ENVIRONMENTAL TRACE ELEMENT SURVEY AT A HEAVY METALS REFINING SITE

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ABSTRACT. A survey of trace elements was conducted in the vicinity of gold mining and refining operations at Yellowknife, Northwest Territories. Instrumental neutron activation analysis techniques were used for multi-element analysis of samples of soil, water, snow, vegetation and human hair collected near the site. The elements studied were related to the refinery effluent.

Concentrations of arsenic, antimony, cobalt, mercury, chromium, lanthanum, europium and gold were determined. Arsenic, antimony, and mercury levels were very high in all environmental samples examined. Cobalt was excessively high in most samples. Hair analyses showed arsenic and mercury mean levels higher than normal levels.

Results were correlated with sample location and physical properties. Observations on biological concentration factors of certain elements also were discussed.

INTRODUCTION

This paper reports on the emission and dispersal of trace elements from the smelters of gold-producing mines at Yellowknife, Northwest Territories. Samples of soil, water, vegetation, and human hair were analyzed by neutron activation at the Ames Laboratory Research Reactor at Iowa State University, Ames, Iowa.

The purpose of the work was twofold: to determine the accumulation of trace elements in the environment resulting from the gold refining process, and to investigate evidence of biological concentration factors in the ecological systems of the area. This information can provide a basis for estimating the levels and rates of trace element contamination of the environment.

Environmental samples were collected by field biologists during the summer of 1970. Hair samples were obtained from volunteers during the summer of 1970. The snow was collected in early spring, 1971.

DESCRIPTION OF AREA

Field sampling was conducted in the vicinity of Yellowknife, Northwest Territories. Yellowknife, the capital since 1967, is the largest town in the Northwest Territories (1). It is situated on the northern shore of Great Slave Lake where the Yellowknife River enters a large bay of the lake.

Ecological Characteristics. Yellowknife is located on the southwestern edge of the Precambrian Shield. The topography is dominated by granitic outcrops of Precambrian bedrock which cover approximately 25-30 percent of the land surface. Except for a few peat areas, the soil is mineral in nature consisting of glacial deposits and lacustrine silts. Soils are subarctic with continuous permafrost and limited differentation (2). Country rocks are predominantly granites of volcanic and metamorphic origin (3) with older andesite and basalt flows in a north-south belt along the west shore of Yellowknife Bay.

The climate of the region is subarctic continental characterized by long, cold winters and short, cool summers (4). There is low annual precipitation (about 10 inches) with moderate snowfall and little rainfall. Prevailing winds are northwesterly in winter and southeasterly in summer.

Yellowknife is located in the Northern Transition Section of the Boreal Forest (5). Theiret recently described the vegetation of the Yellowknife area (6).

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Human Activity. The Yellowknife region was largely a virgin wilderness until mineral exploration began in the late 1920's (7). Prior to that time, the area was inhabited by the Yellowknife and Dogrib Indians and visited by European and Canadian explorers and fur traders.

In the early 1930's, gold was discovered in the vicinity of Yellowknife, and the first gold mine was established. In 1948, the largest gold producer in the Northwest Territories commenced operation and has been in continuous production. Total ore processing approaches 1700 tons per day and gold production in the Northwest Territories is annually a $15-20 million business.

With the expansion of resource exploration and northern development, human population in the vicinity of Yellowknife has increased rapidly, doubling in the 1965-1970 period to over 7,000.

METHODS

SAMPLING PROCEDURES

In the field, samples were collected at varying distances and locations surrounding the smelters. The objective was to obtain environmental samples in close proximity to the smelter chimneys as well as several miles away. Hence, the sampling sites were not randomly selected.

At each sampling location, the following materials were collected within an area of 20-25 square meters: (a) soil, (b) rocks, (c) water, and (d) vegetation. The vegetation consisted of a grass (Northern reedgrass, Calamagrostis canadensis) and leaves and fruit of the wild rose (Rosa acicularis). Each item was placed in an individual plastic bag. Water and snow samples were collected in clean polyethylene bottles.

