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Epidemiology of Eldorado Uranium Workers 1950-1999

Introduction

Eldorado Nuclear, one of the two companies that merged to form Cameco Corporation, funded an epidemiological study of past employees in the early 1980s [1]. During the 1990s, a federal-provincial panel held environmental assessment hearings for new uranium mining projects in northern Saskatchewan. One of the recommendations of that panel [2] was to perform epidemiological studies of past, present and future Saskatchewan uranium miners. The Saskatchewan Uranium Miners Cohort Working Group was formed to address this recommendation. To address the "past" portion of the recommendation, it was decided to update the Beaverlodge sub-cohort of the Eldorado study. At the same time Cameco was interested in the Port Hope sub-cohort of the Eldorado study, about which little had been published. Cameco and the Canadian Nuclear Safety Commission agreed to co-sponsor the study. The Saskatchewan government and COGEMA Resources (now AREVA) subsequently joined the sponsoring group. It proved more cost-effective to update the entire Eldorado study, rather than separately address the Beaverlodge and Port Hope sub-cohorts, thus including the Port Radium mine in the update. This paper presents a preliminary summary of the results. Additional analysis is being done and further, more detailed, papers are planned. The issue of current and future Saskatchewan uranium miners was addressed in a separate feasibility study by SENES Consultants [3].

History

Eldorado Gold Mines was incorporated in 1926 [4]. In 1930 the company discovered pitchblende, a uranium mineral valued for its radium content, on the shores of Great Bear Lake in the Northwest Territories. Mine production started in 1932. Since the extraction process required several tons of chemicals to process one ton of ore, the decision was to upgrade the ore as much as possible by physical processes and ship it out for processing. At that time the Canadian chemical industry was largely concentrated in southern Ontario and Quebec. Eldorado was able to acquire a plant in Port Hope, Ontario, which was on the main line of both national railways and an active port, and set up its radium refinery there. The first radium was produced in early 1933.

World War II interrupted the radium business and the mine and refinery were shut down. However, Fermi's success with a sustained chain reaction created interest in uranium, which had previously had only limited use as a colouring agent for ceramics and glass. The mine was re-opened in April 1942, and the refinery was re-opened to extract uranium. The advent of reactor-produced radioisotopes caused a decline in the radium business and Eldorado stopped refining radium in 1953 and got out of the radium business completely in 1954. Interestingly, most of the Eldorado radioisotope group was spun off to become the Commercial Products Division of Atomic Energy of Canada Ltd, now MDS Nordion. Eldorado had been taken over by the Canadian government during the war and the name was changed to Eldorado Mining and Refining (1944) Ltd. The Port Radium mine shut down in 1960 but Eldorado had developed a new uranium mine at Beaverlodge Lake in northern Saskatchewan, which continued in production from 1953 to 1982. At Port Hope, a modern solvent extraction process was started up in 1955 to refine uranium. Eldorado developed a process to produce ceramic-grade uranium dioxide and Port Hope remains the sole Canadian producer of this fuel for CANDU power reactors. In 1966 the company name was changed to Eldorado Nuclear to better reflect its business interests, and in 1970 uranium hexafluoride production commenced at Port Hope. Eldorado also acquired an interest in the Key Lake mine in the late 1970s and purchased the Rabbit Lake mine from Gulf in 1982. In 1983 a new uranium refinery was started up in Blind River, Ontario. Since the merger with Saskatchewan Mining Development Corporation to form Cameco in 1988, many additional uranium projects have been initiated; however, the current study is confined to those employed at the original three sites and support staff.

Original study

In the late 1970s Eldorado began compiling a nominal roll of all past employees. The National Cancer Institute of Canada was contracted to perform a match to the Canadian Mortality Data Base (CMDB) maintained by Statistics Canada. A cut-off date was eventually set at 31 December, 1980. Since the CMDB electronic files with causes of death only extend back to 1950, the match covered 31 years, 1 January, 1950, to 31 December, 1980. Over 20 000 records were in the original match with only about 5% female. Consequently, analysis was confined to the males. Many duplicate records arose because people had worked at more than one site. With elimination of duplicates and the

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further elimination of persons with insufficient information for the study (birth year, specific work dates, etc.), 14 022 males remained in the study [5]. Both mine sites showed a large excess of lung cancer deaths, with Standardized Mortality Ratios (SMR) of 2.7 at Port Radium and 1.8 at Beaverlodge. External causes, chiefly accidents, were also significantly elevated. Interestingly, the Port Hope sub-cohort did not show any unusual patterns and actually had a non-significant deficit of lung cancer.

A study of the lung cancer mortality at Beaverlodge [6] yielded a relative risk coefficient of 3.28% per Working Level Month (WLM)[2], which was amongst the highest risks recorded in any mining studies. Curiously, a separate paper on the Port Radium miners [7] yielded a relative risk coefficient of 0.27 % per WLM, which was amongst the lowest risks recorded in mining studies. This was particularly strange, since Beaverlodge ore was relatively clean with minimal amounts of other carcinogens, whereas Port Radium ore contained many other elements, including large amounts of arsenic and cobalt. Subsequent investigations suggested that the Beaverlodge radiation exposures might have been substantially underestimated [8].

Current study

When the decision was taken to update the Eldorado study, it was decided to repeat the study with the existing cohort, but to add the few new people who were employed by Eldorado at the Beaverlodge site between the cut-off of the original study and the shut-down of the mine on 30 June, 1982. In fact no new individuals were employed at Beaverlodge and, therefore, added to the cohort after 2 December, 1981. Thus, the cohort consisted of people who had been employed by Eldorado on or after 1 January, 1950, with employment records at Port Hope extending back as far as 1930, at Port Radium as far back as April, 1942, and at Beaverlodge as far back as 1948.

