Dog Mine and the DMTS do not pose a public health concern.

Salmonberries

ADEC, with assistance of the village of Kivalina, collected 10 composite samples (5 washed and 5 unwashed) of salmonberries approximately 1 mile north and 10 composite samples (5 washed and 5 unwashed) approximately 1 mile south of the port (ADEC 2001). The concentrations of washed and unwashed samples were very similar in concentration, indicating little atmospheric deposition has occurred on the salmonberries. The average concentrations of heavy metals in the salmonberries were well below calculated risk-based screening concentrations (Table 6). The adult risk-based screening concentration was calculated using the mean ingestion rate for berries (17.5 g/day) presented in the ADF&G database (ADF&G 2001a). The child risk-based screening concentrations were calculated similarly using an estimated child ingestion rate and a body weight of 15 kg. The estimated child ingestion rate was calculated by multiplying the adult ingestion rate by a correction factor of 0.97. This value was derived from the ratio of the 1995 child (5 years and under) fruit intake rate to the average of the adult male and female (20 years and over) fruit intake rate presented in Table 9-18 in USEPA's Exposure Factors Handbook (USEPA 1997). The potential health effects of lead in berries are evaluated together with the lead concentrations from all other potential exposure media using the standard USEPA IEUBK for lead in children as described below.

The concentrations of heavy metals in the berries were also compared to data presented by Gamberg in the 1998 Arctic Monitoring and Assessment Programme Assessment Report: Arctic Pollution Issues (Table 7) (Gamberg 2001). Eighty-eight berry samples of varying species were collected throughout the Yukon and the Northwest Territories. The concentrations of the salmonberries collected near the port were within the range of concentrations reported by Gamberg, also indicating the collected salmonberries were not impacted by activities at the port. Note that a zero was used for a non-detect sample result in the Gamberg data. This will have the effect of biasing the data low since the heavy metals are present but at concentrations below the detection limits.

The concentrations of heavy metals detected in the salmonberries are consistent with typical background levels and do not pose a public health concern.

Blood Lead Model

Children under six years of age are considered most susceptible to lead exposure and toxicity. To evaluate the likelihood of elevated blood lead levels for children assumed to be chronically exposed to lead containing media, EPHP used the standard EPA IEUBK model for lead in children to estimate blood lead concentrations (USEPA 2001). See Appendix A for a description of the model.

EPHP used these input parameters for the model:

1. Soil Concentration = 52.8 mg/kg
Since residential exposure to the elevated lead concentrations in soil collected near the port will be very limited, it is assumed the residents of Kivalina will be exposed to background concentrations of lead in soil; therefore, the lead background concentration for the port area reported by Cominco during 1990 through 1996 of 52.8 mg/kg was used (RWJ Consulting 1997).

2. Water Concentration = 3.4 ug/L
The mean water concentration of 3.4 µg/L reported by Cominco for 1998 through 2001 at Station 1 was used. One-half the detection limit was used for non-detect values. The mean concentration at the school for 1991, 1992, 1993, 1997, and 1998 was 2.0 µg/L.

3. Fish (Char) Concentration = 0.016 mg/kg
The mean tissue concentrations for Dolly Varden collected from the Wulik River were used to calculate an intake concentration. The concentration was calculated assuming individuals could potentially eat all fish tissues. To calculate the intake concentration (0.016 mg/kg), the concentration of each tissue was multiplied by the tissue percent weight and the result for each tissue was added together to derive the total.

4. Meat (Caribou) Concentration = 0.28 mg/kg
The mean muscle tissue concentration (0.05 mg/kg), mean kidney concentration (10 mg/kg), and mean liver concentration (1.65 mg/kg) for caribou collected near Red Dog mine were used to derive the value of 0.28 mg/kg. The total intake concentration was derived similarly to the fish concentration. It was assumed that kidney and liver comprised 2% each of the child's diet.

5. Fruit Diet (Berry) Concentration = 0.027 mg/kg
The mean salmonberry concentration (unwashed berries) was used.

6. It was assumed that Dolly Varden lead concentration comprised 60% of the total meat and fish diet and the caribou lead concentration comprised 40% of the total meat and fish diet. These values were derived from the ratio of the respective ingestion rates presented in the ADF&G database. The salmonberry lead concentration comprised 100% of the fruit diet.

7. All other input parameters were left as default values.

The modeled blood lead results indicate that blood lead levels will be very low and are not above CDC's/EPA's level of concern (Table 8).

Benefits of Subsistence Food

An evaluation of the health risks possibly associated with consumption of trace heavy metals in Alaskan subsistence foods must include a balanced consideration of the health benefits derived from these foods. Traditional foods contain many healthful nutrients, and are lower in saturated fat than are many non-Native foods (Egeland et al. 1998). Consumption of traditional foods provides significant health benefits such as protection from diabetes and cardiovascular disease, improved maternal nutrition, and enhanced neonatal and infant brain development (Egeland et al. 1998). The importance of subsistence foods goes beyond their nutritional superiority, as the subsistence lifestyle and diet are also crucial to the self-definition, self-determination, cultural, socio-economic, and overall health and well-being of indigenous peoples.

Child Health Initiative: Developmental/Reproductive Effects

The State of Alaska Section of Epidemiology recognizes the unique vulnerability of children to the health risks posed by contaminants in the environment. Pound for pound body weight, children drink more water, eat more food, and breathe more air than adults. The implication for health is that, by virtue of children's lower body weight, given the same exposures, they can receive significantly higher relative contaminant doses than adults. Therefore, children are considered in the evaluation of all chemical exposures.

During this investigation we evaluated levels of contaminants reported for water, soil, and sediment using health guidelines that are protective for children. We also considered the cumulative effects including ingestion of fish, berries and caribou. Substituting the standard child body weight (15 kg) and applying child/adult ingestion rate ratios (derived from the USEPA Exposure Factors Handbook, USEPA 1997) to the ADF&G ingestion rates for fish, berries, and caribou, the results of the risk-based screening did not change.

Children are considered more vulnerable to the effects of lead for several reasons. They absorb and retain lead more readily than adults, they have more frequent hand-to-mouth activity than adults, and their brains and nervous systems are more sensitive to the effects of lead (USEPA 2001). However, anyone with poor nutritional status absorbs lead more easily. In particular, calcium and iron deficiencies enhance lead absorption. An empty stomach also enhances lead absorption. The most sensitive effect of lead poisoning is believed to be impaired development of the central nervous system in children and the unborn. Modeling indicated that lead levels detected in media (water, soil, fish, berries, and caribou) from the Red Dog area do not pose a health threat to infants or young children.

Summary

- The concentrations of heavy metals detected in water, soil, caribou, fish, and berry samples collected from the Red Dog mine area *do not pose a public health hazard* to the residents of Kivalina and Noatak;
- In general, the concentrations of heavy metals detected in collected water, soil, caribou, fish, and berries collected from the Red Dog mine area (excluding the port, DMTS road, and mine) represent natural background concentrations;
- As expected, soil samples at the port contained very high concentrations of lead and zinc; however, the general public is excluded from the Port Area;
- The bioavailability of the lead sulfide in the ore concentrate is very low;
- Recently hired employees with no prior exposure to the ore concentrate had very low blood lead concentrations;
- Past studies documented low blood lead levels among residents of Kivalina and Noatak;
- Employees working at Red Dog who do not work directly with the ore concentrate have very low blood lead concentrations;
- There are no identified exposure pathways for the residents of Kivalina or Noatak. Exposure monitoring by blood lead testing of residents of Kivalina and Noatak is not warranted at this time;
- Certain employees who work directly with the ore concentrate are exposed to high levels of lead; and
- Red Dog Mine employees should continue to have periodic blood lead monitoring in accordance with MSHA and OSHA requirements.

Recommendations

- Residents of Kivalina and Noatak should continue unrestricted harvest and consumption of subsistence resources in their area;
- Teck Cominco should continue to develop and implement methods to limit fugitive dust emissions at the mine, road, and port;
- Water samples from Kivalina's drinking water system should be routinely collected and analyzed in accordance with ADEC policies and regulations;
- Soil samples should be routinely collected near the port and monitored to determine the impact of lead and ore concentrate on the land available for public access;
- In an effort to limit exposure of the general public to industrial site activities, NANA should continue to limit public access to the Red Dog Mine and port facilities;
- EPHP believes the size and scope of the mining operation make the development of an ongoing environmental monitoring program essential; and
- A formal process with active participation of local residents should be established through which State and Federal regulatory agencies and interested parties routinely review and interpret monitoring data.

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List of Figures and Tables

STATE OF ALASKA

ENLARGED AREA

BARROW
BEAUFORT SEA
CHUKCHI SEA
KOTZEBUE
NOME
FAIRBANKS
BETHEL
DILLINGHAM
ANCHORAGE
BRISTOL BAY
UNALASKA/DUTCH HARBOR
KODIAK
GULF OF ALASKA
JUNEAU

POINT HOPE

164°03' W LONG.

DMTS HAUL ROAD

RED DOG MINE

KIVALINA

DMTS PORT SITE

67°34' N LAT.

NOATAK

CAPE KRUSENSTERN

CHUKCHI SEA

KOTZEBUE

KOTZEBUE SOUND

REFERENCE:
NOAA CHART #16005

		Cominco Alaska Incorporated DeLong Mountain Terminal Project
SCALE: NTS	Vicinity Map	

Figure 2. Comparison of Blood Lead Levels in Alaska
Selected Investigations

Legend:
- ☐ Adults
- ▨ Children 6-18
- ■ Children 0-5

CDC adult level of concern

CDC child level of concern

Y-axis: **Blood Lead Level (geometric mean, ug/dl)** (0, 5, 10, 15, 20, 25)

X-axis locations: Kivalina 1991 | Kivalina 1993 | Noatak 1991 | Pt Hope 1992 | Skagway 1989 | CDC NHANES III (1991-1994)

Investigation Location   *Point Hope - all 6 children tested <5 ug/dL

Figure 3. Red Dog Mine: COMINCO Blood Lead Levels
Total Sample: 10,685 Tests

Y-axis: **Number of Tests** (0, 200, 400, 600, 800, 1000, 1200, 1400, 1600)

Annotations:
- Geometric Mean: 9.02 ug/dL
- Median: 10 ug/dL
- Arithmetic Mean: 12.30 ug/dL
- 1,181 Tests (11.06%) GE 25 ug/dL
- 116 Tests (1.09%) GE 40 ug/dL

X-axis: **Blood Lead Levels (ug/dL)** (1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 62, 74)

Figure 4. Red Dog Mine: COMINCO Blood Lead Levels Since 1/1/1995
Total Sample: 8,964 Tests

Geometric Mean: 8.38 ug/dL

Median: 9 ug/dL

Arithmetic Mean: 11.44 ug/dL

783 Tests (8.73%) GE 25 ug/dL

78 Tests (0.87%) GE 40 ug/dL

Figure 5. Red Dog Mine: Changes in Blood Lead Concentrations for Mine Workers with an Interval
of More than 250 Days Between Initial and Most Recent Tests