Hair samples were collected from volunteers at the Public Health Clinic and at a local barbershop as well as through personal contacts. The objective was to obtain hair from individuals who had lived in Yellowknife for varying periods of time and who were employed in a variety of occupations.

ANALYTICAL PROCEDURE

Preparation of Samples and Irradiation. Samples of soil, water, vegetation and hair were prepared for irradiation as follows.

Dried soil samples were ground either in a Pica Blender iron mill or in an iron-diamond mortar. Water samples were filtered through prewashed 47 mm cellulose acetate Millipore filters before irradiation and residues prepared separately. No attempt was made to identify the particulate matter. Vegetation samples, being air dried and friable, were broken up and pulverized with quartz rods. Following irradiation, vegetation samples were pulverized in the Pica mill. Hair samples were handled with clean, Teflon coated instruments in a laminar flow work station. Samples were cut with cleaned carbon steel surgical scissors and washed on clean plastic Buchner funnels using three alternate washings with deionized water and a 50 volume percent acetone and 95% ethanol solution after Perkons (8) followed by air drying.

Solid samples, except for hair, were irradiated in sealed snap-top polyethylene vials. Hair samples were wrapped in aluminum foil and sealed in polyethylene bags. Liquid samples and monitor solutions were sealed in quartz ampoules. All of the glassware, instruments and irradiation containers used in preirradiation treatments were cleaned with nitric acid, rinsed with deionized water and acetone and air dried.

Solution flux monitors accompanied each batch of samples being irradiated and in most cases Al-Co and frequently Al-Au alloy wire flux monitors were included. The wire monitors were sealed in separate pieces of polyethylene tubing.

Irradiations were made in the heavy water moderated, 5 megawatt Ames Laboratory Research Reactor (ALRR). Liquid and solid samples were irradiated in fluxes of 2×10^{13} and 3.5×10^{13} neutrons/cm^2/sec, respectively. The cadmium ratios were, in order, 35 and 18. Samples were irradiated five hours and counted twice. The first counting was three to six days after the irradiation depending on their sodium content and the second one was close to three weeks after the irradiation. Reagent grade chemicals and deionized water were used throughout in preirradiation treatments and in the preparation of flux monitor solutions.

Postirradiation Treatment. Following irradiation, .2 g to 1.4 g of pulverized vegetation and soil samples were individually mixed with 14.5 g of pure $CaSO_4 \cdot \frac{1}{2}H_2O$ (plaster of Paris) and transferred to a modified 50 cc polyethylene syringe and vigorously shaken with 13.5 ml of water. The homogeneous slurries were discharged into containers made from Plexiglas rings 1.27 cm high and 4.45 cm I.D. using 7.8 mg/cm^2 Scotch Mylar transparent tape for bottoms and tops. A Scotch Mylar tape top was applied after the mixtures hardened. This technique is similar to that used by Perkins and Rancitelli (9).

Liquid samples and monitors were pipetted into the syringe containing plaster of Paris and enough water was added to make the required liquid volume. The rest of the procedure was identical to the one described above.

After the irradiation, the hair samples were placed in small polyethylene beakers and each dissolved in 5 ml of a solution of sodium hydroxide made by mixing 8 ml of saturated NaOH solution in 92 ml of distilled water. The solution was neutralized to phenophthalein with H_2SO_4 after dissolution and transferred to the syringe containing the plaster of Paris. Each beaker was rinsed several times with a summed volume of 8.5 ml of H_2O to complete the transfer. The remainder of the procedure, i.e., preparation of the plaster of Paris mixture, etc., was identical to the one described earlier.

Radiometric Analysis. A Ge(Li) detector and a Nuclear Data, Inc. series 50/50, single parameter, 4096 channel analyzer, in conjunction with a PDP-8/L computer and tape punch readout were used to make the gamma ray spectrum analyses. The Ge(Li) detector had a peak to Compton ratio of 16 to 1 at 1332 keV and a relative full energy peak efficiency of 4.3% at 1332 keV when compared with a 3" x 3" NaI(Tl) crystal. Samples prepared as described above were placed in a holder attached to the Ge(Li) detector can to insure reproducible geometry. They were counted for half of the counting period and then turned over and counted for the remainder of the time. The two counts were summed and treated as a single count in data reduction.