Recognising the questions regarding the radiation exposure calculations, radiation exposures at Port Radium and Beaverlodge were re-calculated. When the initial questions arose, SENES Consultants did an extensive study of exposures at both Beaverlodge [9] and Port Radium [10], using all available radon and radon decay product measurements, mine production records and mining contract records to establish arithmetic mean radon decay product concentrations in occupied locations in the mines and mills. Working Level Months were calculated for each person, based on work history records and known hours of work over the years.

In the course of gleaning work history data from the personnel records, many errors were discovered in the electronic files for the original study. Part of the problem appeared to be insufficient quality assurance in the original data coding. Many more duplicate records were discovered, arising from multiple employment periods under variations in a name (full name, name and initials, coding errors, etc.). This was particularly prevalent for aboriginal employees, who may have been employed at one time under an aboriginal name and another time under the English or French equivalent. Also, the search of records collected additional identifying data, which gave greater confidence in the match. In the end, with the addition of new Beaverlodge employees up to 2 December, 1981, and the deletion of duplicates, the nominal roll consisted of 19 855 individuals, of whom 1592 were female. However, after rejecting records that were unsuitable for analysis (missing birth year, no occupational record, missing dose data, etc.), 17 660 subjects remained in the study.

As noted above, radon decay product (RDP) exposures in WLM at the mine sites were calculated from work-place average RDP concentrations and employment times. Initially radon and later radon decay product measurements had been recorded at Port Radium sporadically from 1945 and at Beaverlodge from 1954. At Port Hope there were no early radon or RDP measurements. Estimates were made based on quantities of radium present in the plant in ore and at various stages of refinement, measured radon emanation rates from various radium-bearing materials, building air volumes and estimates of air exchange rates.

For gamma radiation exposures, limited film badge data existed for all sites. At Port Radium, area measurements were made in various work places in the mid to late 1950s. These were used to calculate area average gamma dose rates, which were applied to working hours to yield annual gamma doses for each individual. At Beaverlodge, a sample of employees had worn film badges from the late 1950s, with the number increasing until late in the operation when all employees wore thermoluminescent dosimeters. Again, the sample results were used to calculate dose rates for various jobs and these were used to calculate annual doses for all individuals who had not worn a dosimeter full time. Port Hope had operated its own film dosimetry programme in the late 1940s and early 1950s and later subscribed to the National Dosimetry Service operated by the Radiation Protection Bureau of the federal health department. These records were used to calculate gamma doses for all employees for whom no or incomplete records existed.

It was known that many employees had worked at other operations that may have entailed radiation exposure. To

[1] a One Working Level Month is the exposure to radon decay products equivalent to one working month (170 hours) at a concentration of one Working Level. One Working Level is that concentration of radon decay products in one litre of air that will result in the ultimate release of 1.3×10^5 MeV of alpha particle energy.

collect non-Eldorado dose data, the cohort was matched against the National Dose Registry operated by Radiation Protection Bureau, which contains records from the mid-1950s on [11].

An "alive" follow-up was done by matching the cohort to the Historic Tax Summary File. However, this was only possible for about 60% of the cohort, for whom social insurance numbers employed by the federal income tax department were available. The full cohort was then matched to the CMDB (1950-1980) and to the Canadian Cancer Data Base (1969-1999) [12]. In electronic matching of files, weights are given for each piece of data that matches, e.g., surname, date of birth, place of birth, etc. Records achieving a very high score are deemed to match, records achieving a very low score are deemed not to match, but there is a large grey area between these cut-off points. Manual resolution was used for some 1500 mortality records and somewhat fewer cancer records. By examining the record, a human can often make decisions that are not easily programmed into a computer.

Expected numbers of deaths and cancers were calculated based on the Canadian population, rather than specific regional populations, because workers scattered widely through Canada after they left Eldorado and deaths and cancer cases were similarly scattered. Expected values were adjusted for gender, age (five-year intervals) and calendar year at risk (five-year intervals). Standardized mortality ratios (SMR) and standardized incidence ratios (SIR) were calculated with confidence limits and p-values testing departures of SMR and SIR from 1.0 based on treating the observed numbers of deaths and cases as Poisson variates.

A second series of comparisons was based upon internal comparisons, i.e. with no reference to an external population. These were conducted by using Poisson regression analyses [13]. The relative rate estimated from the latter techniques may be expressed as:

$$\text{Relative Rate} = 1.0 \ (ß\, X) \exp\left(\sum_i \hat{\gamma}_i Z_i\right)$$

where X represents factors such as RDP exposure or gamma ray dose, z_i are potential modifying factors such as time since exposure and ß and $\sum_i$ are coefficients estimated using likelihood techniques. ß is referred to as the excess relative risk (ERR); by adding 1.0 to the ERR one obtains the relative risk at 100 WLM for RDP exposure and per one sievert for gamma ray doses. Regression parameters and p-values were estimated using the method of maximum likelihood using EPICURE software [13].

Risks may be modelled as relative risks, which multiply the background rate, or additive or absolute risks, which add to the background rate. The use in this paper of relative rather than absolute risk measures is based on the following considerations:

- Studies where record linkage has been used to determine outcome are less susceptible to bias in relative rather than absolute measures [14].
- The preferred risk model for RDP exposure and lung cancer chosen by the BEIR VI Committee [15] is a relative risk model and, thus, may be compared directly with the estimates given in this paper.
- Relative risk is probably a more meaningful measure to an individual employed in underground mining, who is interested in knowing whether his risk for a particular disease is increased by 50% or 100% or whatever.