$y = -0.0029x + 5.5512$

$R^2 = 0.1338$
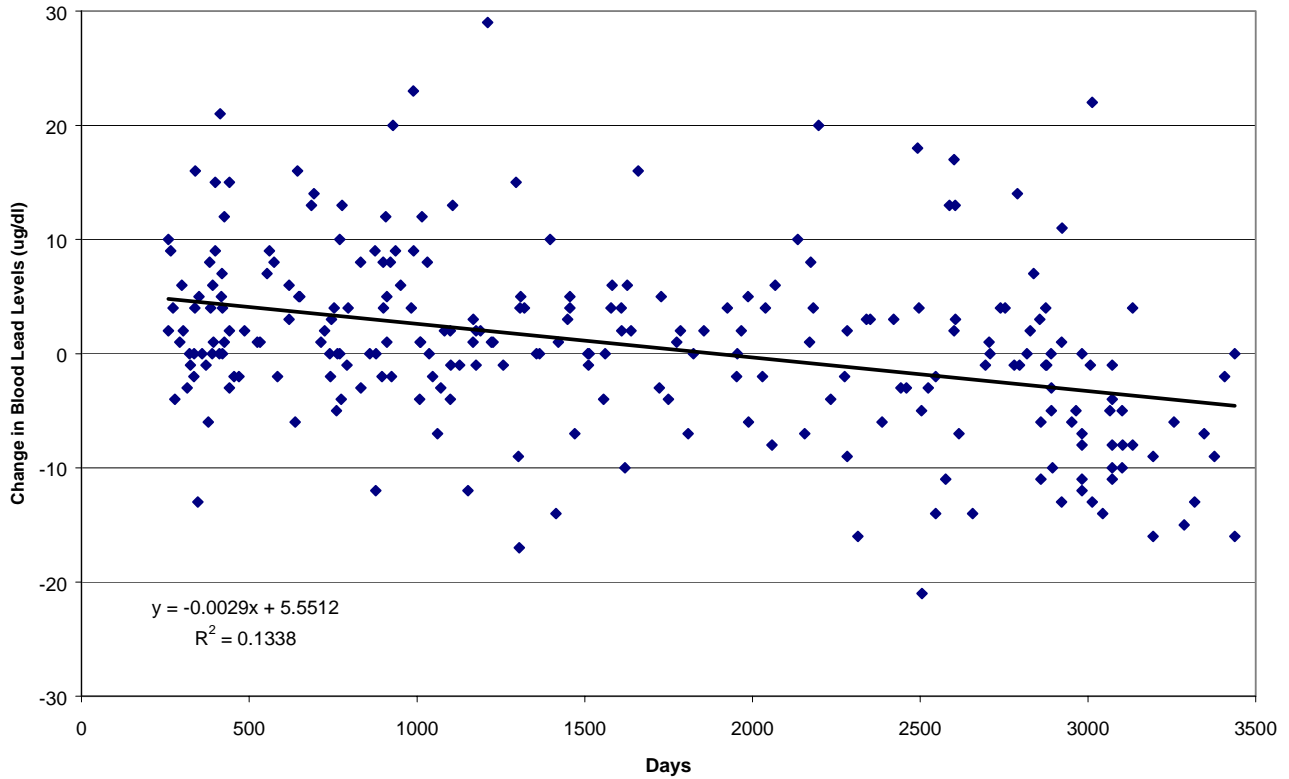
Figure 6. Red Dog Mine: COMINCO Blood Lead Levels
Cominco Subsample: 7,955 Tests
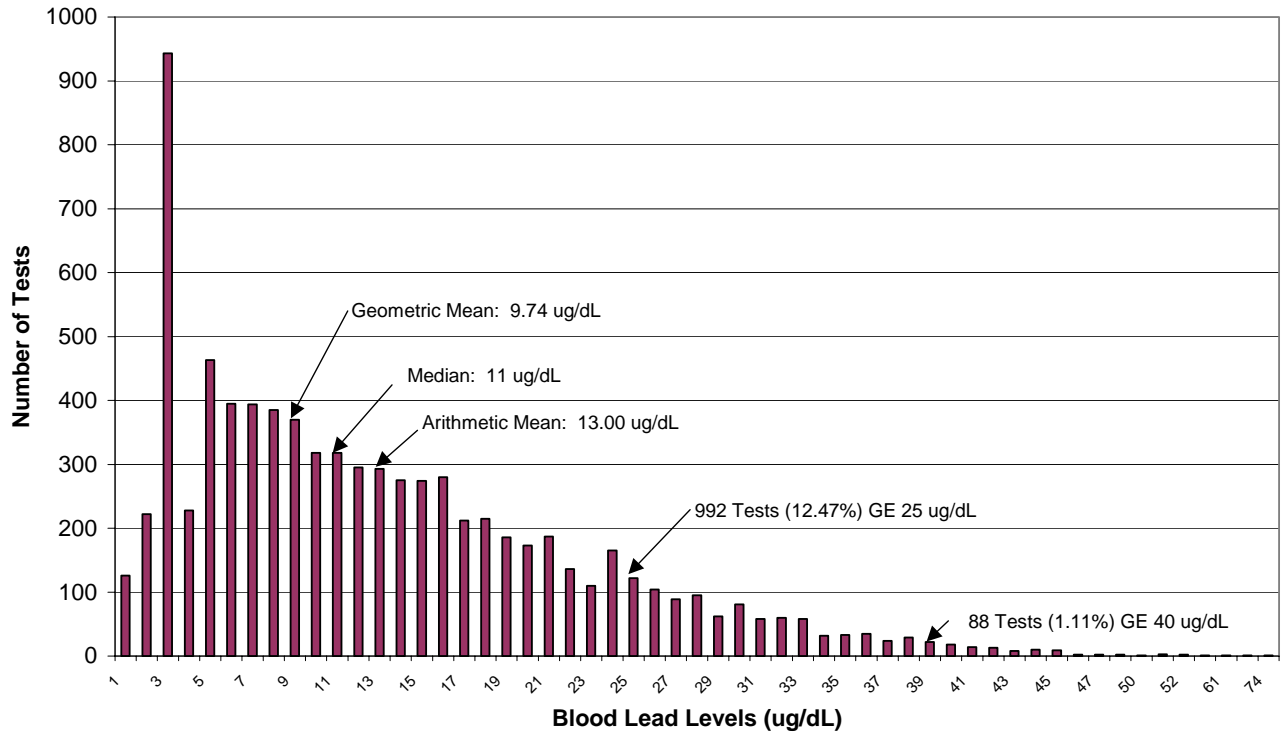
Figure 7. Red Dog Mine: Cominco Blood Lead
Levels for Selected Departments Since 1995
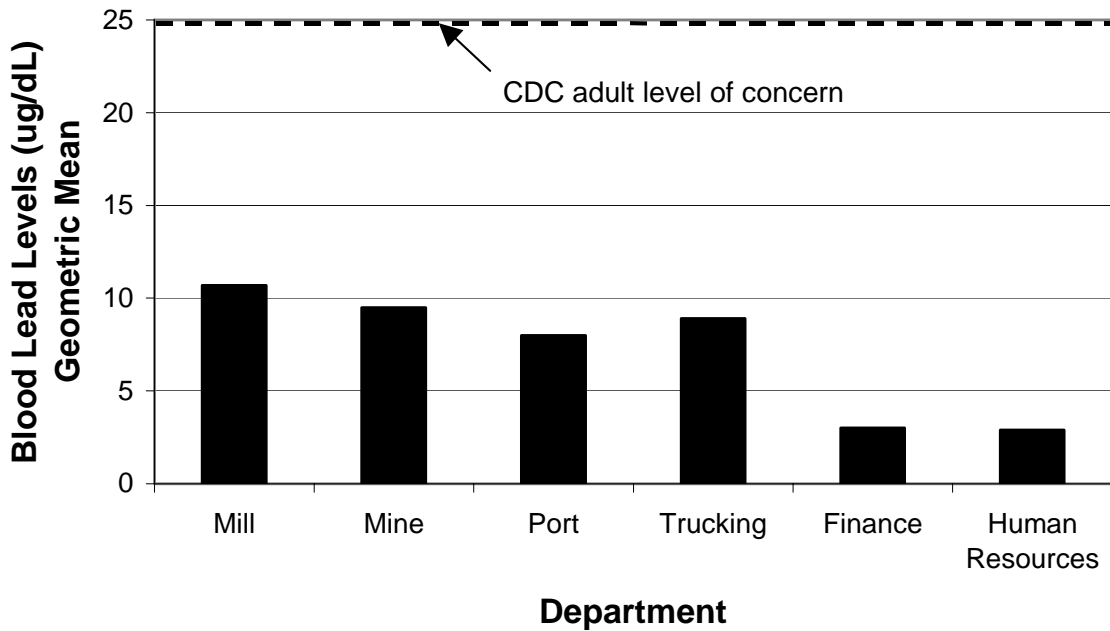
Figure 8. Red Dog Mine: COMINCO Blood Lead Levels
Contractor Subsample: 2,730 Tests
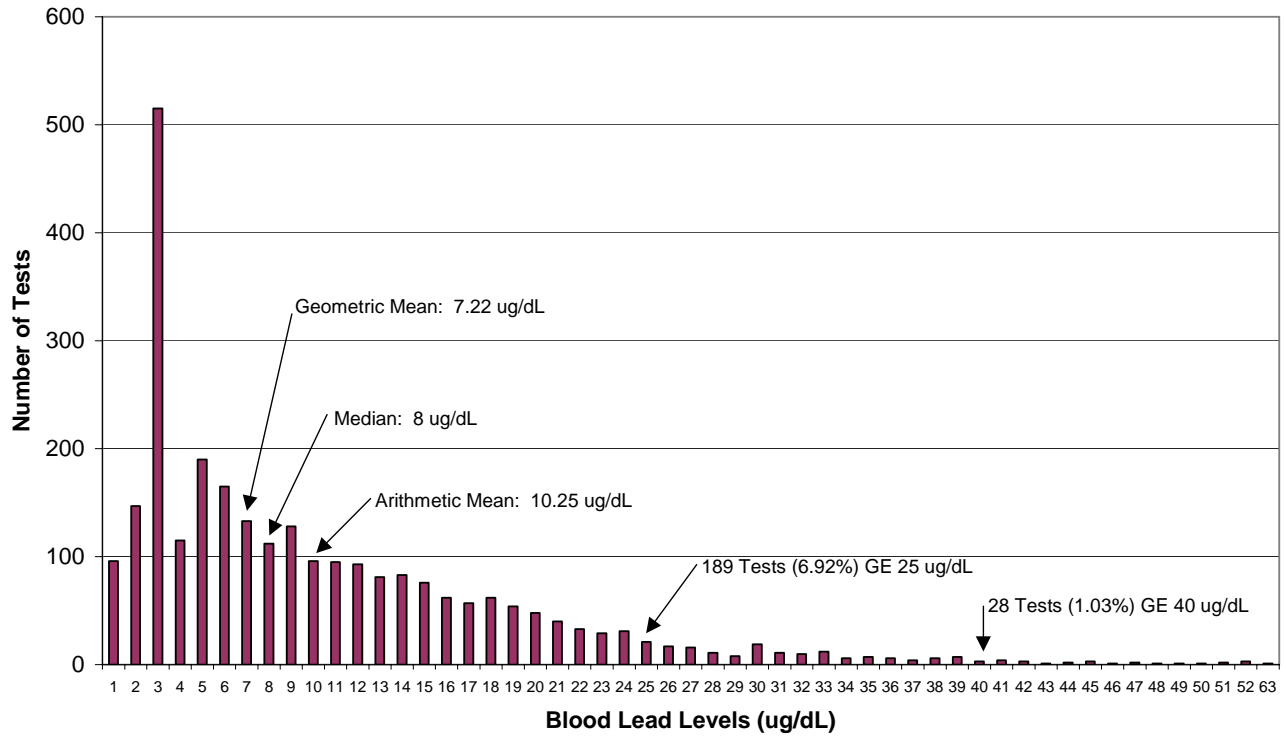
Figure 9-1. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Aluminum Levels
1998-2001
EPA: 36 mg/L
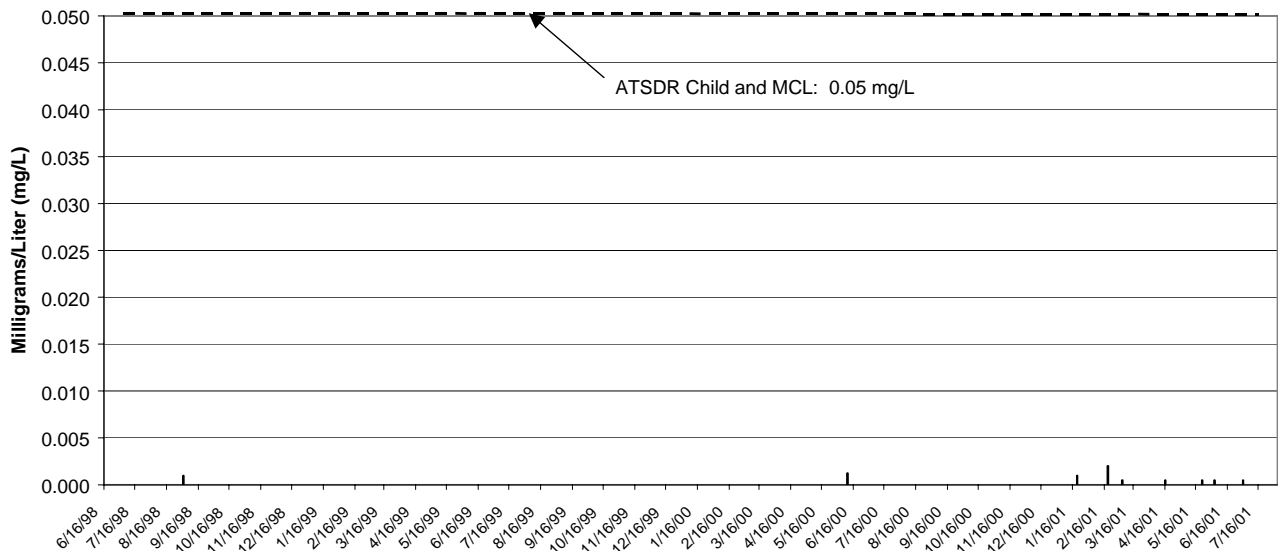**ATSDR Child: 20 mg/L**
ATSDR Adult: 70 mg/L
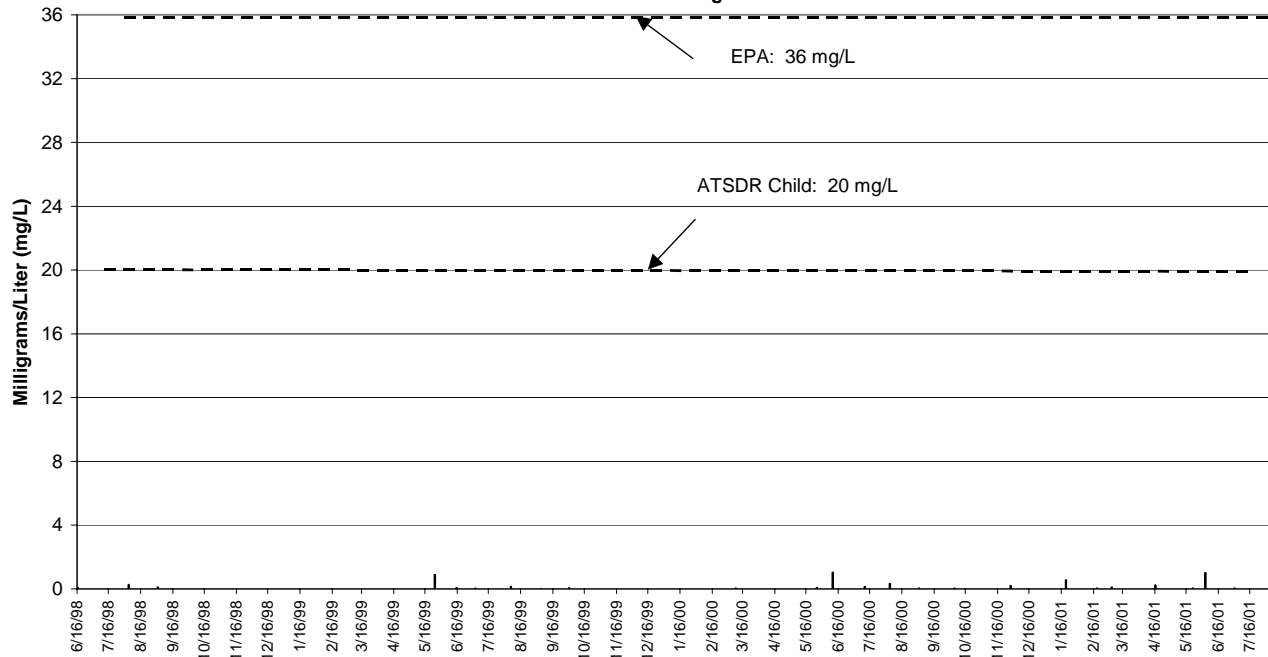
Figure 9-2. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Cadmium Levels
1998-2001
Maximum Contaminant Level: 0.005 mg/L
EPA: 0.018 mg/L
ATSDR Child: 0.002 mg/L
ATSDR Adult: 0.007 mg/L
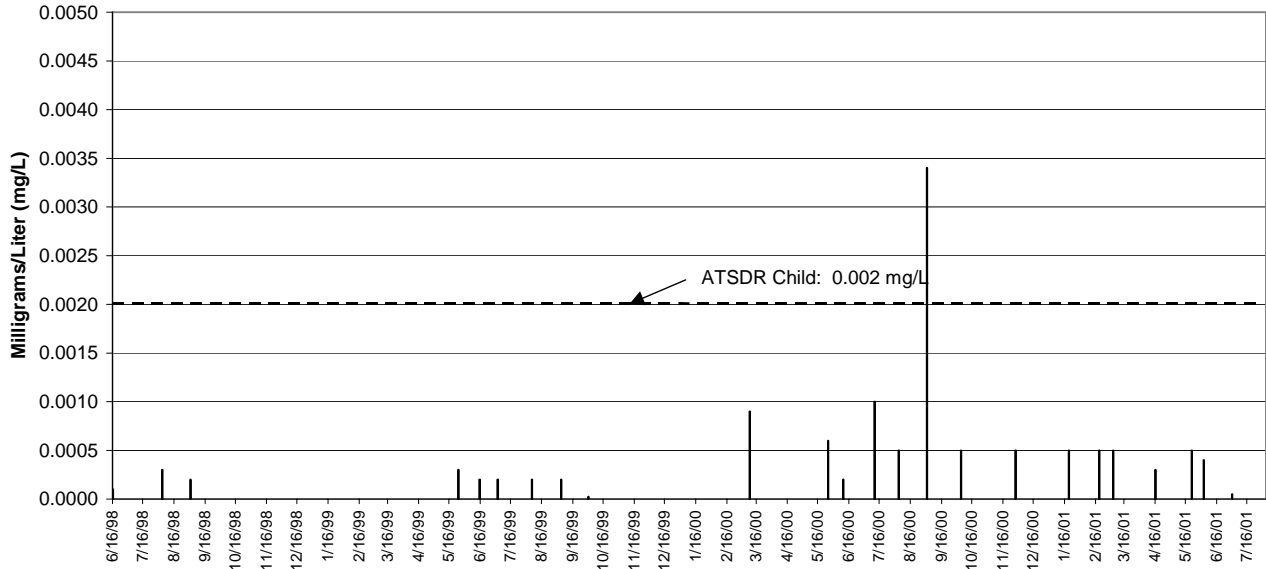
Figure 9-3. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Chromium Levels
1998-2001
Maximum Contaminant Level: 0.1 mg/L
EPA: 0.11 mg/L
ATSDR Child: 0.03 mg/L
ATSDR Adult: 0.1 mg/L
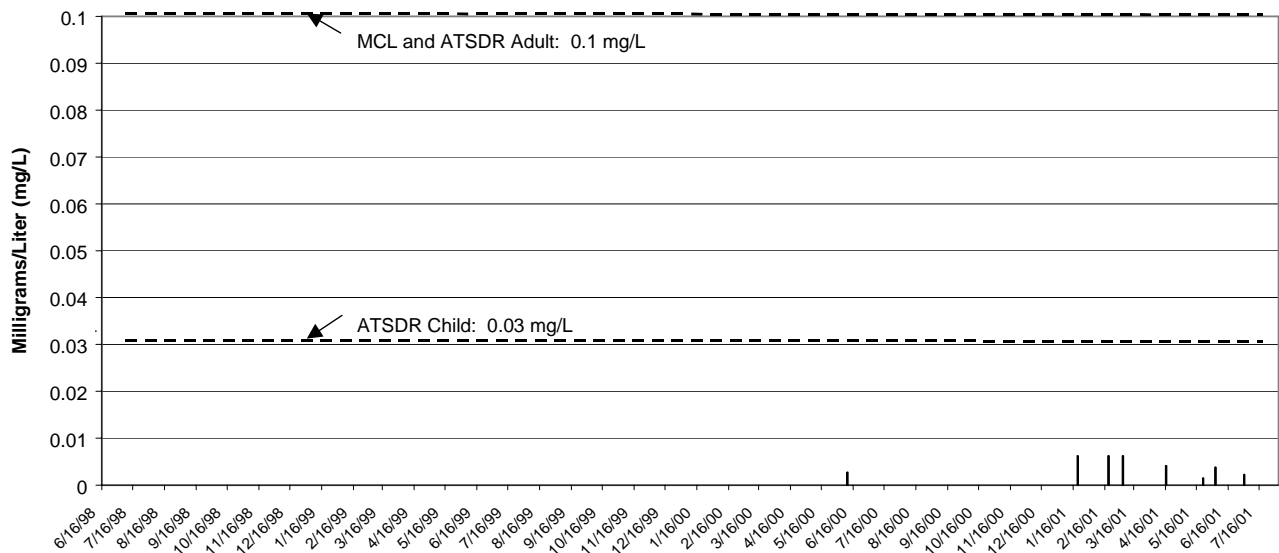
Figure 9-4. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Copper Levels
1998-2001
Action Level: 1.3 mg/L
EPA: 1.4 mg/L
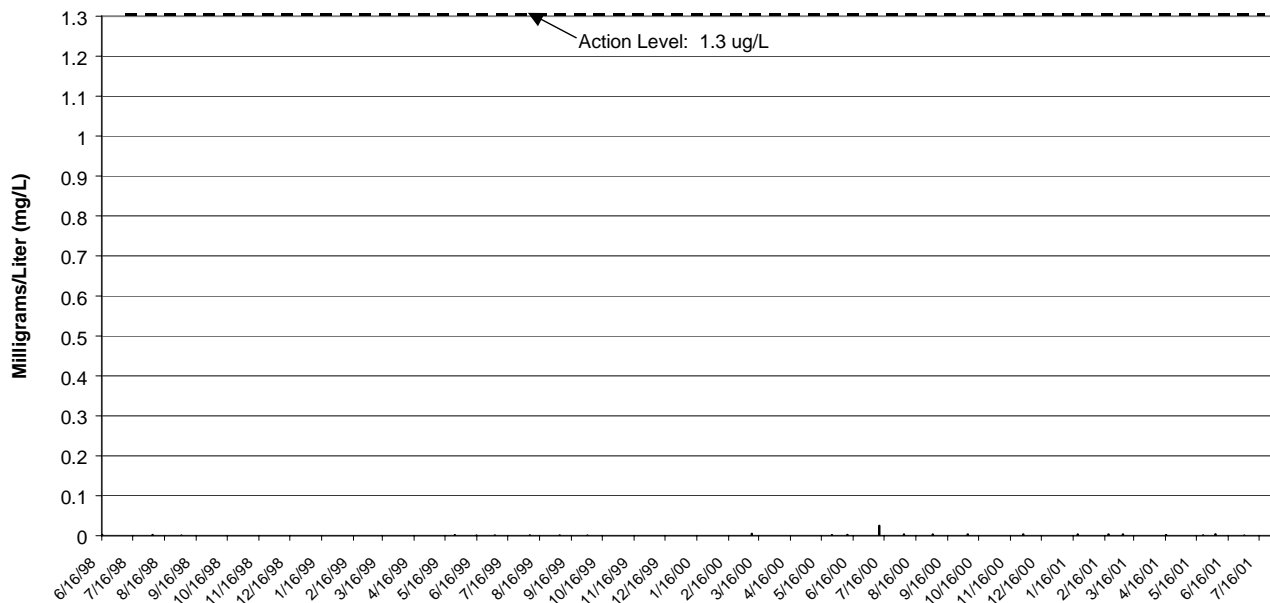
Figure 9-5. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Iron Levels
1998-2001
EPA: 11 mg/L
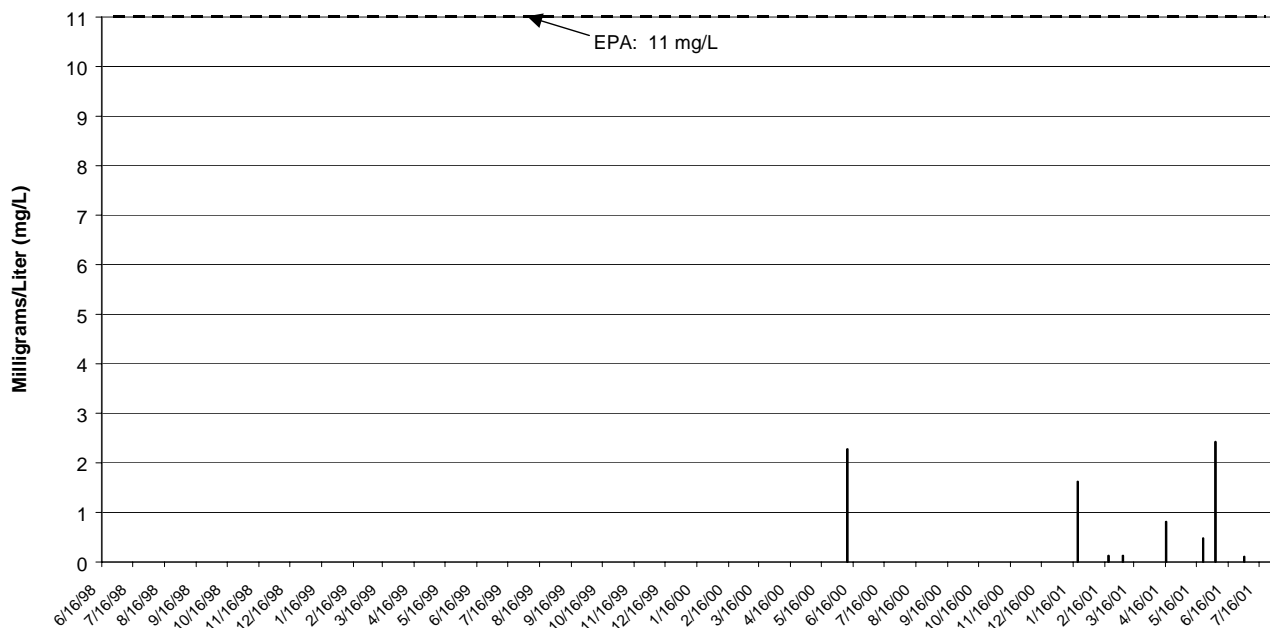
Figure 9-6. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Manganese Levels
1998-2001
EPA: 0.88 mg/L
ATSDR Child: 0.5 mg/L
ATSDR Adult: 2 mg/L
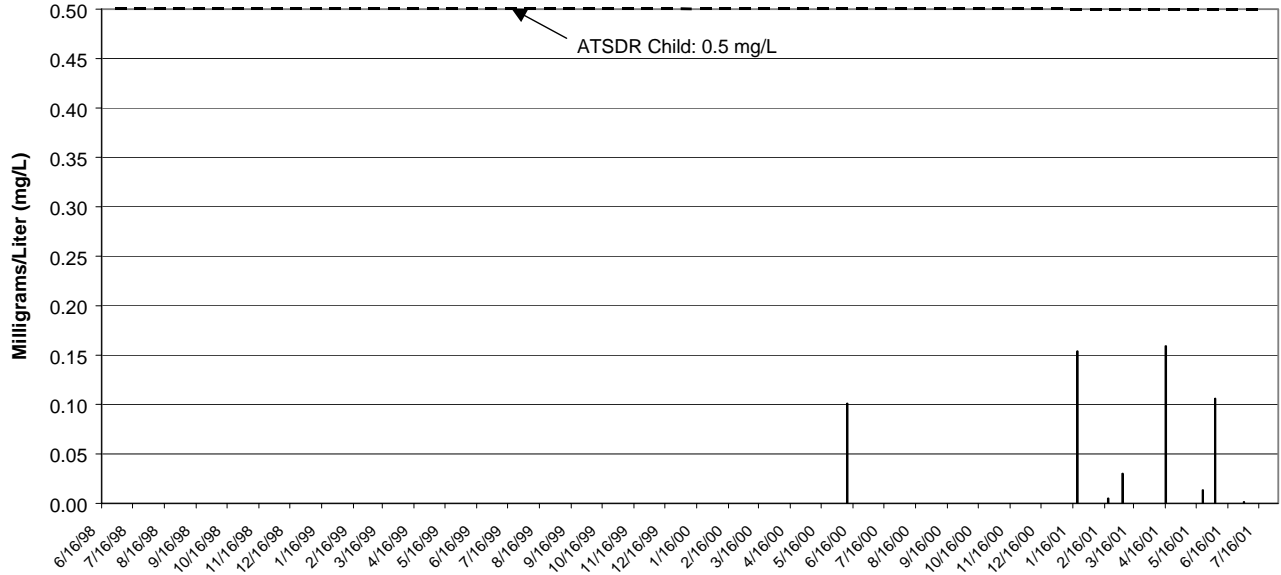
Figure 9-7. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Nickel Levels
1998-2001
Maximum Contaminant Level: 0.1 mg/L
EPA: 0.73 mg/L
ATSDR Child: 0.2 mg/L
ATSDR Adult: 0.7 mg/L
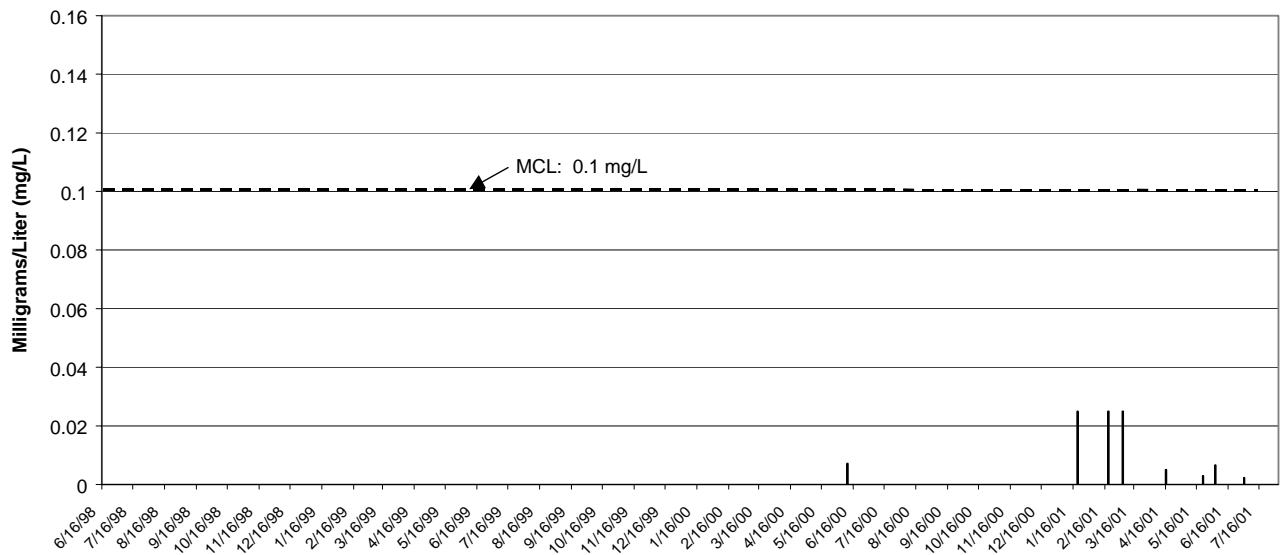
Figure 9-8. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Lead Levels
1998-2001
Action Level: 0.015 mg/L
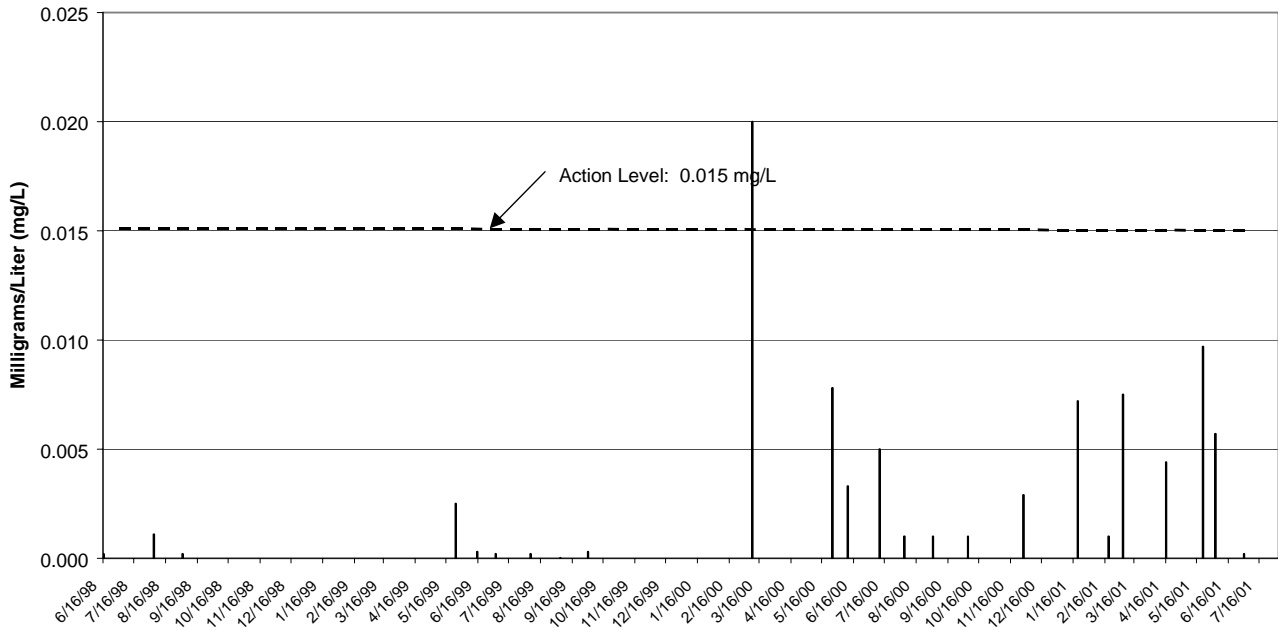
Figure 9-9. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Selenium Levels
1998-2001
Maximum Contaminant Level: 0.05 mg/L
EPA: 0.18 mg/L
ATSDR Child: 0.05 mg/L
ATSDR Adult: 0.2 mg/L