The spectra were collected in 2048 channels with 0.85 to 0.90 keV per channel. The data were read out of the analyzer through a tape punch and transferred to magnetic tape compatible with the computer system. The readouts from the computer were reduced to peak areas, line spectrum plots and listings of the counts in each channel using a modified ICPEAX (10) program and an IBM 360 computer.

RESULTS AND DISCUSSION

ANALYTICAL PRECISION

Limits of detection for the elements reported in this study varied with the sample matrix. Soil presented the largest interferences and minimum detection limits ranged from 5 x 10^{-4} mg for arsenic to 1 x 10^{-7} mg for gold. Mercury was not reported in soil samples due to insufficient sensitivity under the conditions of irradiation and decay. Detection limits in water samples ranged from 5 x 10^{-5} mg for arsenic to 4.2 x 10^{-7} for cobalt. Detection limit for mercury was 1 x 10^{-6} mg.

The error involved in sample preparation and positioning was evaluated by duplicate preparations of standard ^{203}Hg solutions processed as described under sample preparation. The error of duplicate determinations was ± 1%; the difference between topside counts and bottomside was $\pm < 1\%$.

The total procedural error was evaluated by the standard error of duplicate measurements on soil samples. Twenty pairs of soil samples prepared as described exhibited the following mean errors: chromium ± 5.7%, antimony ± 4.8%, cobalt ± 4.2%, gold ± 10.7%, arsenic ± 5.6%.

ELEMENTAL CONCENTRATIONS

Soils. Trace element concentrations in soil samples obtained in the Yellowknife District are shown in Table I. The location of the sampling site is indicated in the second column as distance measured on the map from the nearest smelting operation. The five elements shown are the principal contaminants resulting from gold ore processing operations. Mercury, an additional important element in the soils, is yet to be analyzed. Inspection of the first two columns, arsenic and antimony, in these soils indicate an extremely high concentration compared to standard references reported by Comar (11) as well as the analysis of these elements in the country rocks of the Yellowknife District reported by Boyle (3). The concentration of arsenic is unusually high in a radius of $\frac{1}{2}$

mile of smelter stacks. In general, an inverse relationship of arsenic concentration vs distance is noted. This same relationship is seen in the case of antimony. Relative concentrations of arsenic to antimony are similar to those reported for Yellowknife ore by Boyle (3).

The concentrations of gold and cobalt in these samples are also correlated with smelter proximity but in the case of cobalt the indigenous level in these soils may account for a significant fraction. Chromium concentrations are the most variable. A correlation is not evident in these data.

An additional observation is the difference in concentrations of both cobalt and chromium in soils obtained from the same site but selected from a mineralized type sample (1, 2, 4, 5, 6, 7) and a high organic, mossy type (1A, 2A, 4A, 5A, 6A, 7B). The organic soils show consistently larger values which may be related to bio-organic concentration processes.

"Town sites" represent garden soils from the town of Yellowknife. Of the elements shown, arsenic and chromium are more than an order of magnitude above normal range (11) with antimony and cobalt less than an order of magnitude.

Water. In Table II are reported the values for certain contaminating and trace elements in snow and lake water samples. Background data are represented by "Lake" samples at 10, 20, 26 and 30 miles from the smelters. Although the 10-mile sample value of 0.2 ppm is significantly above background for arsenic, it represents a single analysis.

The numbered samples of lake water exhibit the same inverse correlation of distance with concentration. This is evident when compared to the five elements measured in soil and also in an additional element, mercury. The values reported for mercury in uncontaminated waters in general are < 0.1 ppb (12). In this study, even the distant sources obtained at 30 miles exceed this value by an order of magnitude. The source of this contamination is related to ore processing at least in part as evidenced by the high levels in Lakes 2, 7 and 13.

Levels of the contaminating elements in snow samples parallel lake samples. Arsenic and antimony are the same order of magnitude while cobalt and mercury are one less. It is interesting that the cobalt and mercury from snow was concentrated in the particulate matter on the filter but the soluble form was predominant in the lake samples. The highly contaminated snow sample #10 also shows a high fraction of arsenic and antimony in the particulate fraction.