Mortality

Tables 1 to 9 give the SMRs with confidence limits for up to 39 causes of death. These causes were selected because they had adequate numbers for statistical stability (generally n>10). *Tables 1 and 2* give the results for males and females separately and *Tables 3 to 9* show the results for male sub-cohorts: Port Hope, Port Radium, Beaverlodge, other sites (which comprise eastern and western offices, research and development, exploration and radiochemical), underground workers at Port Radium and Beaverlodge, and mill workers at Beaverlodge. Workers were assigned to the site and sub-cohort at which they had spent the longest employment period.

The males in *Table 1* exhibit a non-significant deficit in deaths by all causes and all cancers. Lung cancer is the only cancer with an elevated SMR. Curiously, hypertensive disease is elevated, despite the fact that ischaemic heart disease, stroke and other cardiovascular disease have significantly lower SMRs. Alcohol-related deaths, accidents, suicides and homicides are also elevated. For females in *Table 2*, lung cancer has a non-significant increase but all other specific causes and all causes in total are lower.

In looking at the site sub-cohorts, hypertensive disease is significantly elevated only at Port Hope (*Table 3*) and lung cancer, alcohol-related, accidents, suicides and homicides are significantly elevated only at the mine sites (*Tables 4 and 5*). A more detailed examination was done of Port Hope mortality, including an examination of the death certificates for the hypertensive cases. No autopsies had been performed on any of these individuals. One case was clearly a coding error when the data from the death certificate was entered into the CMDB. In several other cases, hypertension was mentioned among as many as five underlying causes of death, including diabetes. It could reasonably be argued that hypertension was a symptom arising from the underlying cause of diabetes. At least two of the cases could equally well have been coded as stroke, which does appear as a separate cause in the mortality data. In most of the remaining cases there was insufficient information to clearly implicate anything else. However, the net effect of this examination was to reduce the number of

deaths from hypertensive disease by as much as half, eliminating the statistical significance of the elevated SMR.

At Port Radium, the older mine with very high RDP exposures, lung cancers are elevated by 60% relative to the Canadian male population. At Beaverlodge lung cancers are elevated by 30%. Without the excess lung cancers, all cancers are below expectation at both sites. The elevated alcohol-related deaths, accidents, suicides and homicides in the mine sub-cohorts appear to be related to lifestyle and location. It has often been observed that workers in remote northern sites tend to drink more and suffer morale problems that can contribute to suicides and homicides. A brief examination of Canadian crude mortality from a sampling of years in the 1970s, 1980s and 1990s [16], revealed that deaths from external causes represented about three times the fraction of overall deaths in Canada's northern territories than they did in the southern provinces. Similarly, suicides represented 2.5 times and homicides almost six times the fraction of overall deaths in the north, compared with the south.

The males at other sites (*Table 6*) form the smallest sub-cohort with few causes of death with at least 10 observed and all causes below the expected number.

Tables 7 and 8 for the underground sub-cohorts at Port Radium and Beaverlodge reveal that the excess lung cancers at both sites are confined to the underground workers.

Table 9 for the Beaverlodge mill workers shows no elevated causes of death except the external causes, as discussed above. The nephrotoxicity of uranium has been repeatedly documented in animals [17] and the Colorado Plateau study has reported elevated deaths from nephritis and renal sclerosis [18]. If renal disease were to appear in the Eldorado cohort, one would have expected it in the mill workers and the Port Hope workers, who were exposed to relatively concentrated forms of uranium with greater solubility than that found in the ore. No evidence of this was apparent in the Beaverlodge mill workers. In the re-examination of the Port Hope data, a sub-cohort of 2541 uranium workers was identified. This sub-cohort was examined for kidney cancer (6 observed, 5 expected), nephritis and nephrosis (6 observed, 4.5 expected), and other genitourinary disease (7 observed, 9 expected), with no significant excesses.

In the additional Port Hope work, a further sub-cohort of 582 radium workers was identified. These were people who had worked in the plant extracting radium from the ore and in the laboratories purifying and packaging the radium. There were no statistically significant variations of SMR from 1.0. All cancers showed a non-significant SMR of 0.8. Of particular interest, leukaemias and bone cancers, which have been observed in other radium worker cohorts, were less than Statistics Canada's reporting threshold of 5.

Cancer incidence

Table 10 shows the cancer incidence data for the cohort for 1969 to 1999. All cancers except lung cancer are less than expected. The Port Hope incidence data (*Table 11*) has no statistically significant departures of SIR from 1.0. Both Port Radium (*Table 12*) and Beaverlodge (*Table 13*) have a significantly elevated SIR for lung cancer, but most other cancers show decreased SIRs, with many of these decreases being statistically significant. Because of the small numbers in the other sites sub-cohort, no evaluation was possible, except to observe that all cancers were significantly decreased relative to the population. The underground workers at Port Radium (*Table 14*) and at Beaverlodge (*Table 15*) show a similar pattern with only lung cancer being significantly elevated. It is apparent that the excess lung cancers at these two sites are confined to the underground workers.

Analysis

Table 16 shows the distribution of the numbers of lung cancer deaths and person-years at risk through the ranges of RDP exposure expressed as WLM for four male sub-cohorts and for females. The mean exposure (weighted by person-years) is 117 WLM and the maximum is over 4200 WLM. Some cells are blank because Statistics Canada will not allow publication of numbers less than five for privacy reasons.

Table 17 shows the results of fitting a linear excess relative risk model to all males and the three male sub-cohorts. The data were stratified by sub-cohort, age at risk, calendar year at risk and duration of employment (greater or less than six months). Whole body (gamma ray) dose was also considered but addition of this risk term did not improve the fit of the model. With the exception of Port Hope, the relation between RDP exposure and lung cancer mortality is highly statistically significant. The excess relative risk for Port Hope is positive but not statistically significant, but recall also that the lung cancer SMR for Port Hope did not significantly differ from 1.0.