Figure 9-10. Red Dog Mine: COMINCO Data
Wulik River Monitoring Station 1
Zinc Levels
1998-2001
Maximum Contaminant Level: 5.0 mg/L
EPA RBSC: 11 mg/L
ATSDR Child: 3 mg/L
ATSDR Adult: 10 mg/L
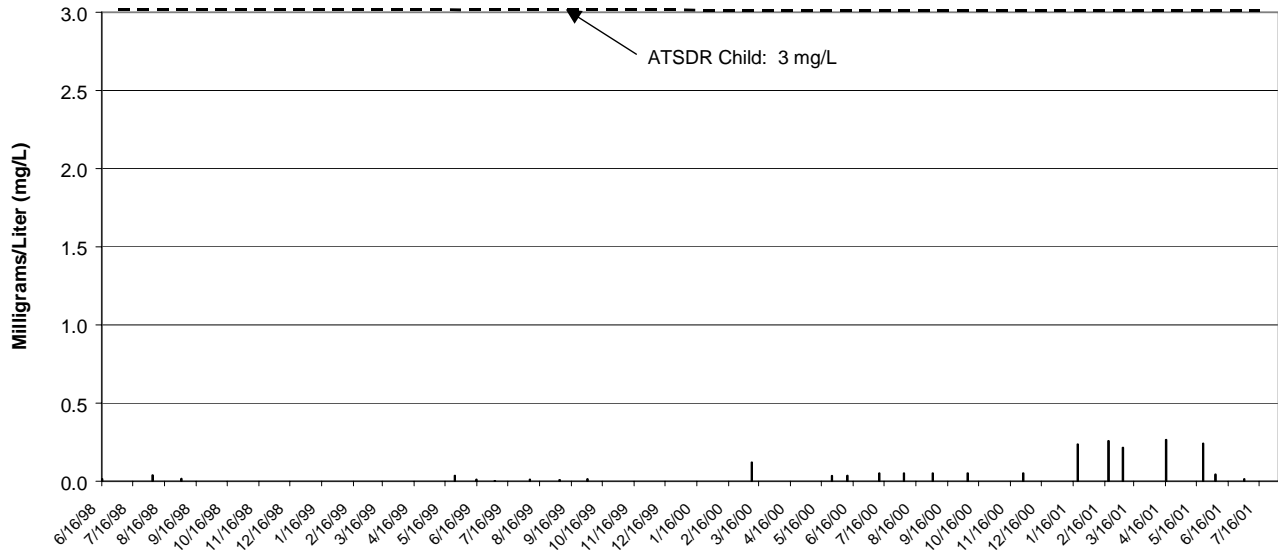
Figure 10-1. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Muscle: Arsenic
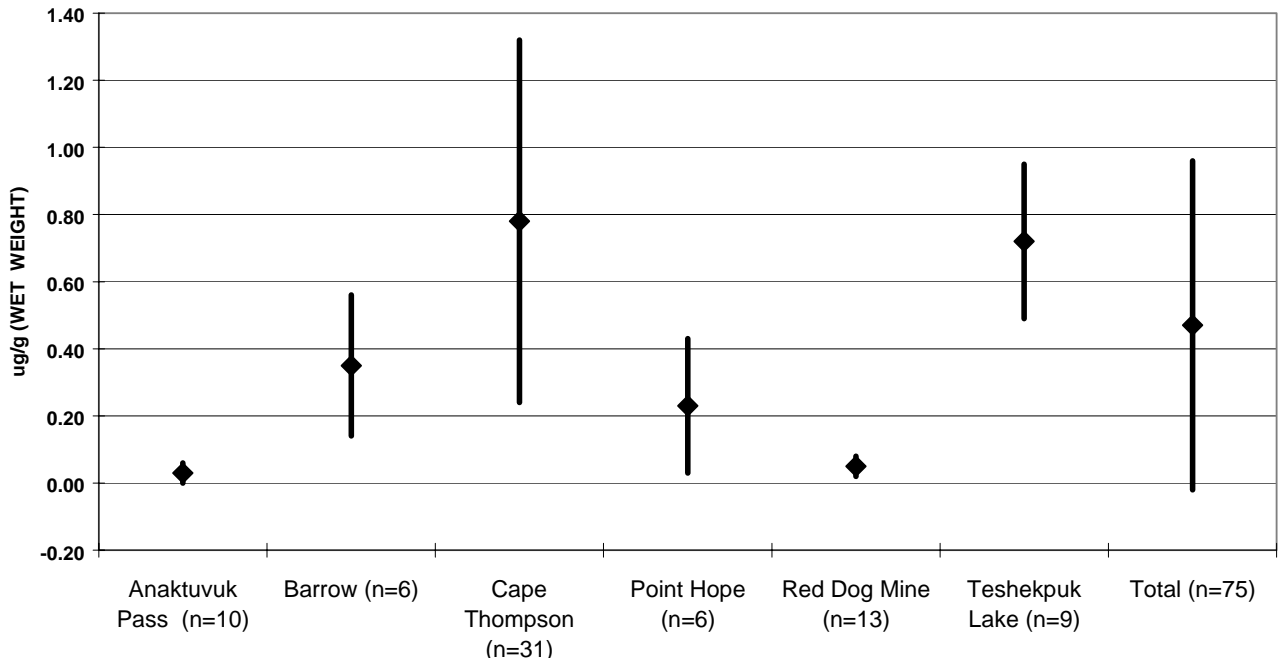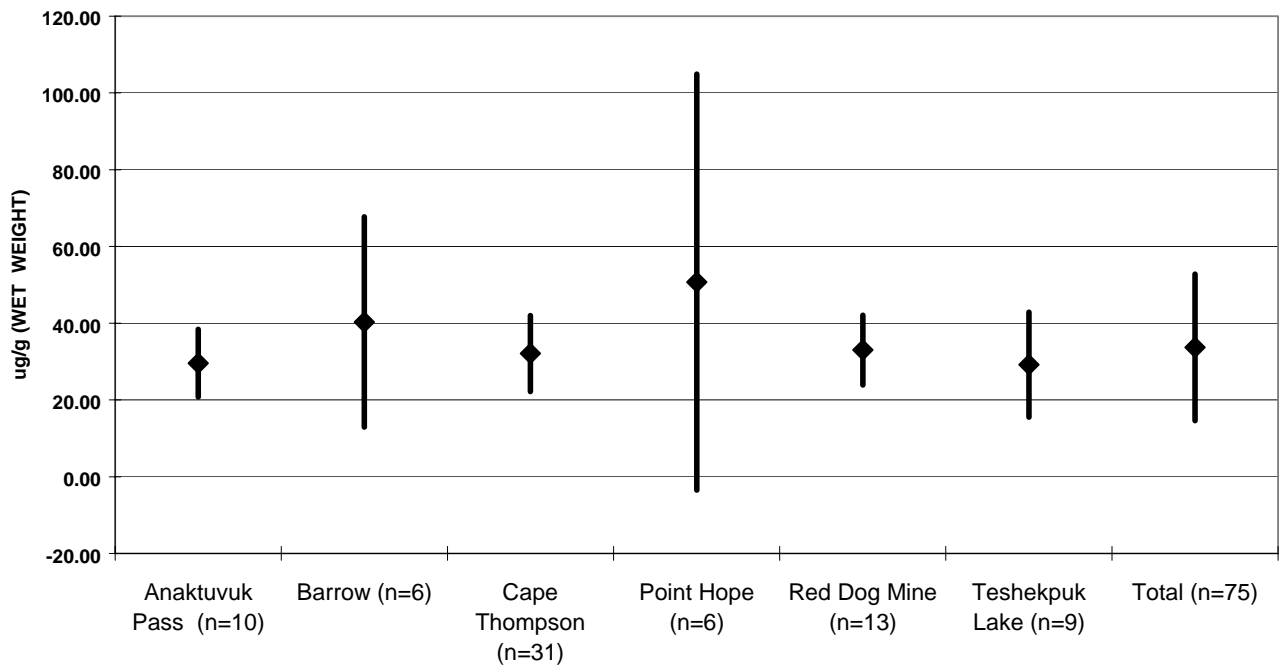Mean Micrograms/Gram Wet Weight +/- One Standard Deviation
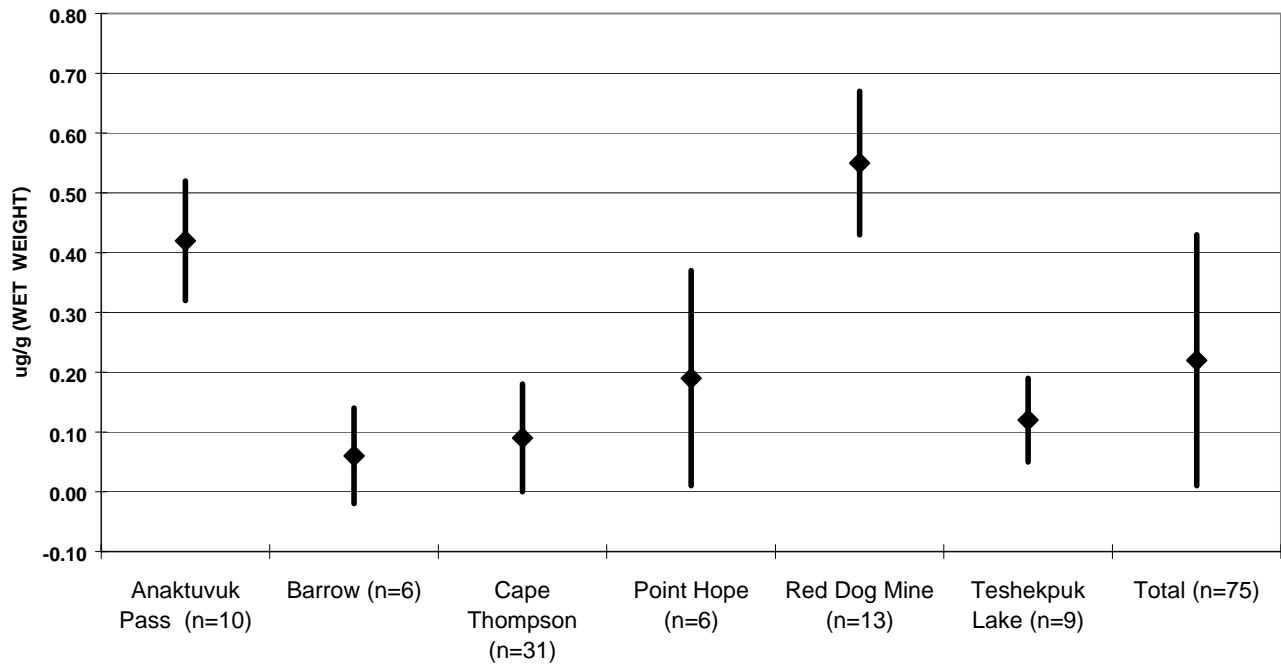
**Figure 10-2. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Muscle: Cadmium
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation**
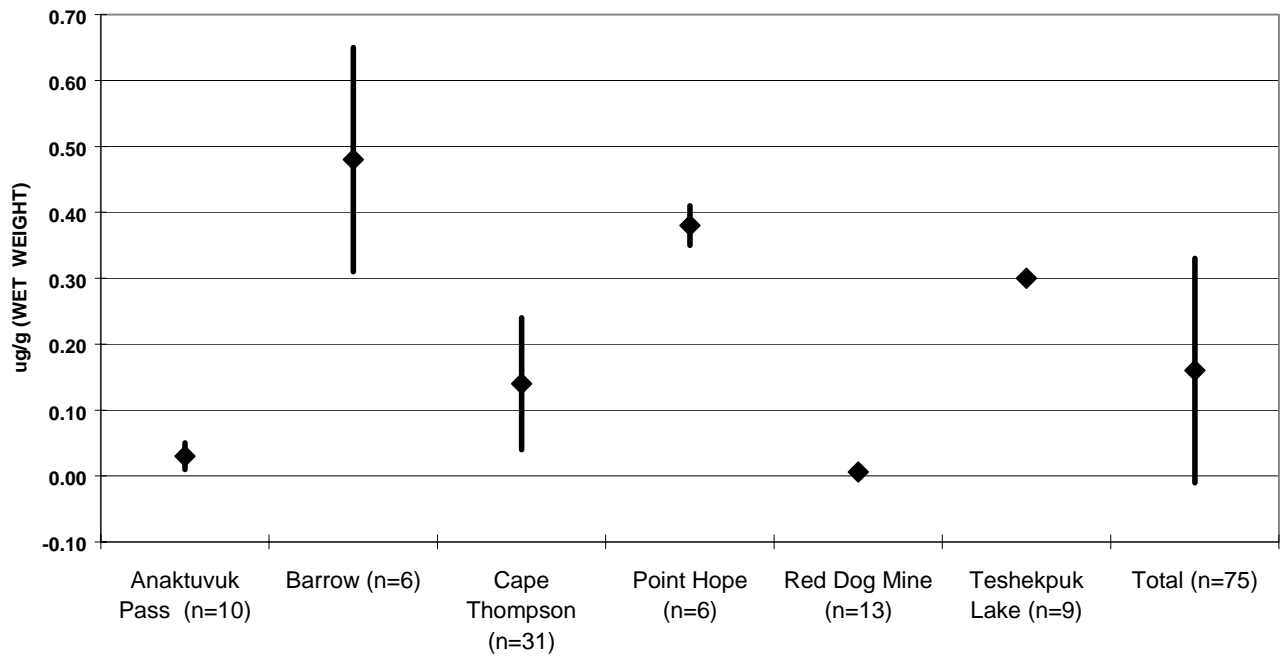
**Figure 10-3. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Muscle: Copper
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation**
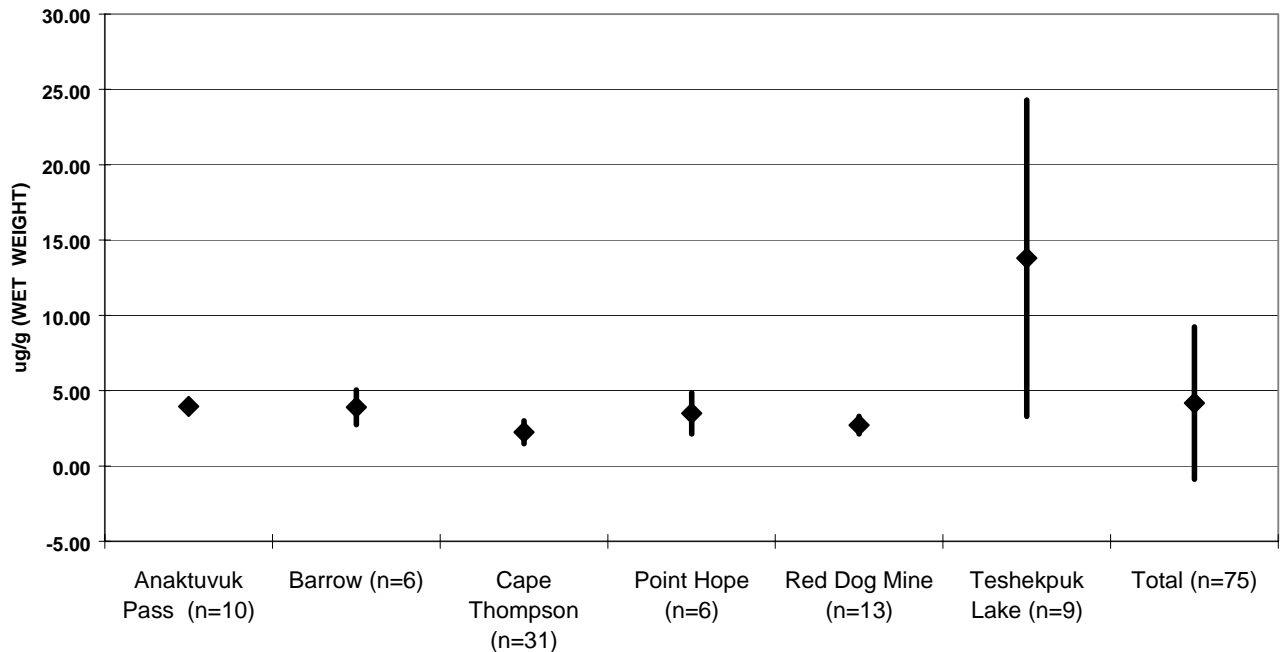
**Figure 10-4. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Muscle: Lead**
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