The rare earth elements lanthanum and europium also show a direct correlation with contaminating elements, but their significance is not clear.

Vegetation. Analyses of native grass samples and rose leaves are reported in Table III. The concentrations related to distance are apparent in the rose but not as evident in the grass. The higher concentrations of arsenic in the rose leaves may be related to leaf surface and fallout density, but in the case of grass no such simple correlation is suggested. Grass with the lowest arsenic concentration came from the highest soil concentration. The latter observation also is true for antimony. A very significant difference is evident in the antimony levels of grass compared to rose leaves where the average of the four grasses is eight times the average of the four rose samples. This specific difference of grass to rose also is evident in the mercury values, in spite of the one anomalous value for grass #6. Cobalt values are also higher in grass but lanthanum values are reversed, rose approximating 40 times the concentration in grass on a dry weight basis. According to Bowen (13) and Schaklette (14) the levels of all elements reported in these plant samples exceeded the normal ranges, with two to three orders of magnitude for arsenic and antimony, one order for mercury and up to one order for cobalt.

Hair. In Table IV the analyses of human hair samples are reported in numerical order on the basis of the increasing residence time in Yellowknife, sample #12 having the longest residence time. The individual resident times range from 1.5 to 23 years. The range of elemental concentrations in this work is compared in Table V to reports on much larger samples by Quittner et al. (15) and Perkons (8). A comparison of average values indicates Yellowknife samples to be higher in arsenic and mercury and lower in antimony and gold.

The range of arsenic and mercury in these hair samples is greater than the other elements, with coefficients of variation of ± 147% and ±107% respectively. This coincides with the known biological concentration of these elements in hair. Although clinical data associating arsenic levels of this magnitude with pathology are not available, there is positive evidence for mercury. Wallace et al. (12) summarized a report describing mercury toxicity symptoms in Swedish subjects which coincided with hair levels of 36 ppm. These Yellowknife data show one sample (#12) at twice this concentration and two additional ones approaching half this concentration. The significance of these observations is obscured by the lack of information on individual habits and dietary intake on these and other inhabitants. The mean selenium levels in this group, while higher than the reference data, may or may not be significant. It is interesting to note that the sample #12 is in excess of two times the mean values for three observed contaminating elements, mercury, arsenic and selenium.

ELEMENTAL RATIOS

In the evaluation of differential rates of movement of trace elements through a natural system, the calculation of elemental ratios is a frequently used practice. This technique is particularly useful in indicating biological mechanisms in organisms or ecosystems which concentrate, precipitate, or otherwise discriminate against individual elements or groups of elements with like characteristics. The individual data on elements which are considered contaminants in this study are viewed in different levels of the environment as arsenic ratios. Arsenic was selected as the common denominator element because it is the contaminant found in highest concentration and exhibits a fairly high constant level of concentration in the ore (3).

Arsenic/Antimony. A second abundant contaminant found regularly in Yellowknife ores is antimony (3). Assuming a constant source of contamination, the ratio of arsenic to antimony in a particular environmental system would reflect differences in chemical and/or biochemical reactivity. A comparison of As/Sb ratios in snow, lake and soil (Table VI) shows values in close agreement with soil being slightly but significantly lower, although the snow samples represent only six to eight months' accumulation. The relatively non-volatile properties of their oxides and other similar inorganic chemical properties anticipate this observation. Lower ratios in soil may indicate relative differences in adsorption properties or soil microbiological effects. Furthermore, the decrease in the soil ratio is not related to arsenic concentration.

In the two plant species observed, the As/Sb ratio varies significantly from an average of about 4.0 in grass to over 50.0 in rose. Examining the individual elemental concentrations in Table III shows arsenic levels in rose to be twice as high and antimoney levels only one-sixth those in grass. While this observation may be simply a leaf surface effect for arsenic, it does suggest that grass exhibits a relative discrimination for antimony. The variance of the As/Sb ratio in these plants is less than the variance of elemental concentrations. Such elemental discrimination factors are not unusual in the plant world.