The excess relative risk estimate for Port Radium is 0.37%, compared with 0.27% found in the original study [7]. For Beaverlodge the current estimate is 0.96%, compared with 3.28% in the original study [6] and 3.25% in a later review [19] of the original study. In effect the risk estimates for the two mines have moved closer together and closer to the mid-range of the various mining cohorts that have been studied [20].

Table 18 shows excess relative risks by exposure ranges for all males and for the three site sub-cohorts. The exposure ranges were selected to distribute the cases equally. Again, the associations are highly statistically significant except for Port Hope. An interesting observation on this table is that the lowest exposure range (0.001 to 3.58 WLM) shows a

lower risk than the unexposed group for the entire cohort and two of the three sub-cohorts.

The preferred model of the BEIR VI Committee [15] has effect modification by time since exposure, exposure rate and age at risk. This model was fitted to the present data using the same parameterisation as used by the BEIR VI Committee. *Table 19* shows the results. The fit was significantly improved with the addition of time since exposure in windows of 5-14, 15-24 and 25+ years. Similarly, adding six categories of exposure rate (<0.5, 0.5-1.0, 1.0-3.0, 3.0-5.0, 5.0-15.0 and 15+ WL) gave a further improvement in fit. Finally, the addition of age at risk (<55, 55-64, 65-74 and 75+ years) made a small improvement in fit, which was not statistically significant.

Table 20 shows the parameter estimates for Model 4 of *Table 19*, together with the corresponding estimates from BEIR VI [15]. Given the fact that only 122 lung cancer deaths from the Eldorado cohort contributed to the BEIR VI model, which considered nearly 2700 deaths, the present results could be considered essentially independent of the BEIR VI data set. As can be seen in *Table 20*, most of the parameter estimates from the BEIR VI lie within the confidence intervals of the present study. Thus, this study provides further evidence of the importance of effect modifiers and lends support to the BEIR VI model.

Theses analyses were repeated using the male cancer incidence data from *Tables 10 to 13* with similar results to those from the mortality analysis. The excess relative risk for the male cohort was identical to that from the mortality analysis at 0.55% per WLM. The results for the three site sub-cohorts were similar: Port Hope 0.68 versus 0.18, Port Radium 0.40 versus 0.37 and Beaverlodge 0.70 versus 0.96, again with only the Port Hope result lacking statistical significance. The similarity of results should not be surprising since over 500 cases were included in both data sets. The pattern of relative risks by exposure category for all males and the three site sub-cohorts was similar to that shown in *Table 18*. Again, it was observed that the lowest exposed category exhibited a lower risk than the unexposed category in three of the four sub-cohorts. The parameter estimates for the BEIR VI model showed a similar pattern to those from the mortality analysis, although fewer of the BEIR VI parameter estimates fell within the 95% confidence limits for the current study.

To test whether RDP exposure had any influence on mortality other than lung cancer, the linear excess relative risk model was fitted to the 21 causes of death with at least 50 deaths plus leukaemia, which had only 34 deaths. The only cause that showed a statistically significant positive excess relative risk was non-motor vehicle accidents. However, when this result was adjusted for time of employment, the positive ERR was reduced by a factor of three and the statistical significance disappeared. This analysis was repeated using whole body gamma ray dose instead of RDP exposure with the same result that only non-motor vehicle accidents showed a statistically significant positive ERR. Again, when adjusted for time of employment, this association was substantially reduced and statistical significance was lost.

The simple excess relative risk model for RDP exposure was fitted to the 9 cancers that yielded an incidence of more than 50 cases plus chronic lymphatic leukaemia (22 cases) and all other leukaemias (31 cases). Few of these yielded a positive ERR and none of them was statistically significant. Finally, the simple excess relative risk model was fitted to the same cancer incidence data using whole body gamma ray dose in place of RDP exposure with none of the ERR showing a statistically significant result.

Discussion

In any study of lung cancer, smoking should not be ignored. Unfortunately, no smoking data are available for the Eldorado cohort. The analysis has assumed a multiplicative risk factor in causing lung cancer, which is valid if smoking is not correlated with RDP exposure. A previous case-control study of the Beaverlodge cohort [21] suggested that such correlation was not present, meaning that smoking should not affect the risk estimates made here.

The possible presence of other lung cancer risk factors should also be considered. It is known that the Beaverlodge ore was relatively clean, i.e. lacking other known carcinogens. Port Radium ore, on the other hand, did contain substantial quantities of arsenic and cobalt but no data are available that could be used for any exposure assessment. On the positive side, Port Radium was a very wet mine throughout its operating life, which would have helped minimize dust. Diesel equipment was not used underground at Port Radium. Only limited use was made of diesel equipment in the last few years at Beaverlodge.

The mortality analysis shows that lung cancer is significantly elevated in the whole cohort and several of the sub-cohorts. However, examination of the results indicates that the excess lung cancers are primarily confined to the underground mine workers. The non-significant increase in lung cancers at Port Hope may have arisen from exposures at other work sites. The small female sub-cohort also exhibited a non-significant increase in lung cancer. It is known that about 10% of this sub-cohort worked in jobs with radiation exposure potential, particularly during and after World War II, which could have contributed to this.

For most causes of death the Eldorado cohort and the various sub-cohorts exhibit reduced risks of death relative to the Canadian population, likely representing the healthy worker effect. The notable exceptions to this are the excess

of deaths related to hypertensive disease and various external causes. Investigation of the hypertensive cases suggests that this excess is overstated. The external causes, suicides, homicides and accidents, appear to be related to the remote locations and lifestyle, as well as job-related accidents.

The cancer incidence data for the various sub-cohorts mirrors the mortality data, which is not surprising when it is considered that over 500 cases appear in both data sets.