**Figure 10-5. Heavy Metal Concentrations, Caribou Tissue,
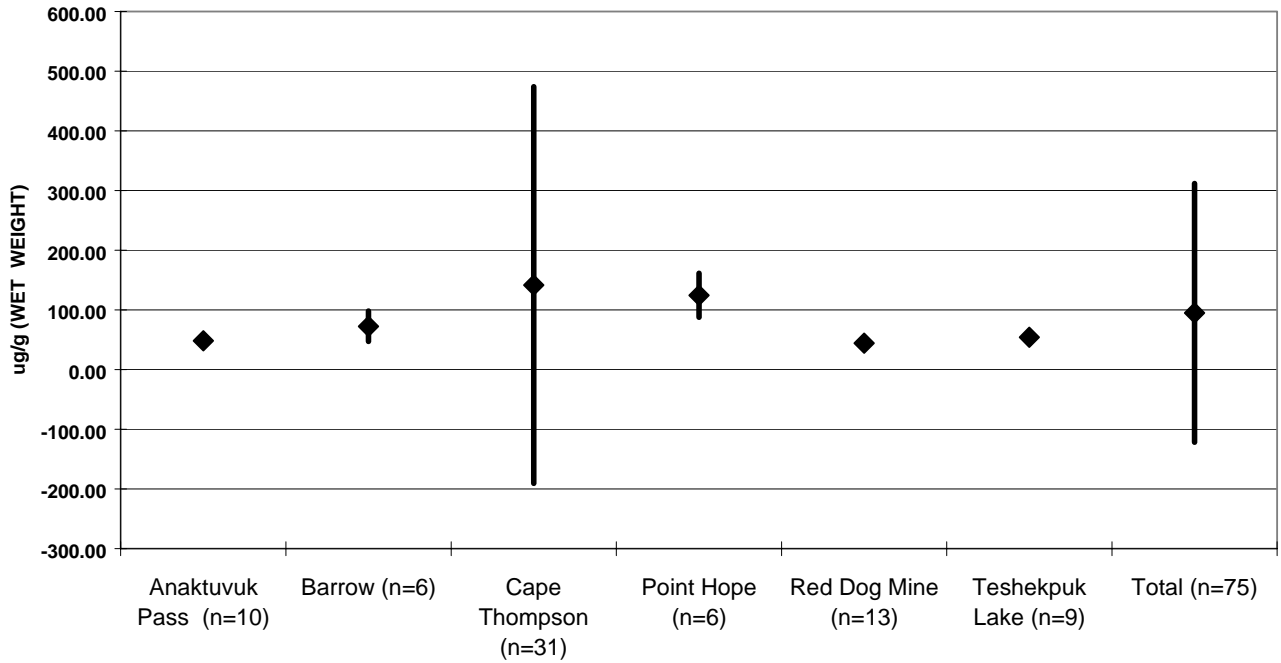Samples from Northern Alaska (1996)
Muscle: Zinc**
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

**Figure 10-6. Heavy Metal Concentrations, Caribou Tissue,
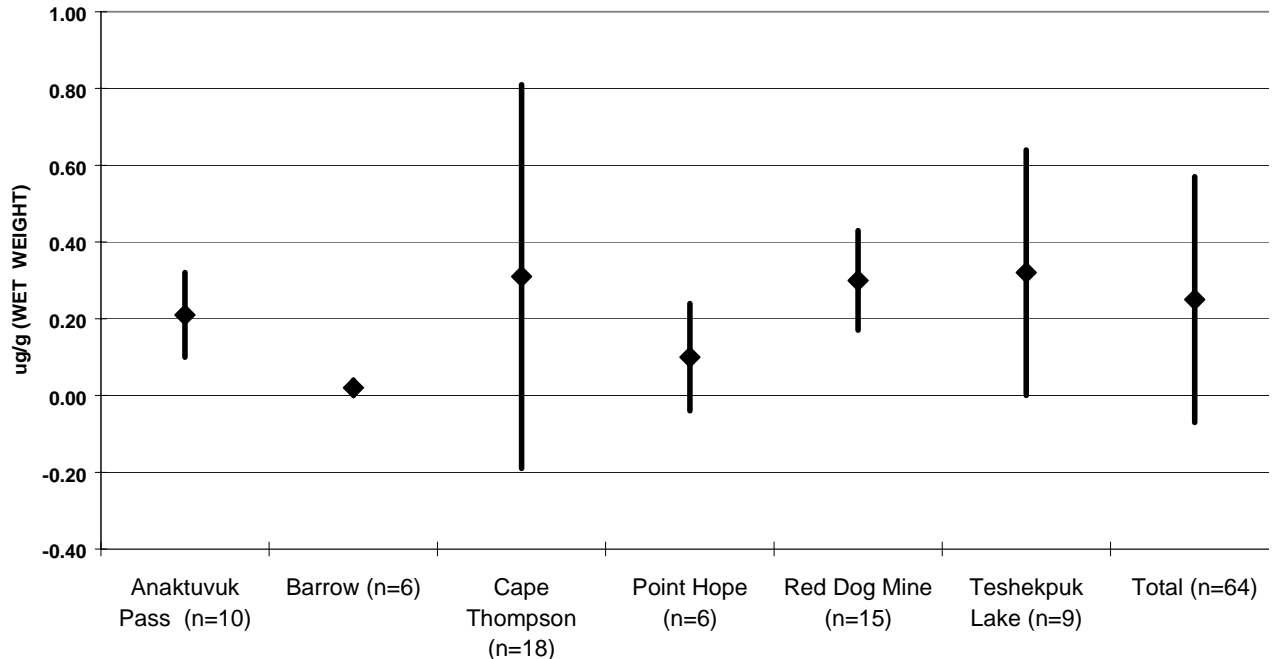Samples from Northern Alaska (1996)**
Muscle: Iron
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

**Figure 10-7. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)**
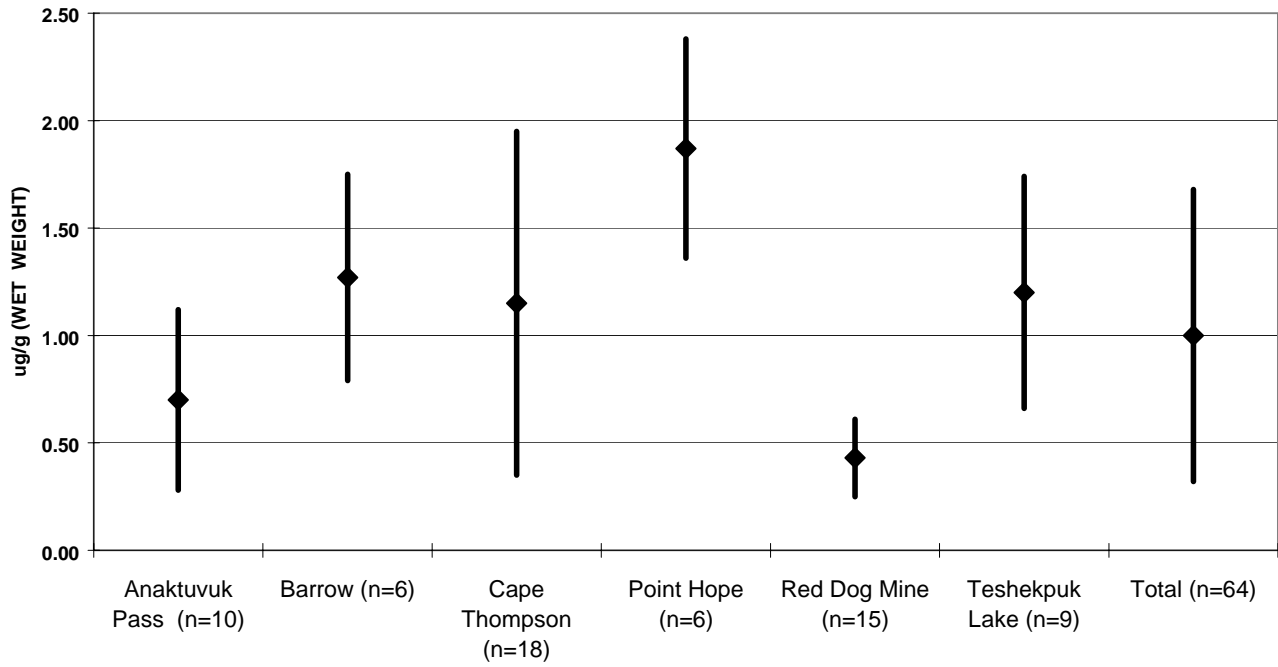**Liver: Arsenic**
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