The ratio of As/Sb in hair samples exhibits a large variance which is due principally to the arsenic variance (C.V. 147%). Antimony concentrations vary less (C.V. 49%). Although the antimony values fall within the normal range (Table V) the factors governing biological concentration of antimony are less understood than those of arsenic.

Arsenic/Mercury. Arsenic/mercury ratios in these environmental samples suggest both physical and biological effects. Unlike the close agreement of As/Sb ratios in lake and snow samples, the As/Hg ratios in these same samples are a factor of 20 times different. Since snow and lake arsenic levels are of the same magnitude (Table II) the very low mercury levels in snow increase the As/Hg ratio.

This relatively low mercury level in snow may be due to a vaporization loss of mercury that is prevented in lake water by ionization or chelation, or to an unusually high Hg background in lakes of the entire district. This latter possibility is placed in doubt by very high mercury concentration associated with the high levels of other contaminating elements in lake sample #7. Furthermore, only particulate fractions of snow water contained mercury, while soluble fractions were a major part of lake samples.

The As/Hg ratios in the grass and rose samples exhibit a large difference of almost an order of magnitude. This is due to the much higher concentration of mercury in grass samples, a probable result of bioconcentration, especially since mercury concentration appears to be independent of other contaminants, as well as site. This capacity to concentrate mercury may be common to the grass family, since high mercury levels have been reported in cultivated grains (12).

Arsenic/Cobalt. In the case of cobalt the As/Co ratios vary considerably in snow. A reasonable explanation is not evident. The As/Co ratio in lakes is lower due principally to the higher cobalt concentration in lake water. This concentration may be maintained by equilibrium processes within sediments and recycling through the biological systems. Examination of background lake waters at 10, 20, 26 and 30 miles out, however, show cobalt levels only 1.0 to 10.% of lakes in the smelter vicinity. These high cobalt levels parallel high arsenic and antimony levels in the same waters.

In grass and rose the specific biological effects are again evident. Although cobalt concentrations in the dried plants vary greatly (Table III) the greater ability of grass to concentrate cobalt is evident in a fourfold difference.

SUMMARY

Samples of soil, snow, water and vegetation were obtained in the vicinity of gold smelting operations at Yellowknife, Northwest Territories. Concentrations of arsenic, antimony, cobalt, mercury, chromium, lanthanum, europium and gold were determined by neutron activation analysis using instrumental techniques.

Human hair samples were obtained from individuals residing in Yellowknife for varying periods and analyzed for trace elements by the same procedures.

Concentrations of the contaminating elements, arsenic, antimony and mercury, were very high in all environmental samples examined. Cobalt was excessively high in most samples.

Hair analyses showed arsenic and mercury mean levels higher than previously reported normal levels. One sample showed mercury levels over ten times normal and seven of ten arsenic determinations exceeded published normal values.

Ratios of contaminating elements were calculated and variances between the different environmental samples were discussed on the basis of physical and chemical properties and evidences of biological and chemical discrimination.

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TABLE I

Soil Analyses at Yellowknife NWT

Element (ppm)

Sample	Miles Distant[a]	As	Sb	Au	Cr	Co
1	2.7 SW	219	14.0	0.0105	967	7.6
1A		199	12.4	0.0088	2144	15.4
2	1.9 SW	115	21.3	0.0075	3	1.9
2A		164	19.3	0.0115	1936	15.3
4	1.2 SE	601	39.3	0.069	16	8.2
4A		814	43.0	0.082	46	19.2
5	.4 NE	602	21.9	0.047	41	8.4
5A		852	46.3	0.064	53	21.3
6	.3 NE	3108	202	0.220	86	43.1
6A		2641	136	1.175	100	40.2
7	.2 SW	6852	124	0.140	51	43.0
7A		2449	132	0.16	80	35.4
7B		7598	280	0.32	3566	50.0
8	.8 NE	269	24.6	0.035	5464	44.0
9	1.3 SW	153	10.7	0.011	80	16.2
12	1.8 NW	163	9.0	0.0073	76	10.0
13	1.8 NW	110	4.5	0.0033	443	18.9
14	.7 NW	45	2.6	Not Found	60	10.8
Town Sites		119	1.4	0.0071	1417	16.6
		34	1.4	0.0035	2248	17.1
		178	8.3	0.039	3274	24.2
Comar (11)		5	2		150	8
Country Rocks YKNWT (3)		2-10	.1-1		∼ 20	< 10