Fitting a simple excess linear risk model resulted in a highly significant result for the entire male cohort and the Port Radium and Beaverlodge sub-cohorts. The results show an increase in the excess relative risk for Port Radium by about one-third and a decrease in the excess relative risk for Beaverlodge by almost a factor of three, compared with the original study. This moves the risks from these two sites closer together and towards the mid-range of the pooled miner studies. Several factors have contributed to these changes. The additional data extracted from Eldorado files in preparing the cohort should have improved the precision of matches to the Canadian Mortality Data Base. Since the current study involves five times the number of lung cancer deaths seen in the original Port Radium and Beaverlodge studies, the statistical power should be considerably greater than that of the original studies. The re-calculation of the radiation exposures has had a small impact on the Port Radium exposure estimates but has significantly increased the Beaverlodge exposure estimates.

The small reduction in risk for the lowest exposed group when compared with the unexposed group in three of the sub-cohorts may warrant further examination. Similar observations have been made in other data sets and could be a manifestation of radiation hormesis [22]. There could be implications for those engaged in reducing domestic radon exposure.

The application of the BEIR VI model allowing for effect modification for time since exposure, exposure rate and age at risk to the data generally improves the fit, although the improvement for age at risk is not statistically significant. However, the data do indicate a substantial reduction in risk for those aged 75 years or more. The resultant parameter estimates lend support to the BEIR VI model.

No effect of whole body gamma ray dose on the risk of lung cancer mortality was observed.

Repeating the analysis for the cancer incidence data gave similar results to those from the mortality data.

The final analysis examined mortality and cancer incidence for diseases other than lung cancer for possible relationships with RDP exposure and whole body gamma ray dose. The only suggestion of a relationship was for external causes but this was explained by taking account of time of employment in the risk calculations. Time of employment would affect accident risk, but would also correlate with RDP exposure, giving a false relationship of accidents with RDP exposure. In summary, no meaningful evidence was found of any causal relationship between RDP exposure and mortality or cancer incidence other than lung cancer. Similarly, no meaningful evidence was found of any relationship between whole body gamma ray dose and mortality or cancer incidence.

Finally, since about 70% of the Eldorado cohort is still alive, a further follow-up in ten to fifteen years would be well worthwhile.

Acknowledgement

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Table 1 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
All infectious diseases	53	58.6	0.9	0.7	1.2	0.513
Buccal cavity cancer	25	37.7	0.7	0.4	1	0.038
Esophageal cancer	25	37.1	0.7	0.4	1	0.047
Liver cancer	16	16.7	1	0.5	1.6	0.991
Stomach cancer	75	81.7	0.9	0.7	1.2	0.501
Colon cancer	82	134.3	0.6	0.5	0.8	<0.001
Rectal cancer	46	44.7	1	0.8	1.4	0.888
Pancreatic cancer	67	72.5	0.9	0.7	1.2	0.568
Laryngeal cancer	19	21.3	0.9	0.5	1.4	0.713
Lung cancer	618	470.3	1.3	1.2	1.4	<0.001
Skin cancer	17	19.1	0.9	0.5	1.4	0.739
Prostate cancer	98	123.8	0.8	0.6	1	0.019
Kidney cancer	25	35.6	0.7	0.5	1	0.08
Bladder and other urinary cancer	29	39.4	0.7	0.5	1.1	0.106
Brain and other CNS cancer	33	41.6	0.8	0.5	1.1	0.204
Non-Hodgkins lymphoma	42	46.3	0.9	0.7	1.2	0.59
Multiple myeloma	18	22.1	0.8	0.5	1.3	0.45
All leukaemia	34	49	0.7	0.5	1	0.031
Diabetes mellitus	64	97.8	0.7	0.5	0.8	<0.001
All mental disorders	29	66	0.4	0.3	0.6	<0.001
All nervous system diseases	61	92.2	0.7	0.5	0.8	0.001
Hypertensive disease	42	24.5	1.7	1.2	2.3	0.002
Ischaemic heart disease	1235	1508.1	0.8	0.8	0.9	<0.001
Stroke	244	309.4	0.8	0.7	0.9	<0.001
All other cardiovascular disease	317	363.7	0.9	0.8	1	0.014
Chronic obstructive lung disease	79	210.8	0.4	0.3	0.5	<0.001
Pneumonia	134	130.9	1	0.9	1.2	0.809
All digestive diseases	179	222.5	0.8	0.7	0.9	0.003
Alcoholism and related	54	34.8	1.6	1.2	2	0.003
Genitourinary diseases	51	73.1	0.7	0.5	0.9	0.008
Musculoskeletal and connective	11	11.5	1	0.5	1.7	0.999
Motor vehicle accidents	180	139.1	1.3	1.1	1.5	0.001
Suicide	208	122.7	1.7	1.5	1.9	<0.001
Homicide	28	14.7	1.9	1.3	2.7	0.003
Other external causes	365	215.6	1.7	1.5	1.9	<0.001
All cancers	1406	1425.7	1	0.9	1	0.613
All causes	5148	5284.2	1	0.9	1	0.061

Adjusted for age and calendar year at risk.

Table 2 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Females

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
Lung cancer	21	14.4	1.5	0.9	2.2	0.121
Breast cancer	16	17.8	0.9	0.5	1.5	0.777
Ischaemic heart disease	34	44.9	0.8	0.5	1.1	0.112
Stroke	14	18.3	0.8	0.4	1.3	0.381
All other cardiovascular disease	10	17	0.6	0.3	1.1	0.098
All cancers	74	81.4	0.9	0.7	1.1	0.447
All causes	184	234.2	0.8	0.7	0.9	0.001

Adjusted for age and calendar year at risk.