**Figure 10-8. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Liver: Cadmium**
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

Figure 10-9. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Liver: Copper
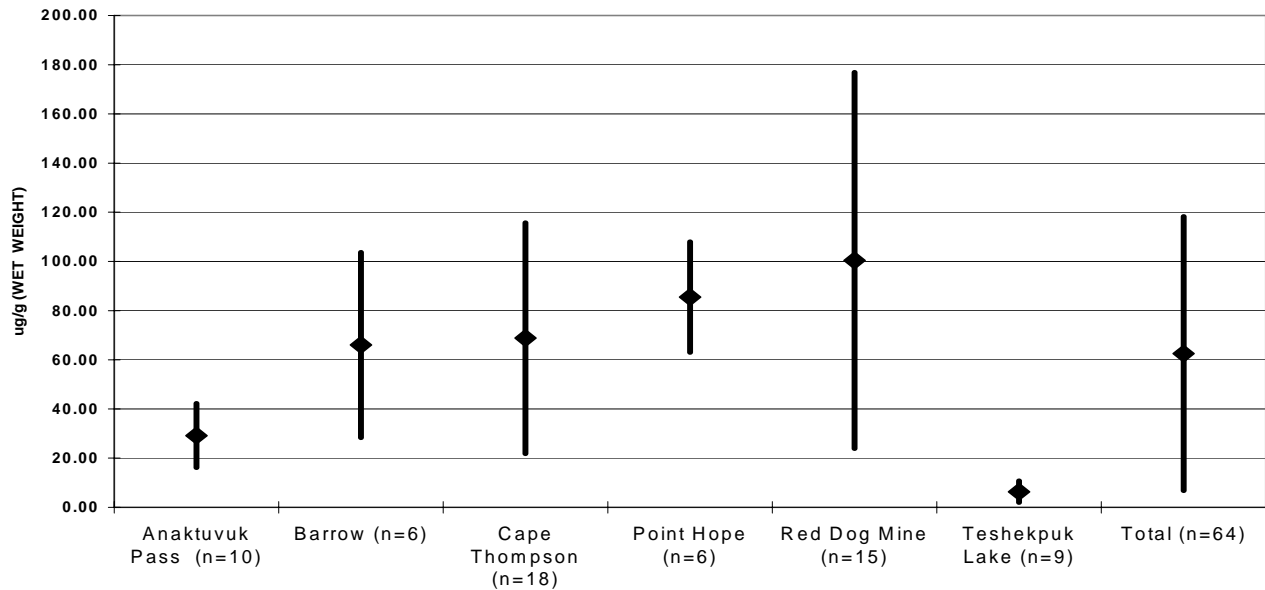Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

Figure 10-10. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)
Liver: Lead
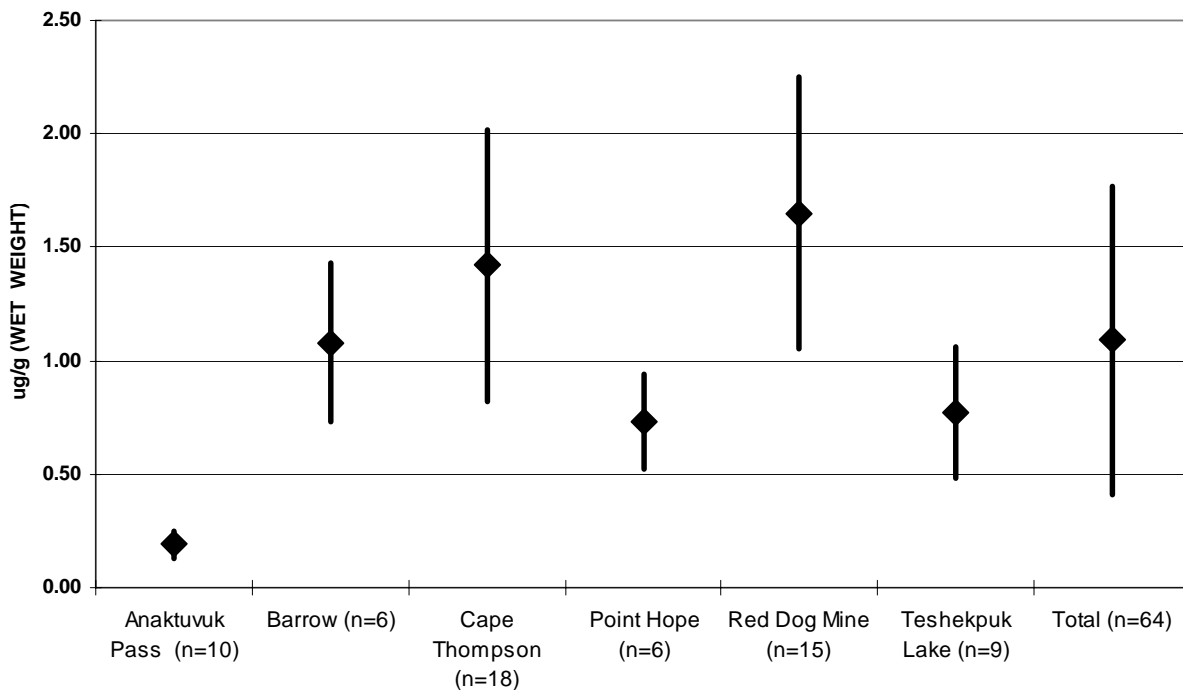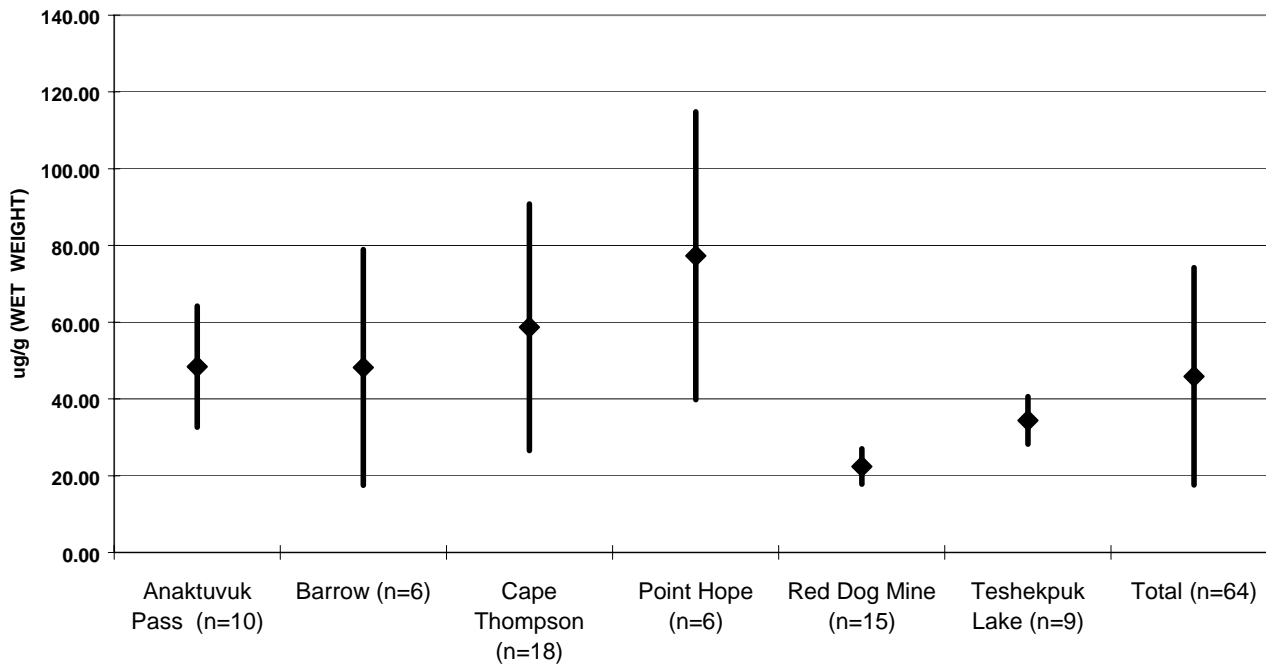**Mean Micrograms/Gram Wet Weight +/- One Standard** Deviation

**Figure 10-11. Heavy Metal Concentrations, Caribou Tissue,
Samples from Northern Alaska (1996)**
Liver: Zinc
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

**Figure 11-1. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Muscle: Arsenic**
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

**Figure 11-2. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Muscle: Cadmium**
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-3. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Muscle: Copper
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-4. Heavy Metal Concentrations in Caribou Tissue
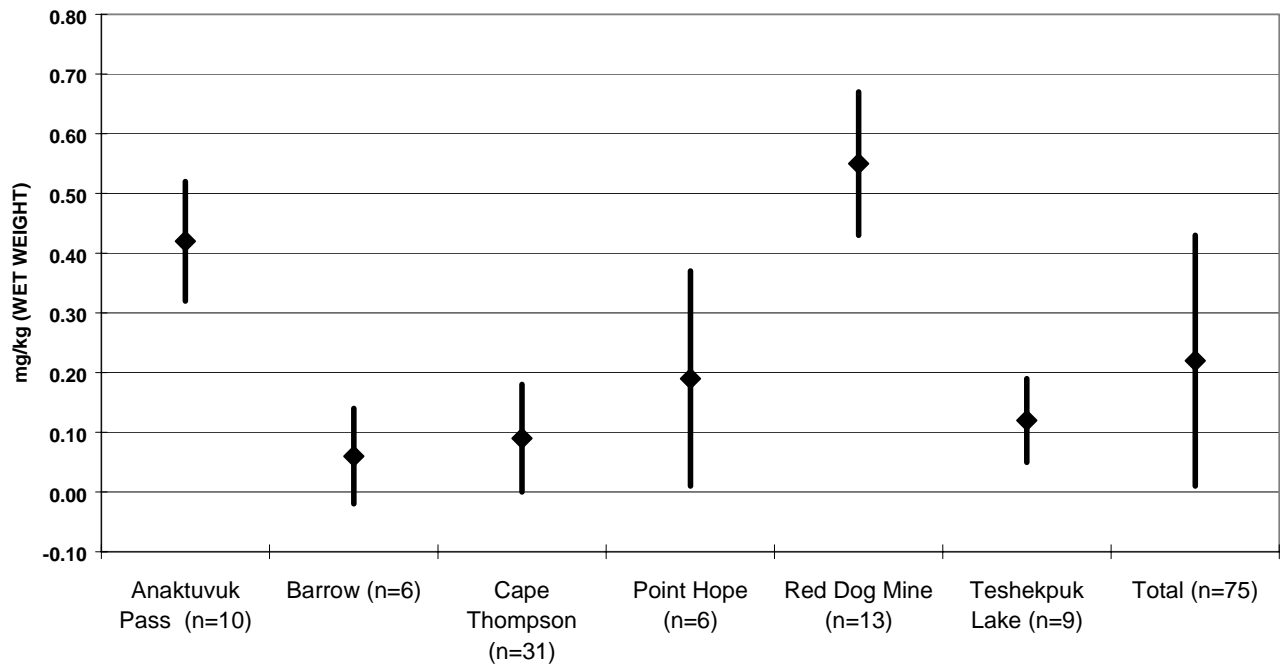**Samples from Northern Alaska (1994 - 1996)**
Muscle: Lead
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

**Figure 11-5. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Muscle: Zinc**

Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation
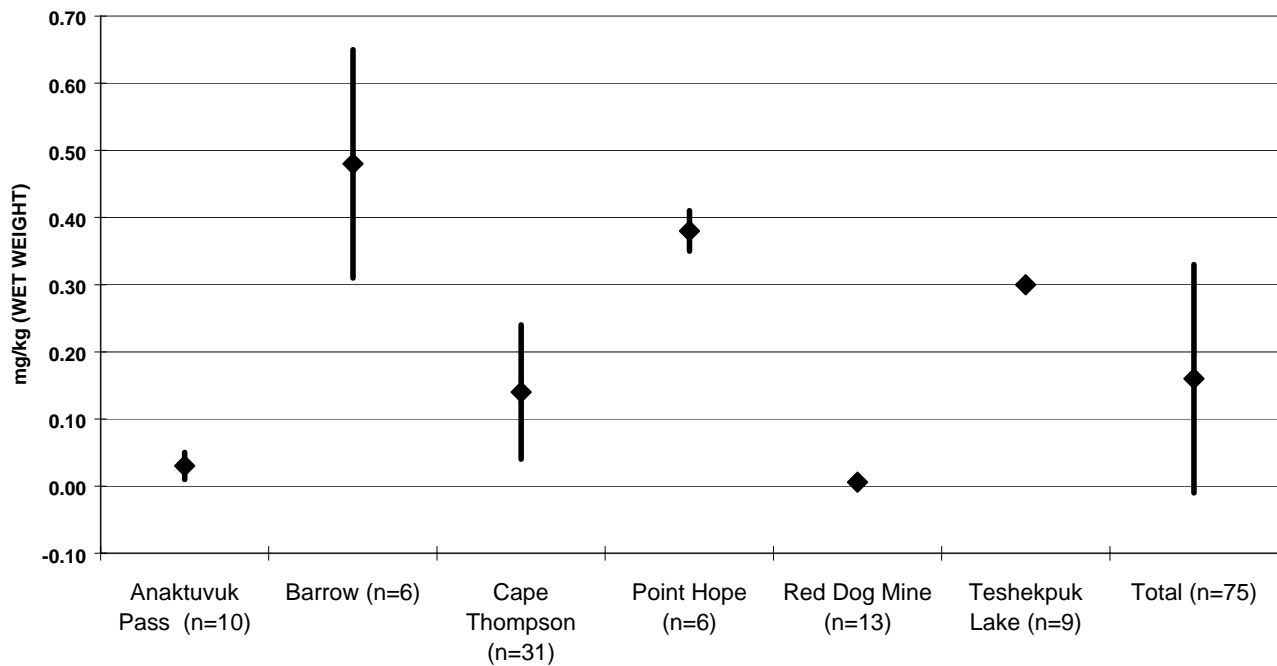

**Figure 11-6. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Muscle: Iron**

Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation
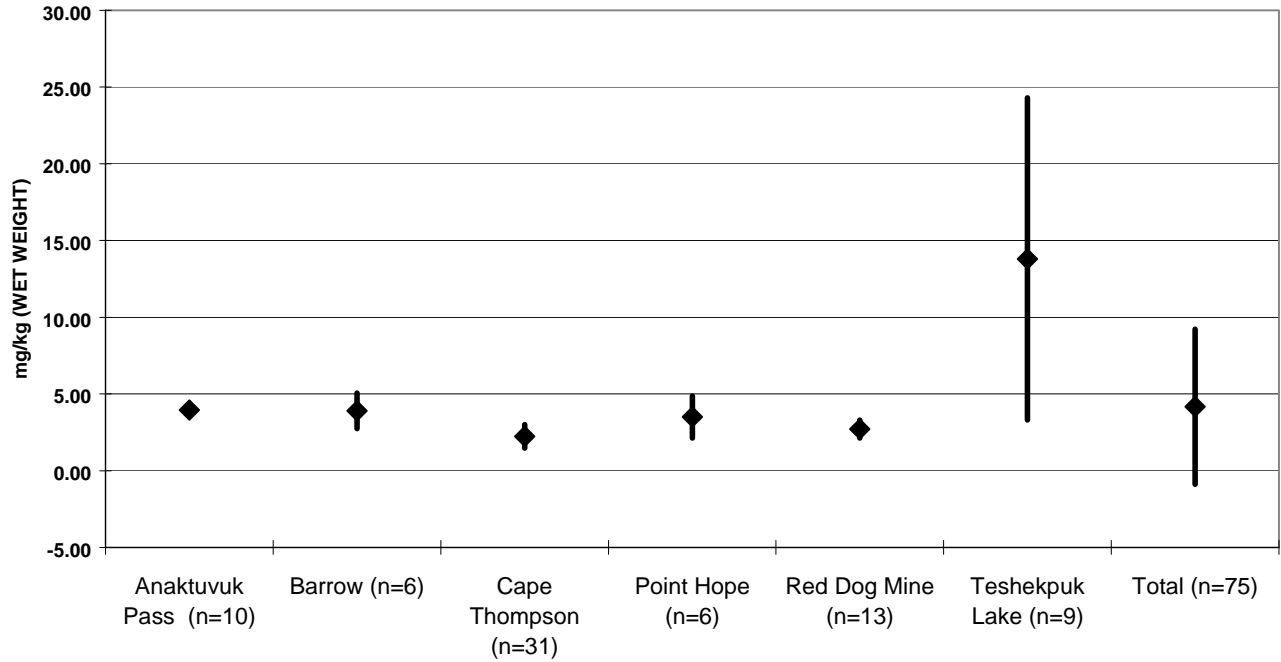
**Figure 11-7. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Liver: Arsenic**
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

**Figure 11-8. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Liver: Cadmium**
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-9. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994-1996)
I.   Liver: Copper
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation

Figure 11-10. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994-1996)
II.   Liver: Lead
Mean Micrograms/Gram Wet Weight +/- One Standard Deviation
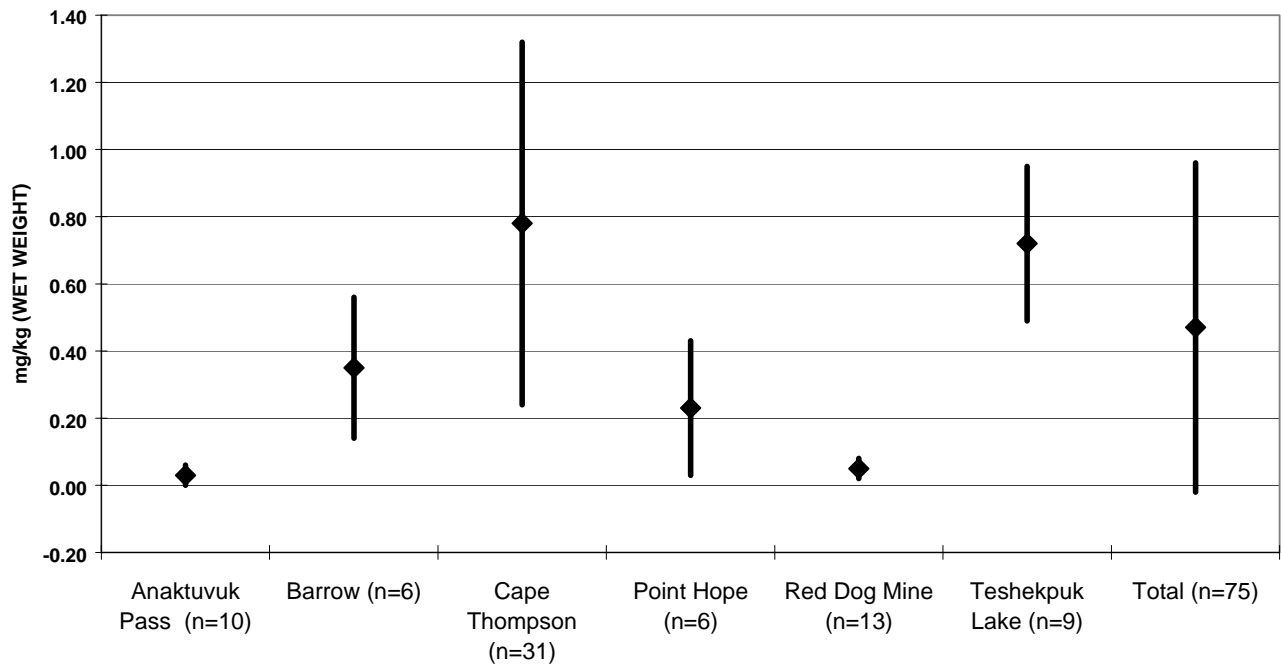
**Figure 11-11. Heavy Metal Concentrations in Caribou Tissue
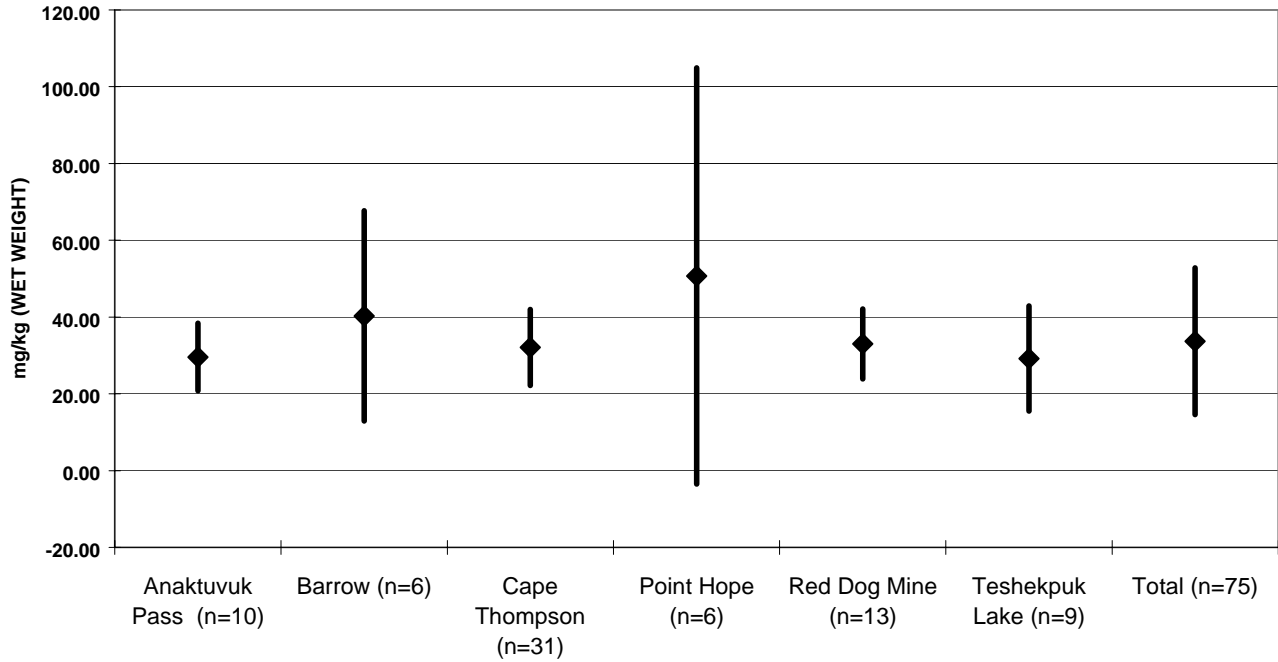Samples from Northern Alaska (1994 - 1996)
Liver: Zinc
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation**

**Figure 11-12. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
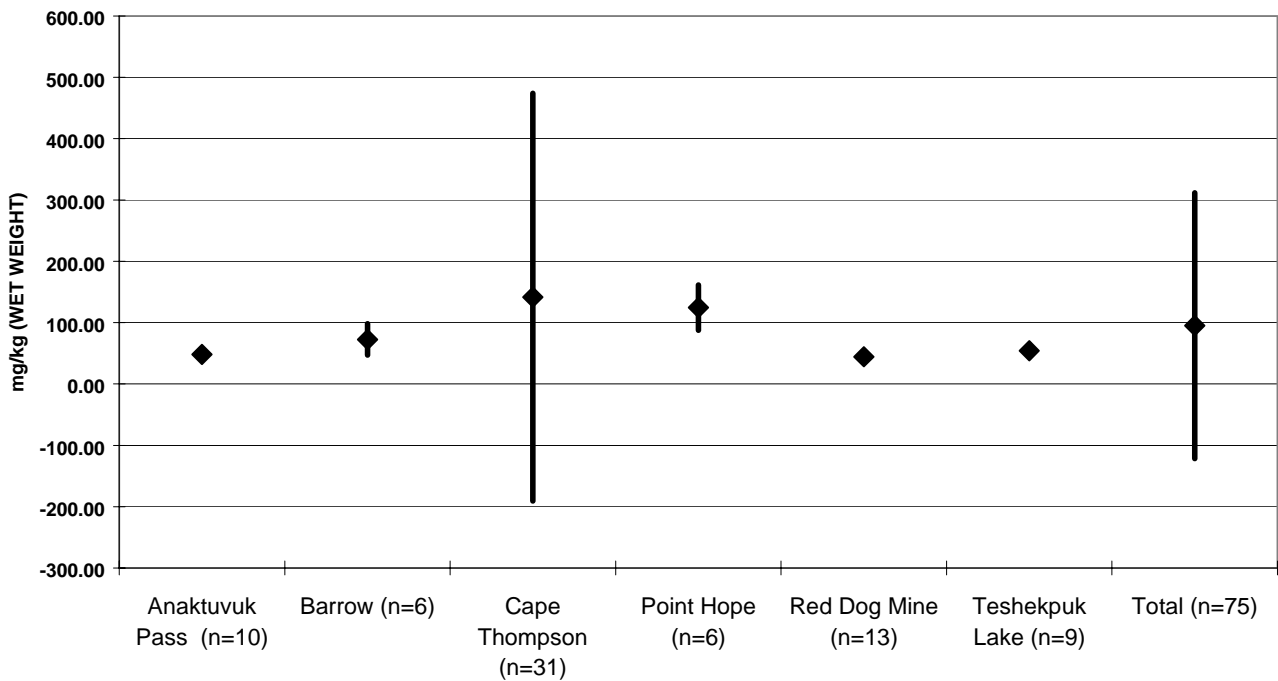Liver: Iron
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation**

Figure 11-13. Heavy Metal Concentrations Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Kidney: Arsenic
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-14. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
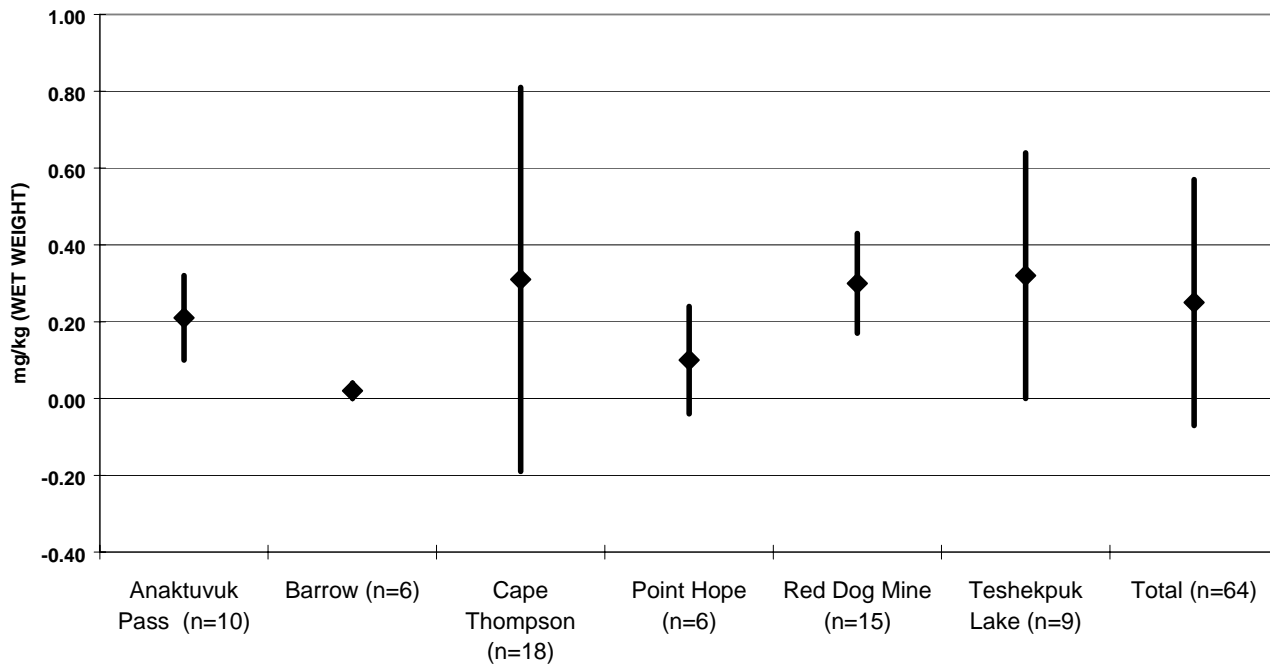**Kidney: Cadmium**
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-15. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Kidney: Copper
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation

Figure 11-16. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Kidney: Lead
Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation
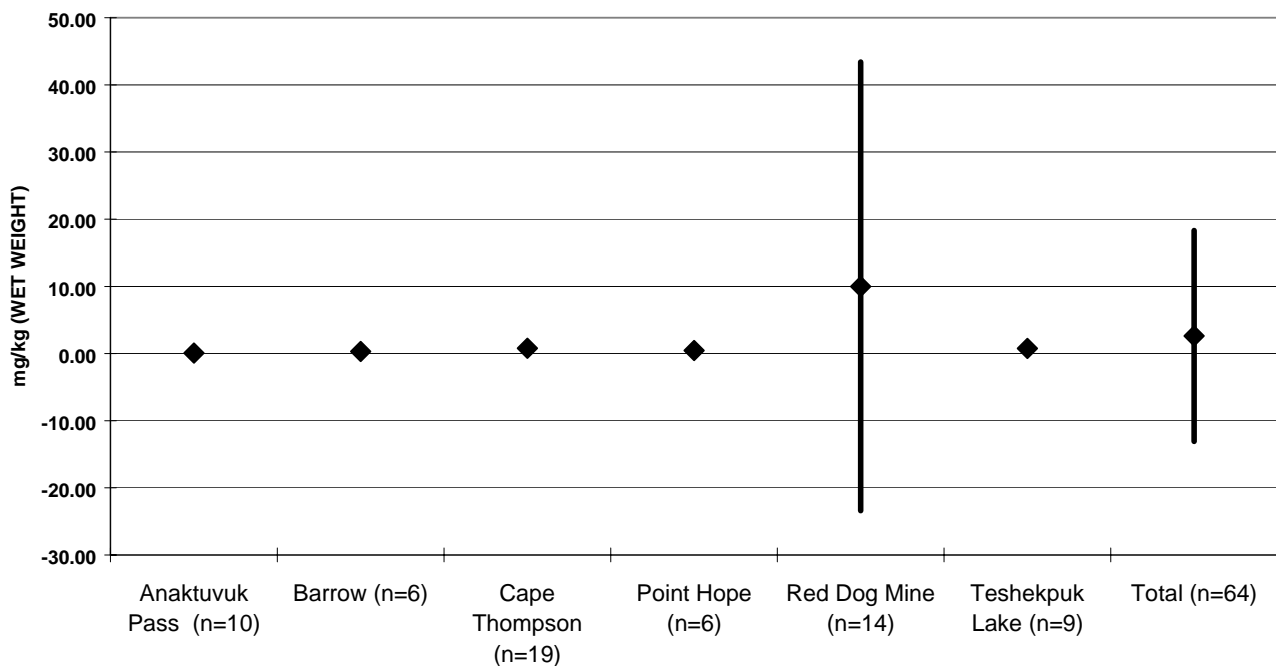
**Figure 11-17. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Kidney: Zinc**
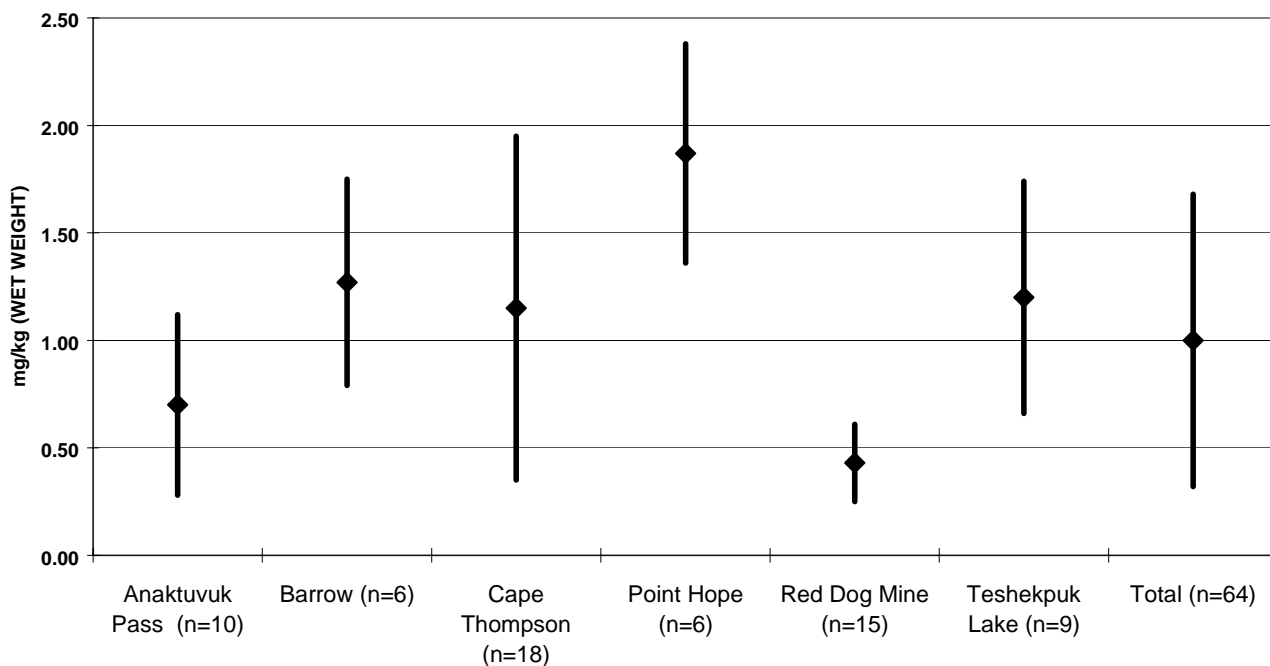Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation
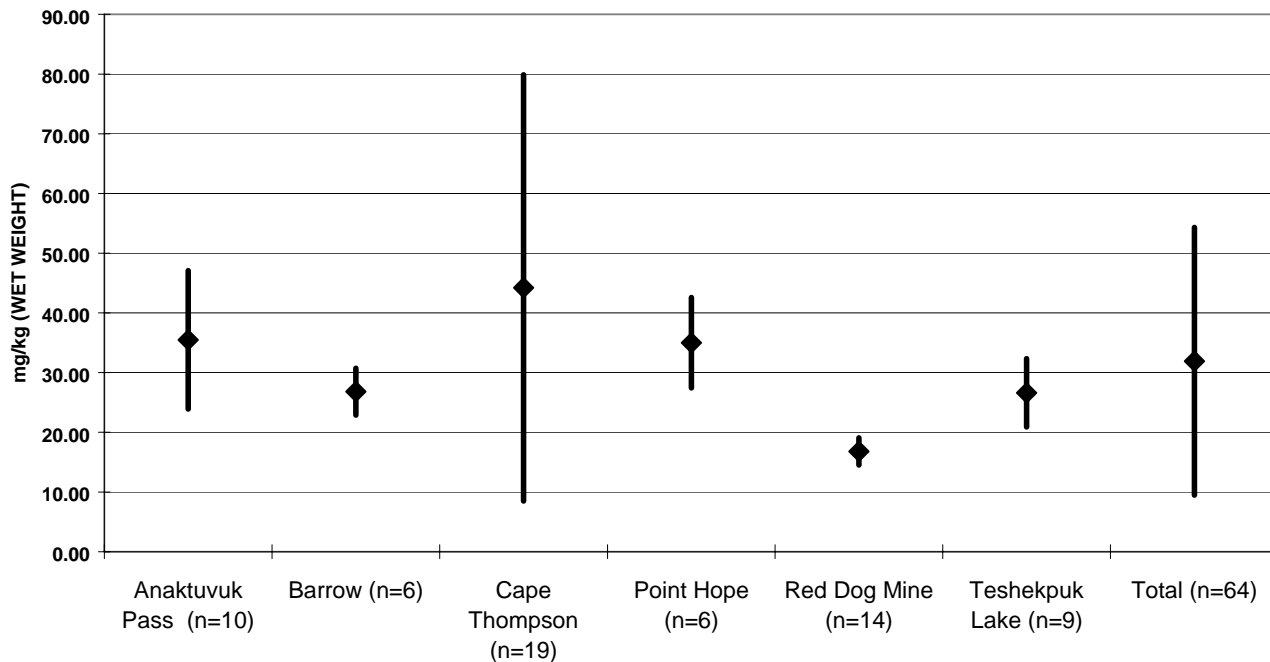
**Figure 11-18. Heavy Metal Concentrations in Caribou Tissue
Samples from Northern Alaska (1994 - 1996)
Kidney: Iron**
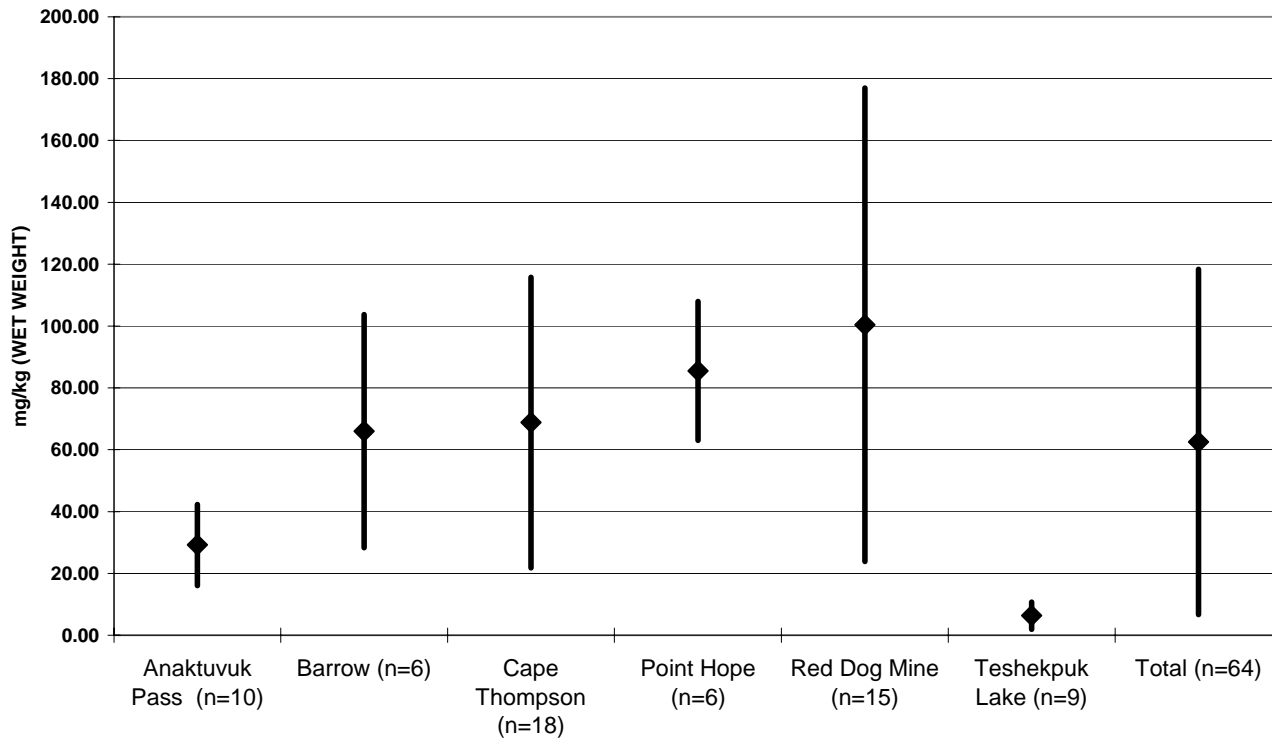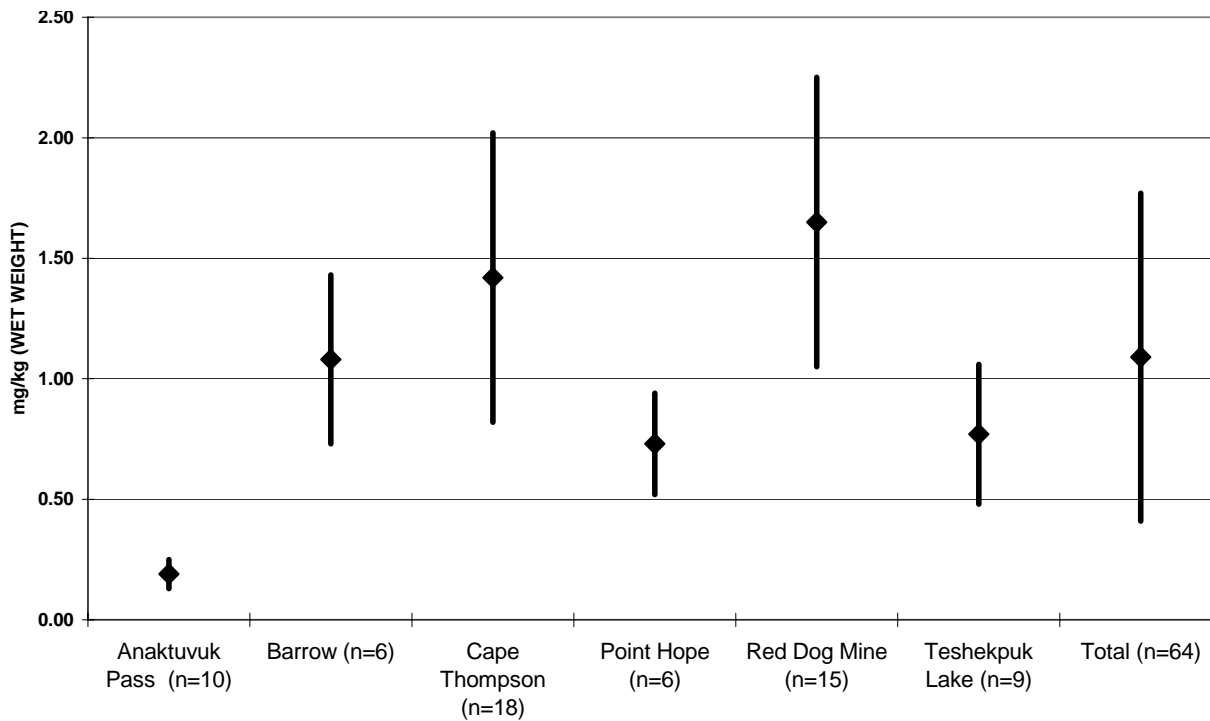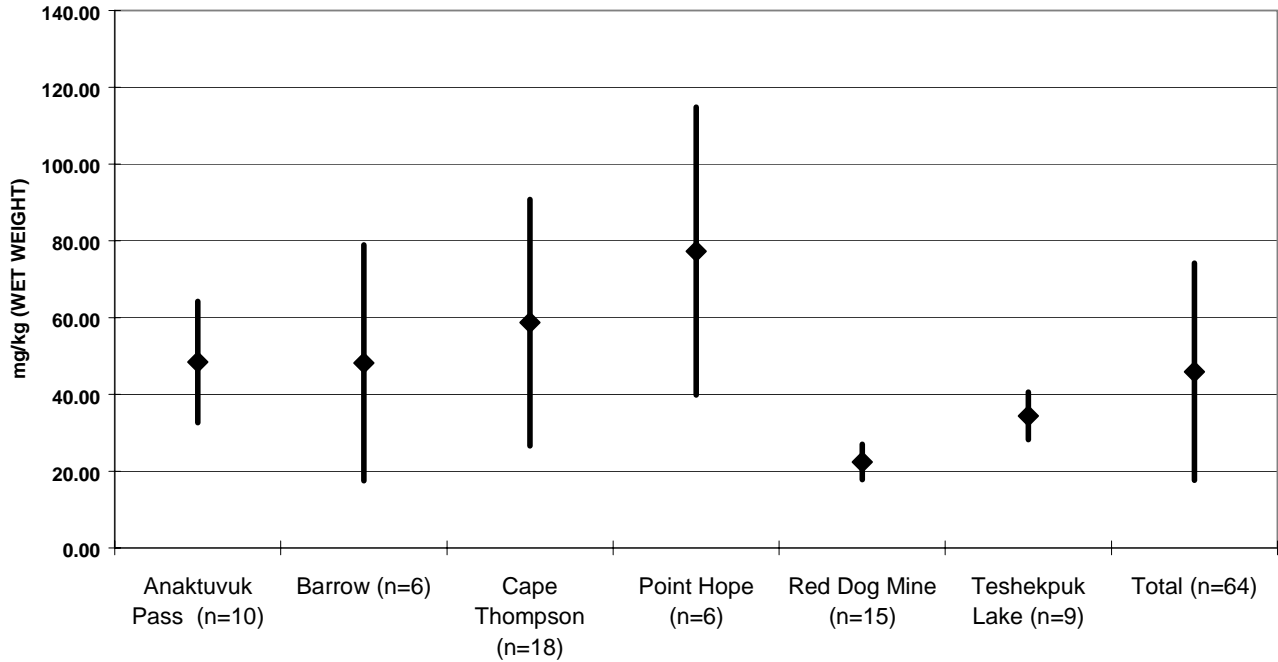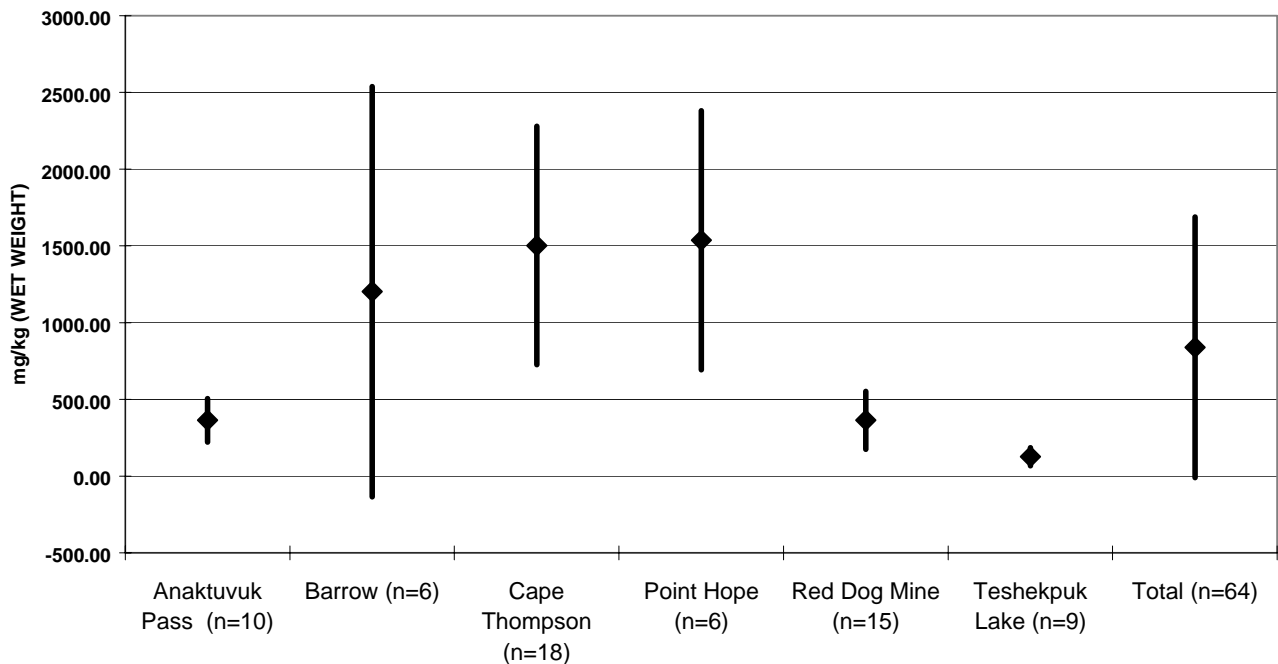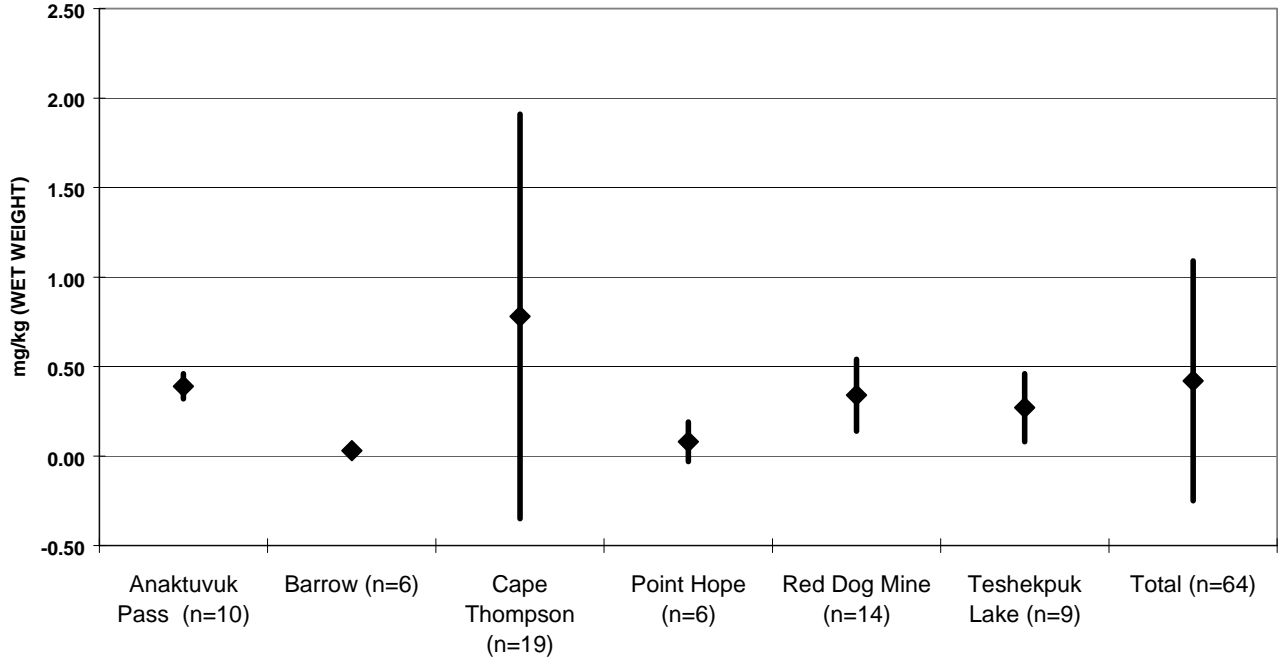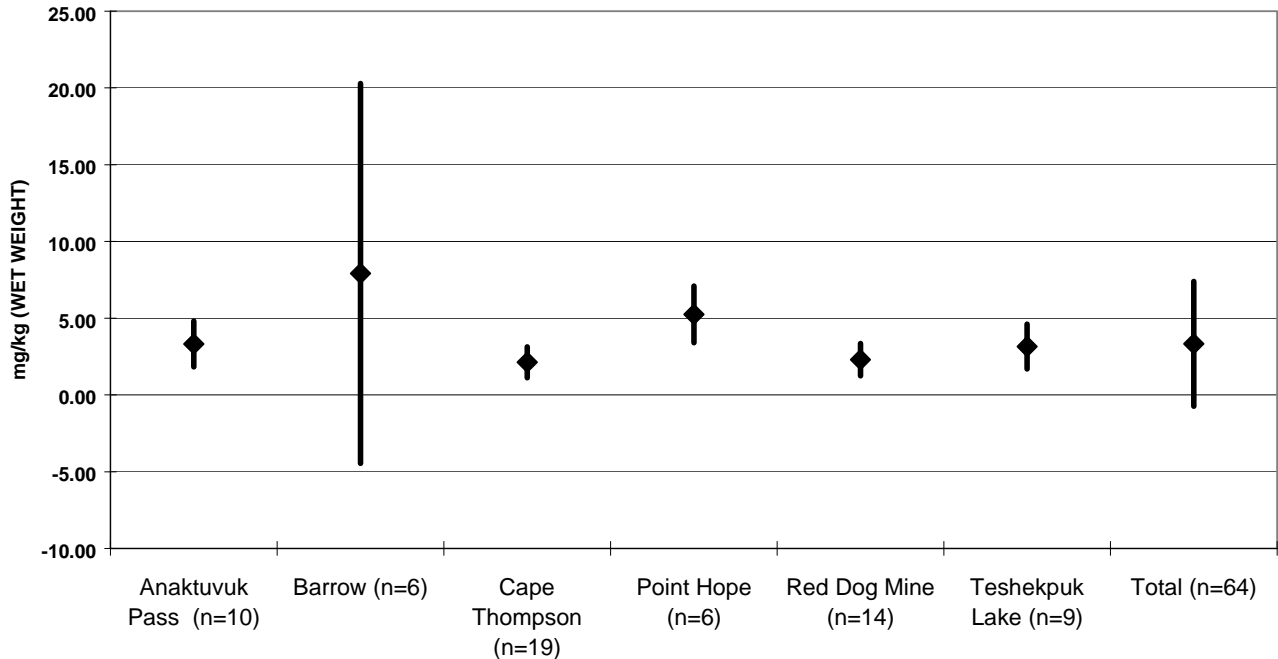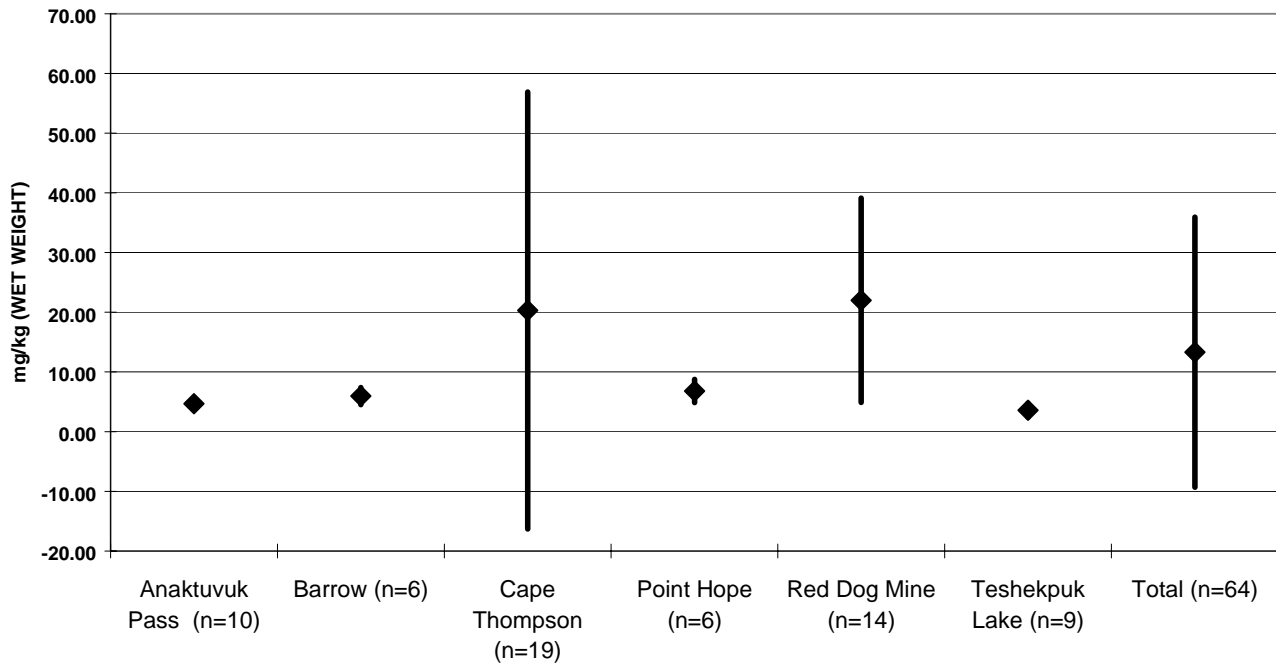Mean Milligrams/Kilogram Wet Weight +/- One Standard Deviation
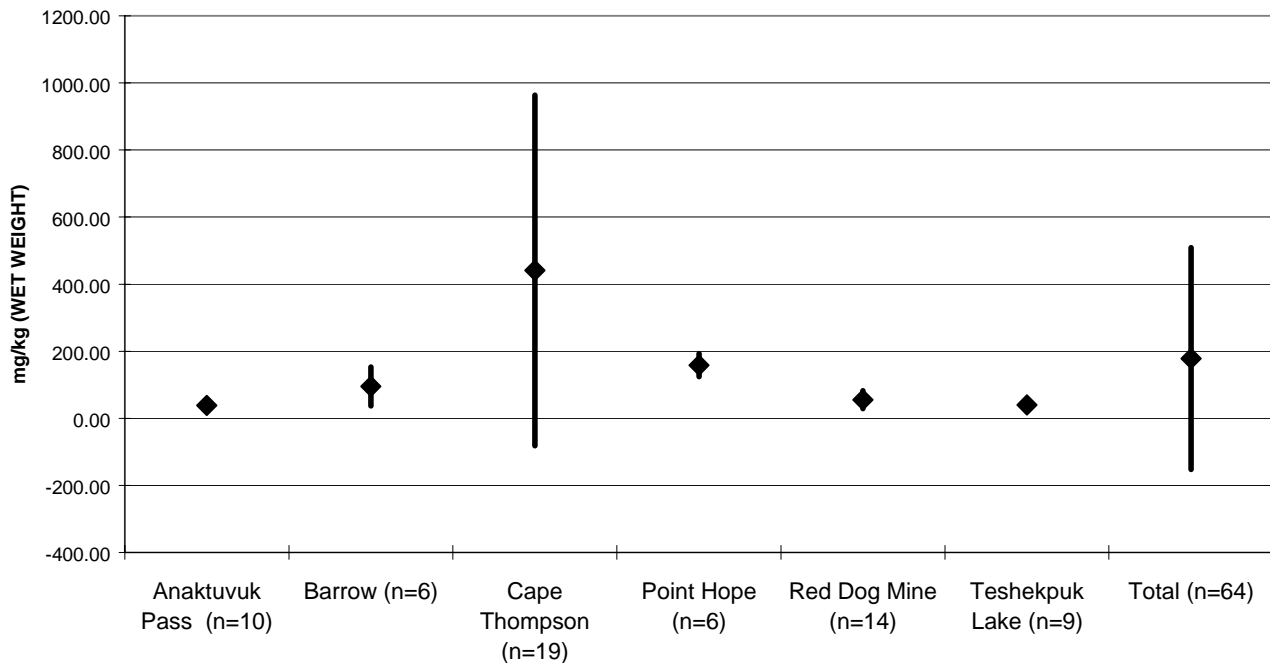
Table 1. **Red Dog Mine Blood Lead Level Reporting: All Tests Between 1992 and 2001**
       Data provided by Cominco