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[a] Distance from nearest smelter

TABLE II
Snow and Lake Water Analyses at Yellowknife District NWT
Elements (mg/L)

Sample	Dist.	As x10^2	Sb x10^3	Co x10^4	Hg x10^4	Cr x10^4	La x10^5	Eu x10^5	Au x10^7
Snow 5	.35 NE	68.	19.	11.	--	--	--	--	--
Residue		3.4	4.7	5.4	1.3	22.	19.	57.	15.
Snow 9	1.3 NE	120.	30.	10.	--	--	--	--	--
Residue		12.	10.	3.5	3.8	16.	14.	--	--
Snow 10	.22 NW	875.	840.	21.	--	--	--	--	--
Residue		1702.	426.	48.	23.	94.	103.	6042.	1666.
Snow 21	2.0 SE	47.	22.	11.	--	--	--	--	--
Residue		14.	5.1	2.1	1.1	10.	38.	146.	6.9
Lake 2	1.9 SW	390.	150.0	120.	57.	--	--	--	--
Residue		.50	.20	50.	.32	--	1.9	343.	5.6
Lake 7	.3 SW	1240.	210.0	630.	800.	--	--	--	--
Residue		117..	.14	28.	2.7	35.	23.0	305.	751.
Lake 9	1.9 SW	19.	11.0	40.	7.3	--	--	--	--
Residue		7.5	2.0	29.	5.4	132.	2553.	125.	32.
Lake 13	1.8 NW	56..	22.0	9.0	31.	--	--	--	--
Residue		2.0	1.0	.50	1.9	10.	45.	--	> 1.
Lake	10 mi.	20.	1.	2.	5.				
Lake	20 mi.	.1	.5	4.	4.				
Lake	26 mi.	--	--	2.	24.				
Lake	30 mi.	--	.4	1.	12.				

TABLE III
Plant Element Analysis at Yellowknife NWT
Element (ppm)

Sample	Miles[a]	As	Sb	Co	Hg	Cr	La
Grass 6	.3	12.6	2.47	0.83	17.11	0.59	0.13
Grass 15	1.0	19.8	7.02	5.78	1.95	21.9	5.07
Grass 12	1.8	89.4	15.4	3.29	0.89	2.08	0.85
Grass 17	2.3	12.9	4.13	1.61	1.93	2.53	0.97
Rose 5	.4	138.	1.85	1.14	0.19	3.9	16.2
Rose 8	.8	39.1	1.82	1.09	0.23	3.5	47.7
Rose 12	1.8	26.9	0.79	0.79	0.11	3.9	31.6
Rose 2	1.9	15.4	0.17	0.06	0.14	---	162.2
Orch. Lv.[b]		.015	.003	.0001	.0002	.002	
Citrus Lv.[b]		.005	.00004	.00002	.0001	.0005	
Kale[c]		.140	.070	.056	.160	.33	

[a] Distance from smelter

[b] Rancitelli (<u>16</u>)

[c] Comar (<u>11</u>)