Table 3 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Port Hope

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
Stomach cancer	14	18.4	0.8	0.4	1.3	0.371
Colon cancer	22	26.9	0.8	0.5	1.2	0.404
Rectal cancer	16	9.4	1.7	1	2.8	0.064
Pancreatic cancer	11	14.7	0.7	0.4	1.3	0.411
Lung cancer	101	92	1.1	0.9	1.3	0.376
Prostate cancer	21	25.9	0.8	0.5	1.2	0.388
Bladder and other urinary cancer	11	8.3	1.3	0.7	2.4	0.433
Diabetes mellitus	14	19.5	0.7	0.4	1.2	0.253
All nervous system diseases	12	17.6	0.7	0.4	1.2	0.213
Hypertensive disease	13	4.9	2.7	1.4	4.5	0.003
Ischaemic heart disease	345	324.2	1.1	1	1.2	0.261
Stroke	72	69.3	1	0.8	1.3	0.777
All other cardiovascular disease	85	79.4	1.1	0.9	1.3	0.555
Chronic obstructive lung disease	25	43.4	0.6	0.4	0.9	0.004
Pneumonia	29	26.8	1.1	0.7	1.6	0.715
All digestive diseases	41	43.9	0.9	0.7	1.3	0.735
Genitourinary diseases	19	16	1.2	0.7	1.9	0.518
Motor vehicle accidents	24	23.2	1	0.7	1.5	0.931
Suicide	18	20.2	0.9	0.5	1.4	0.736
Other external causes	28	38.4	0.7	0.5	1.1	0.101
All cancers	272	283.8	1	0.8	1.1	0.505
All causes	1104	1077.5	1	1	1.1	0.427

Adjusted for age and calendar year at risk.

Table 4 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Port Radium

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
All infectious diseases		13	0.8	0.4	1.4	0.563
Stomach cancer	21	27.1	0.8	0.5	1.2	0.277
Colon cancer	27	42.3	0.6	0.4	0.9	0.016
Rectal cancer	14	14.4	1	0.5	1.6	0.999
Pancreatic cancer	24	22.6	1.1	0.7	1.6	0.829
Lung cancer	230	142.7	1.6	1.4	1.8	<0.001
Prostate cancer	35	44.2	0.8	0.6	1.1	0.184
Non-Hodgkins lymphoma	14	13.3	1	0.6	1.8	0.928
Diabetes mellitus	16	31.5	0.5	0.3	0.8	0.004
All nervous system diseases	17	29.8	0.6	0.3	0.9	0.016
Hypertensive disease	14	8.5	1.7	0.9	2.8	0.101
Ischaemic heart disease	395	508.2	0.8	0.7	0.9	<0.001
Stroke	81	111	0.7	0.6	0.9	0.003
All other cardiovascular disease	102	126.5	0.8	0.7	1	0.029
Chronic obstructive lung disease	33	75.1	0.4	0.3	0.6	<0.001
Pneumonia	48	49.3	1	0.7	1.3	0.924
All digestive diseases	45	69.3	0.6	0.5	0.9	0.002
Alcoholism and related	23	9.1	2.5	1.6	3.8	<0.001
Genitourinary diseases	20	26.3	0.8	0.5	1.2	0.25
Motor vehicle accidents	46	32.4	1.4	1	1.9	0.028
Suicide	48	25.7	1.9	1.4	2.5	<0.001
Other external causes	110	58.1	1.9	1.6	2.3	<0.001
All cancers	459	442.4	1	0.9	1.1	0.443
All causes	1616	1700.5	1	0.9	1	0.04

Adjusted for age and calendar year at risk.

Table 5 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Beaverlodge

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
All infectious diseases	30	27.8	1.1	0.7	1.5	0.726
Buccal cavity cancer	12	17.9	0.7	0.3	1.2	0.194
Esophageal cancer	14	17.4	0.8	0.4	1.4	0.501
Stomach cancer	39	33.5	1.2	0.8	1.6	0.382
Colon cancer	31	60.2	0.5	0.3	0.7	<0.001
Rectal cancer	14	19.3	0.7	0.4	1.2	0.27
Pancreatic cancer	29	32.5	0.9	0.6	1.3	0.615
Lung cancer	279	217.8	1.3	1.1	1.4	<0.001
Prostate cancer	38	49.4	0.8	0.5	1.1	0.112
Kidney cancer	16	16.6	1	0.6	1.6	0.999
Bladder and other urinary cancer	11	16.1	0.7	0.3	1.2	0.243
Brain and other CNS cancer	19	20.9	0.9	0.5	1.4	0.78
Non-Hodgkins lymphoma	19	22.3	0.9	0.5	1.3	0.562
Multiple myeloma	12	10	1.2	0.6	2.1	0.611
All leukaemia	22	22.6	1	0.6	1.5	0.999
Diabetes mellitus	32	43.3	0.7	0.5	1	0.092
All mental disorders	16	30.1	0.5	0.3	0.9	0.007
All nervous system diseases	26	41.1	0.6	0.4	0.9	0.016
Hypertensive disease	14	10.2	1.4	0.7	2.3	0.308
Ischaemic heart disease	460	625.1	0.7	0.7	0.8	<0.001
Stroke	86	119.3	0.7	0.6	0.9	0.002
All other cardiovascular disease	121	145.8	0.8	0.7	1	0.04
Chronic obstructive lung disease	20	85	0.2	0.1	0.4	<0.001
Pneumonia	57	50.6	1.1	0.9	1.5	0.402
All digestive diseases	88	101.2	0.9	0.7	1.1	0.204
Alcoholism and related	27	18.1	1.5	1	2.2	0.06
Genitourinary diseases	11	28.4	0.4	0.2	0.7	<0.001
Motor vehicle accidents	105	76.2	1.4	1.1	1.7	0.002
Suicide	139	69.8	2	1.7	2.4	<0.001
Homicide	20	8.7	2.3	1.4	3.5	0.001
Other external causes	219	109.2	2	1.7	2.3	<0.001
All cancers	635	646.1	1	0.9	1.1	0.681
All causes	2289	2311.3	1	1	1	0.653

Adjusted for age and calendar year at risk.