Company	Department	N	Mean	Geometric Mean	Median	Grouped Median	Std. Deviation	Minimum	Maximum	Range
Cominco	Construction Projects	6	3.7	3.5	3	3.4	1.2	3	6	3
	Environmental	134	5.0	4.1	4	4.0	3.3	1	20	19
	Finance	119	3.5	3.2	3	3.1	1.6	1	9	8
	Human Resources & Admin	161	3.5	3.1	3	3.1	2.0	1	16	15
	Loss Control	113	10.7	8.2	8	8.4	8.7	1	42	41
	Material Management	647	8.1	6.4	7	6.6	6.0	1	39	38
	Mill	3767	15.0	11.7	14	13.6	9.5	1	61	60
	Mine	2369	13.2	10.1	11	11.2	9.1	1	74	73
	Port	618	12.0	8.8	10	9.8	8.7	1	44	43
	Project Expansion	21	6.1	5.1	6	5.6	3.2	1	12	11
	Total	7955	13.0	9.7	11	10.9	9.3	1	74	73
Contractor	1	105	11.8	10.0	10	9.8	6.6	2	30	28
	2	310	22.5	19.7	21	21.0	10.6	2	63	61
	3	2	4.5	4.2	4.5	4.5	2.1	3	6	3
	4	36	8.8	7.4	6.5	6.7	5.4	3	23	20
	5	65	6.1	5.1	5	5.5	3.8	1	22	21
	6	6	11.8	10.8	10.5	10.5	5.2	5	19	14
	7	40	4.2	3.8	3.5	3.9	1.8	2	9	7
	8	4	16.5	15.4	17.5	16.0	6.6	9	22	13
	9	6	3.3	3.3	3	3.3	0.8	3	5	2
	10	1234	6.4	4.6	4	4.0	6.1	1	52	51
	11	771	11.0	9.1	10	10.3	6.4	1	47	46
	12	141	16.3	13.8	15	14.8	8.6	2	49	47
	13	10	1.8	1.6	1	1.8	1.0	1	3	2
	Total	2730	10.3	7.2	8	7.6	8.7	1	63	62
Total	Total	10685	12.3	9.0	10	10.0	9.2	1	74	73

Table 2. **Red Dog Mine Blood Lead Level Reporting: Tests Since January 1, 1995**
Data provided by Cominco

Company	Department	N	Mean	Geometric Mean	Median	Grouped Median	Std. Deviation	Minimum	Maximum	Range
Cominco	Construction Projects	6	3.7	3.5	3	3.4	1.2	3	6	3
	Environmental	114	4.8	3.9	4	3.9	3.3	1	20	19
	Finance	92	3.3	3.0	3	3.1	1.5	1	8	7
	Human Resources & Admin	125	3.3	2.9	3	3.0	1.6	1	9	8
	Loss Control	84	8.5	6.9	8	7.7	6.0	1	34	33
	Material Management	541	7.9	6.2	6	6.3	6.0	1	39	38
	Mill	3023	13.6	10.7	12	12.3	8.7	1	52	51
	Mine	1902	12.6	9.5	10	10.3	9.1	1	62	61
	Port	552	10.8	8.0	9	8.8	8.0	1	44	43
	Project Expansion	19	5.5	4.7	5	5.2	2.8	1	11	10
	Total	6458	12.0	9.0	10	9.9	8.7	1	62	61
Contractor	1	82	11.0	9.3	9	9.0	6.3	2	30	28
	2	287	22.4	19.6	21	20.8	10.8	2	63	61
	3	2	4.5	4.2	4.5	4.5	2.1	3	6	3
	4	30	7.7	6.5	6	5.9	5.0	3	23	20
	5	62	5.9	4.9	5	5.4	3.6	1	22	21
	6	6	11.8	10.8	10.5	10.5	5.2	5	19	14
	7	37	4.2	3.8	4	4.0	1.8	2	9	7
	9	5	3.4	3.3	3	3.4	0.9	3	5	2
	10	1165	6.3	4.6	4	4.0	5.9	1	52	51
	11	690	10.8	8.9	10	9.9	6.5	1	47	46
	12	130	15.7	13.4	14	14.3	8.2	2	39	37
	13	10	1.8	1.6	1	1.8	1.0	1	3	2
	Total	2506	10.0	7.0	7	7.2	8.6	1	63	62
Total	Total	8964	11.4	8.4	9	9.2	8.7	1	63	62

Table 3.   The Concentration (mg/kg) of Lead and Zinc in Soils Collected from the Port Facility, 1996, Cominco.

Sample area	Number of samples	Lead Maximum	Lead Median	Zinc Maximum	Zinc Median
CSB Building	27	1,200	25	4,500	85
End of CSB Building	60	27,000	59	22,000	265
Conveyor	196	32,000	645	95,000	3,600
Dock	40	32,000	370	130,000	1,350
Roadway	73	5,800	43	25,000	160
Unloading	38	36,000	235	180,000	1,300
Fuel Storage	39	450	18	5,800	79

Table 4.   Comparison of the Calculated Heavy Metal Intake Concentration for Dolly Varden Tissues (wet weight, mg/kg) with Calculated Risk-Based Screening Concentrations.

Analyte	EPA Reference Dose mg/kg/day	Risk-Based Screening Concentration[1]		Average Tissue Concentrations[2]					Calculated Intake Concentration[3]
		Adult	Child	Muscle	Liver	Kidney	Gill	Reproductive	
Aluminum	1.00E+00	**278**	**110**	0.698	0.898	0.92	11.9	0.287	**0.84**
Cadmium	1.00E-03	**0.28**	**0.11**	0.003	0.165	0.38	0.077	0.008	**0.011**
Copper	3.70E-02	**10**	**4**	0.574	14	1.9	0.800	4.490	**0.91**
Lead	NA	**NA**	**NA**	0.015	0.018	0.019	0.058	0.007	**0.016**
Selenium	5.00E-03	**1.39**	**0.55**	0.208	1.1		0.617	1.167	**0.24**
Zinc	3.00E-01	**83**	**33**	4.660	28	21.1	16.9	57.0	**5.7**

[1]Risk-Based Screening Concentration =   THQ * mg/kg-day (RfD) * 1/g/day (mean intake) *kg (body weight) * 1000g/kg (conversion factor)

Constants

Adult char ingestion rate	g/day	252	ADF&G subsistence database (mean intake)
Adult body weight	kg	70	adult
Child char ingestion rate	g/day	136	ADF&G subsistence database (mean intake) adjusted for child ingestion (see text)
Child body weight	kg	15	child
Target Hazard Quotient for Noncarcinogens		1	

[2]The average tissue concentration for fish collected from the Wulik River 1990 through 2000 (ADF&G 2000). One-half the detection limit was used for non-detects.

[3]The concentration was calculated assuming individuals could potentially eat all fish tissues. The concentration of each tissue was multiplied by the tissue percent weight and the result for each tissue was added together to derive the total. The percent weight for each tissue is based on an average of three fish: 2.3 % for the liver, 0.99% for the kidney, 1.2% for the gills, and 0.39% for the reproductive organs (based only on one fish) (Scannell 2001).

Table 5. **Comparison of the Calculated Heavy Metal Intake Concentration for Caribou Tissues (wet weight, mg/kg) with Calculated Risk-Based Screening Concentrations.**

Analyte	EPA Reference Dose mg/kg/day	EPA Slope Factor (mg/kg/day)-1	Adult Risk-Based Screening Concentration[1] Non-Cancer	Cancer	Child Risk-Based Screening Concentration[1] Non-Cancer	Cancer	Average Tissue Concentrations Muscle n=13	Liver n=15	Kidney n=14	Calculated Intake Concentration[2]
Arsenic	3.00E-04	1.5	**0.12**	**0.00026**	**0.062**	**0.00014**	0.55	0.3	0.34	**0.54**
Cadmium	1.00E-03		**0.40**		**0.21**		0.006	0.43	2.3	**0.060**
Copper	3.70E-02		**15**		**7.6**		2.71	100.4	22	**5.0**
Lead							0.05	1.65	10	**0.28**
Zinc	3.00E-01		**119**		**62**		33	22.4	16.8	**32**
Iron	3.00E-01		**119**		**62**		44.5	363	55.5	**51**

[1]**Risk-Based Screening Concentration** = (noncancer) THQ * mg/kg-day (RfD) * 1/g/day (mean intake) *kg (body weight) * 1000g/kg (conversion factor)

(cancer) TR * 1/(mg/kg-day)$^{-1}$ (SF) * 1/g/day (mean intake) *kg (body weight) * 1000g/kg (conversion factor)

Constants

Adult caribou ingestion rate	g/day	177	ADF&G subsistence database (mean intake)
Adult body weight	kg	70	adult
Child caribou ingestion rate	g/day	73	ADF&G subsistence database (mean intake) adjusted for child ingestion (see text).
Child body weight	kg	15	child
Target Hazard Quotient for Noncarcinogens		1	
Target Risk Level for Carcinogens		1.E-06	

[2]The calculated heavy metal intake concentration assumes muscle contributes 96% of caribou ingestion and liver and kidney contribute 2% each.

Table 6. Comparison of the Average Unwashed Salmonberry Concentration (n=10, net weight, mg/kg) with Calculated Risk-Based Screening Concentrations.

Analyte	EPA Reference Dose mg/kg/day	Risk-Based Screening Concentration[1] Adult	Child	Average Berry Concentration
Cadmium	1.00E-03	**4.0**	**0.88**	**0.021**
Chromium(III)	1.50E+00	**6000**	**1325**	**0.029**
Cobalt	2.00E-02	**80.0**	**18**	**0.013**
Copper	3.70E-02	**148.0**	**33**	**0.50**
Lead				**0.027**
Manganese	1.40E-01	**560**	**124**	**17**
Nickel	2.00E-02	**80.0**	**18**	**0.30**
Selenium	5.00E-03	**20.0**	**4.4**	**<0.064**
Zinc	3.00E-01	**1200**	**265**	**3.1**

[1]**Risk-Based Screening Concentration** = THQ * mg/kg-day (RfD) * 1/g/day (mean intake) *kg (body weight) * 1000g/kg (conversion factor)

Constants

Adult berry ingestion rate	g/day	17.5	ADF&G subsistence database (mean intake)
Adult body weight	kg	70	adult
Child berry ingestion rate	g/day	17.0	ADF&G subsistence database (mean intake) adjusted for child ingestion (see text).
Child body weight	kg	15	child
Target Hazard Quotient for Noncarcinogens		1	

Table 7.   The Concentration of Heavy Metals in Salmonberries from the Red Dog Mine Port Facility and Selected Berry Samples from the Yukon and Northwest Territories. All concentrations in mg/kg wet weight.

Analyte	Port Facility Samples[1] n=10			Gamberg 2001[2] n=88		
	Mean	Range		Mean	Range	
Cadmium	0.021	0.013 –	0.031	0.0092	ND –	0.28
Chromium	0.029	0.025 –	0.033	0.079	ND –	1.1
Cobalt	0.013	0.0098 –	0.019	0.0075	ND –	0.25
Copper	0.50	0.4 –	0.58	1.2	0.32 –	5.6
Lead	0.027	0.015 –	0.040	0.022	ND –	0.36
Manganese	16.9	13 –	22	16.2	0.3 –	194
Nickel	0.30	0.18 –	0.39	0.26	ND –	3.3
Selenium	ND			0.0091	ND –	0.12
Zinc	3.1	2.6 –	3.8	3.4	0.39 –	19.6

[1]Unwashed salmonberry samples
[2]All non-detects were assumed to be zero in the calculation of the mean. Species analyzed include bearberry, black current, blueberry, cloudberry, cranberry (low and highbush), crowberry, gooseberry, juniper, nagoon berry, raspberry, red current, rose, saskatoon, silver berry, soap berry, strawberry.

Table 8.   Calculated Blood lead levels. United States Environmental Protection Agency Uptake/Biokinetic Model for lead (Version 1.0).

Age (years)	CDC Blood Lead Level of Concern (μg/dL)	Estimated Blood Lead Level (μg/dL)
0.5 –1	10	3.0
1 – 2	10	4.1
2 – 3	10	4.1
3 – 4	10	4.0
4 – 5	10	3.8
5 – 6	10	3.6
6 –7	10	3.5