TABLE IV
Elemental Hair Analyses - Residents of Yellowknife NWT

Sample	Element (ppm)										
	As	Sb	Co	Hg	Cr	La	Eu	Au	Se	Zn	Sc
1	1.04	0.64	0.12	3.96	1.92	--	0.009	0.062	1.72	374	0.011
2	--	0.24	0.026	6.46	1.38	--	--	--	2.55	566	0.030
3	1.19	0.69	0.135	6.33	--	0.059	0.004	0.023	2.53	319	0.057
4	15.9	0.81	0.32	7.59	0.96	0.059	0.026	0.042	2.94	531	0.071
5	3.96	0.97	0.39	6.86	3.10	0.170	0.026	0.022	2.43	421	0.113
6	8.80	0.89	0.22	14.2	3.32	0.180	0.021	0.190	1.95	444	0.079
7	3.37	0.50	0.44	12.6	--	0.084	0.026	0.009	2.76	864	0.010
8	4.90	0.31	0.24	5.36	2.17	--	0.010	0.092	2.29	615	0.057
9	--	0.27	0.19	8.96	1.46	0.130	0.015	--	2.85	645	0.081
10	3.13	0.20	0.083	5.38	0.40	0.130	0.017	0.011	2.58	522	0.031
11	1.70	0.27	0.34	5.39	--	0.036	0.020	0.085	2.65	515	0.018
12	25.3	0.69	0.47	78.8	6.43	0.260	0.016	0.056	5.64	820	0.110
Mean	13.5	0.54	0.25	6.9	2.46	0.123	0.0211	0.059	2.7	553	0.0556
C. V.	±147%	±49%	±56%	±107%	±69%	±41%	±38%	±92%	±35%	±25%	±62%

TABLE V
The Range of Concentrations of Elements in Hair
Yellowknife NWT

Element	Concentration (ppm)		
	Quittner[a]	Perkons[b]	This Work
Zn	100 - 1000	300 - 800	319 - 864
Sb	1 - 20	0 - 10	0.2 - 1
Cr	2 - 4	2 - 5.5	0 - 6.4
Hg	0.2 - 6	0.8 - 2.3	4 - 79[c]
Se	0.5 - 3	1 - 2.5	1.7 - 5.6
As	0.2 - 3	1 - 2.5	0 - 25[c]
Au	0.2 - 3	0.5 - 1.6	0 - 0.2
Co	0.1 - 1	0 - 1	0.03 - 0.5
La	0.05 - 0.5	0 - 0.3	0 - 0.3
Eu			0.004 - 0.3
Sc			0.01 - 0.1

[a] Quittner (15)

[b] Perkons (8)

[c] Above reported normal range

TABLE VI
Elemental Ratios in Yellowknife Samples

Sample	No.	As/Sb	As/Co	As/Hg
Snow	5	30.1.	435	5328
	9	33.0	978	3492
	10	20.3	3719	11453
	21	22.6	467	5416
Lake	2	26.1	313	682
	7	64.6	206	169
	9	20.4	79.8	209
	13	25.2	607	175
Soil	1	16.0	12.9	--
	2	8.5	10.7	--
	4	18.9	42.4	--
	5	18.4	40.0	--
	6	19.4	65.7	--
	7	18.6	69.2	--
	8	10.9	6.1	--
	9	14.3	9.4	--
	12	18.1	16.3	--
	13	24.4	5.8	--
	14	17.6	4.2	--
Grass	6	5.10	15.2	0.74
	12	5.81	27.2	101.0
	15	2.82	3.43	10.2
	17	3.12	8.01	6.70
Rose L.	2	90.6	257	110
	5	74.6	121	726
	8	21.5	36.0	170
	12	34.1	34.0	245
Hair	1	1.6	8.7	0.26
	3	1.7	8.8	0.19
	4	19.6	49.7	2.09
	5	4.1	10.0	0.58
	6	9.9	40.0	0.62
	7	6.5	7.7	2.67
	8	15.8	20.4	0.91
	10	15.7	37.7	0.58
	11	6.3	5.0	0.31
	12	36.6	53.8	0.32

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May 1 1972

Dear Mrs. Reimann:

My Minister, the Honourable John Munro has asked me to thank you for your letter of January 7 together with enclosures addressed to the Minister of Environment, which was forwarded to my attention by Mr. Davis.

As the Honourable Jack Davis indicated in his reply to you, this Department has done considerable work with respect to the health implications of heavy metal accumulation resulting from the gold refining process at Yellowknife. In this connection, particular attention has been given to the presence of arsenic in the environment, with a detailed Report on the subject having been published back in 1966. A copy of this Report is enclosed in case you have not seen it.