Table 6 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Other sites

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
Ischaemic heart disease	35	50.5	0.7	0.5	1	0.027
All cancers	40	53.4	0.7	0.5	1	0.069
All causes	139	194.9	0.7	0.6	0.8	<0.001

Adjusted for age and calendar year at risk.

Table 7 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Port Radium underground workers

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
Stomach cancer	14	13.8	1	0.6	1.7	0.999
Colon cancer	15	22.1	0.7	0.4	1.1	0.146
Pancreatic cancer	13	11.8	1.1	0.6	1.9	0.81
Lung cancer	159	75.5	2.1	1.8	2.5	<0.001
Prostate cancer	17	23.3	0.7	0.4	1.2	0.223
Diabetes mellitus	10	16.5	0.6	0.3	1.1	0.123
All nervous system diseases	10	16.1	0.6	0.3	1.1	0.148
Ischaemic heart disease	183	263.5	0.7	0.6	0.8	<0.001
Stroke	36	56.2	0.6	0.4	0.9	0.005
All other cardiovascular disease	57	65.2	0.9	0.7	1.1	0.343
Chronic obstructive lung disease	20	40.1	0.5	0.3	0.8	0.001
Pneumonia	24	25.8	0.9	0.6	1.4	0.818
All digestive diseases	19	36.4	0.5	0.3	0.8	0.002
Alcoholism and related	13	4.8	2.7	1.4	4.6	0.003
Genitourinary diseases	12	13.6	0.9	0.5	1.5	0.795
Motor vehicle accidents	24	16.7	1.4	0.9	2.1	0.11
Suicide	27	13.4	2	1.3	2.9	0.001
Other external causes	74	30.6	2.4	1.9	3	<0.001
All cancers	286	232.2	1.2	1.1	1.4	0.001
All causes	896	887	1	0.9	1.1	0.773

Adjusted for age and calendar year at risk.

Table 8 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Beaverlodge underground workers

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
All infectious diseases	11	15.2	0.7	0.4	1.3	0.344
Stomach cancer	21	17.9	1.2	0.7	1.8	0.516
Colon cancer	17	32.8	0.5	0.3	0.8	0.004
Pancreatic cancer	20	17.8	1.1	0.7	1.7	0.66
Lung cancer	198	120.7	1.6	1.4	1.9	<0.001
Prostate cancer	16	25.3	0.6	0.4	1	0.065
Kidney cancer	14	9.2	1.5	0.8	2.6	0.169
Brain and other CNS cancer	10	11.9	0.8	0.4	1.5	0.718
Non-Hodgkins lymphoma	11	12.4	0.9	0.4	1.6	0.825
All leukaemia	14	12.4	1.1	0.6	1.9	0.712
Diabetes mellitus	22	23.3	0.9	0.6	1.4	0.89
All mental disorders	11	16.2	0.7	0.3	1.2	0.231
All nervous system diseases	11	22	0.5	0.2	0.9	0.015
Ischaemic heart disease	271	332.6	0.8	0.7	0.9	0.001
Stroke	40	61	0.7	0.5	0.9	0.006
All other cardiovascular disease	61	76.2	0.8	0.6	1	0.086
Chronic obstructive lung disease	11	43.8	0.3	0.1	0.4	<0.001
Pneumonia	26	25.5	1	0.7	1.5	0.976
All digestive diseases	49	55.8	0.9	0.6	1.2	0.399
Alcoholism and related	15	10.4	1.4	0.8	2.4	0.213
Motor vehicle accidents	63	42.4	1.5	1.1	1.9	0.004
Suicide	84	39.6	2.1	1.7	2.6	<0.001
Homicide	14	5	2.8	1.5	4.7	0.001
Other external causes	148	61.1	2.4	2	2.8	<0.001
All cancers	395	354.1	1.1	1	1.2	0.034
All causes	1348	1244	1.1	1	1.1	0.004

Adjusted for age and calendar year at risk.

Table 9 - Standardized Mortality Ratios (SMR) and 95% confidence interval compared to Canadian mortality rates (1950-1999) for selected causes

Males: Beaverlodge mill workers

Cause	Observed	Expected	SMR	Lower Limit	Upper Limit	p-value
Lung cancer	24	28.1	0.9	0.5	1.3	0.507
Ischaemic heart disease	47	75.4	0.6	0.5	0.8	0.001
Stroke	12	14.1	0.9	0.4	1.5	0.704
Motor vehicle accidents	13	12.8	1	0.5	1.7	0.999
Suicide	22	11.3	1.9	1.2	3	0.006
Other external causes	25	16.4	1.5	1	2.2	0.059
All cancers	68	83.5	0.8	0.6	1	0.094
All causes	247	297.6	0.8	0.7	0.9	0.003

Adjusted for age and calendar year at risk.