The studies which formed the basis for the Report were, I would emphasize, part of a continuing review of the situation, and plans are currently under development for much more extensive investigations which would include reference to all trace metals of significance to health. These investigations could also involve participation of the Department of the Environment as well as interested members of the academic community. With regard to the latter, officers of my Department have examined the results of the preliminary study carried out by Iowa State University scientists and would be pleased to give consideration to any proposal which they might care to put forward concerning further research in this field.

Yours sincerely,

C.A. Pearson
Executive Assistant

Mrs. Helga Reimann
P.O. Box 1090
Yellowknife, N.W.T.

Minister
Environment Canada

Ministre
Environnement Canada

Ottawa, Ontario.
K1A OH3
[illegible]

Mrs. Helga Reimann,
Ecology North,
P.O. Box 1090,
Yellowknife, N.W.T.

Dear Mrs. Reimann:

I was pleased to receive your letter of January 7, 1972, outlining the human health and welfare implications of heavy metals accumulation resulting from the gold refining process at Yellowknife. Your letter also brings to my attention a research proposal on this subject by scientists at Iowa State University.

As this is primarily a human health problem. I have taken the liberty of forwarding a copy of your letter and enclosure to my colleague, the Honourable John Munro, Minister of National Health and Welfare. I understand some of his staff have been doing work in this field and I have asked him to write you directly with his views on the matter.

I have also brought this matter to the attention of my own scientific staff for their future consideration in the framework of environmental impact study proposals. We are not in a position at this time, though, to take action with respect to the Iowa State University research proposal.

Thank you for having taken the time to bring this matter to my attention. I greatly appreciate your interest in environmental quality.

Yours sincerely,

Jack Davis.

P.O. Box 1090
Yellowknife, N.W.T.

January 7, 1972

The Honorable Jack Davis
Minister of Environment
Ottawa, Ontario

Dear Minister Davis:

For several years many residents of Yellowknife have become increasingly concerned about the possible accumulation of toxic poisons, particularly arsenic, as a result of the local gold refining operations.

In 1970, an opportunity to study the significance of arsenic and other heavy metal accumulations in the vicinity of Yellowknife, developed. Dr. David L. Trauger, associated with the Iowa State University, Ames, was conducting ecological studies in the area. When he was contacted by several residents of Yellowknife with regard to this problem, he indicated that his associates at the University were using highly sophisticated analytical methods for detecting heavy metals in environmental samples, and would be interested in conducting preliminary analyses at the Ames Research Reactor, an installation of the U.S. Atomic Energy Commission at Iowa State University. There, the research was directed by Dr. James J. O'Toole and colleagues, to determine the nature and significance of the heavy metal contamination at Yellowknife. Enclosed is a copy of the results of the preliminary study. After a careful review of these findings, we have reached the following conclusions.

There are serious implications to human health and welfare related to the amount and variety of heavy metal accumulation due to the gold refining process at Yellowknife. These toxicants include not only arsenic and antimony originating in the native ores but also mercury used in the refining process. Hence, we request that the Department of Environment support a comprehensive evaluation of the environmental impact of the refining effluents on the human population and wilderness environment in the Yellowknife district. The situation provides a unique opportunity to study the distribution and accumulation of toxic metals from limited point sources through the eco system and man in an area free of peripheral contamination. Furthermore, the mixture of transient and resident inhabitants at Yellowknife provide an unusual opportunity to determine the rate of accumulation of toxic elements in relation to exposure periods in man.

We encourage your Department to review a proposal being prepared by scientists at Iowa State University to conduct this study at the earliest opportunity. The unusual analytical capability of this institution working in co-operation with representatives of the Canadian Government, has important implications of scientific as well as health significance.

....2

We understand that Dr. James Hill, M.D., University of Alberta Hospital, and Dr. Robert Jervais, Ph.D., University of Toronto, have already indicated an interest in this problem in discussions with Drs. O'Toole and Trauger.

We believe that this project would provide a unique opportunity for an international, interdisciplinary research program of great importance to human welfare and environmental protection.

Having met with you and corresponded with you over the past six months, we have every confidence that the enclosed will receive sincere appraisal and evaluation by you and your Department.

Sincerely yours,

ECOLOGY NORTH

per:
(Mrs.) Helga Reimann

HR/ma
encls.