Table 10 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males and females

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Buccal cavity cancer	52	112.8	0.5	0.3	0.6	<0.001
Esophageal cancer	28	34.8	0.8	0.5	1.2	0.285
Liver cancer	15	22.5	0.7	0.4	1.1	0.128
Stomach cancer	71	94.9	0.7	0.6	0.9	0.013
Colon cancer	131	230.3	0.6	0.5	0.7	<0.001
Rectal cancer	103	137.8	0.7	0.6	0.9	0.002
Pancreatic cancer	61	70	0.9	0.7	1.1	0.307
Laryngeal cancer	36	54.1	0.7	0.5	0.9	0.012
Lung cancer	688	555.8	1.2	1.1	1.3	<0.001
Malignant melanoma	46	56.2	0.8	0.6	1.1	0.19
Breast cancer	46	58.1	0.8	0.6	1.1	0.121
Prostate cancer	354	501.9	0.7	0.6	0.8	<0.001
Kidney cancer	36	78.5	0.5	0.3	0.6	<0.001
Bladder and other urinary cancer	100	161.2	0.6	0.5	0.8	<0.001
Brain and other CNS cancer	36	46.9	0.8	0.5	1.1	0.12
Non-Hodgkins Lymphoma	85	96	0.9	0.7	1.1	0.283
Multiple myeloma	24	32.5	0.7	0.5	1.1	0.152
Leukaemia	55	70.5	0.8	0.6	1	0.066
All cancers	2210	2651.2	0.8	0.8	0.9	<0.001

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 11 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males: Port Hope

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Stomach cancer	13	17.5	0.7	0.4	1.3	0.344
Colon cancer	34	39.9	0.9	0.6	1.2	0.392
Rectal cancer	23	24	1	0.6	1.4	0.938
Pancreatic cancer	10	12.4	0.8	0.4	1.5	0.61
Laryngeal cancer	11	9.6	1.1	0.6	2.1	0.731
Lung cancer	110	100.3	1.1	0.9	1.3	0.359
Malignant melanoma	11	8.3	1.3	0.7	2.4	0.421
Prostate cancer	91	94.7	1	0.8	1.2	0.753
Bladder and other urinary cancer	27	29.7	0.9	0.6	1.3	0.703
Non-Hodgkins Lymphoma	15	15.4	1	0.5	1.6	0.999
Leukaemia	10	12.2	0.8	0.4	1.5	0.66
All cancers	426	455.3	0.9	0.8	1	0.174

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 12 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males: Port Radium

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Buccal cavity cancer	13	30	0.4	0.2	0.7	0.001
Stomach cancer	19	27.8	0.7	0.4	1.1	0.105
Colon cancer	37	63.5	0.6	0.4	0.8	<0.001
Rectal cancer	23	37.4	0.6	0.4	0.9	0.016
Pancreatic cancer	21	19.7	1.1	0.7	1.6	0.832
Laryngeal cancer	13	14.7	0.9	0.5	1.5	0.794
Lung cancer	204	155.8	1.3	1.1	1.5	<0.001
Prostate cancer	112	154.2	0.7	0.6	0.9	<0.001
Bladder and other urinary cancer	28	47.2	0.6	0.4	0.9	0.004
Non-Hodgkins Lymphoma	21	22.5	0.9	0.6	1.4	0.864
All cancers	596	710.1	0.8	0.8	0.9	<0.001

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 13 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males: Beaverlodge

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Buccal cavity cancer	31	55.6	0.6	0.4	0.8	<0.001
Esophageal cancer	14	16.5	0.8	0.5	1.4	0.643
Stomach cancer	38	42.8	0.9	0.6	1.2	0.517
Colon cancer	50	103	0.5	0.4	0.6	<0.001
Rectal cancer	44	64.5	0.7	0.5	0.9	0.009
Pancreatic cancer	26	31.4	0.8	0.5	1.2	0.381
Lung cancer	337	259.7	1.3	1.2	1.4	<0.001
Malignant melanoma	24	29.5	0.8	0.5	1.2	0.357
Prostate cancer	135	233.7	0.6	0.5	0.7	<0.001
Kidney cancer	23	38.9	0.6	0.4	0.9	0.009
Bladder and other urinary cancer	37	74.4	0.5	0.4	0.7	<0.001
Brain and other CNS cancer	18	24	0.7	0.4	1.2	0.254
Non-Hodgkins Lymphoma	39	47.9	0.8	0.6	1.1	0.22
Multiple myeloma	11	14.8	0.7	0.4	1.3	0.403
Leukaemia	34	33	1	0.7	1.4	0.909
All cancers	973	1212.1	0.8	0.8	0.9	<0.001

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 14 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males: Port Radium underground workers

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Buccal cavity cancer	11	15.8	0.7	0.3	1.2	0.274
Stomach cancer	13	14.7	0.9	0.5	1.5	0.792
Colon cancer	20	33.7	0.6	0.4	0.9	0.016
Rectal cancer	10	19.8	0.5	0.2	0.9	0.025
Pancreatic cancer	13	10.5	1.2	0.7	2.1	0.507
Lung cancer	138	83	1.7	1.4	2	<0.001
Prostate cancer	51	81.8	0.6	0.5	0.8	<0.001
Bladder and other urinary cancer	16	25.1	0.6	0.4	1	0.073
Non-Hodgkins Lymphoma	11	11.8	0.9	0.5	1.7	0.967
All cancers	344	376.3	0.9	0.8	1	0.098

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 15 - Standardized Incidence Ratios (SIR) and for various cancers and 95% confidence interval compared to Canadian incidence rates (1969-1999)

Males: Beaverlodge underground workers

Cause	Observed	Expected	SIR	Lower Limit	Upper Limit	p-value
Buccal cavity cancer	19	31.6	0.6	0.4	0.9	0.022
Stomach cancer	19	23.6	0.8	0.5	1.3	0.401
Colon cancer	31	57.2	0.5	0.4	0.8	<0.001
Rectal cancer	27	36.2	0.7	0.5	1.1	0.137
Pancreatic cancer	19	17.5	1.1	0.7	1.7	0.778
Lung cancer	230	145.8	1.6	1.4	1.8	<0.001
Malignant melanoma	13	17	0.8	0.4	1.3	0.406
Prostate cancer	69	128.6	0.5	0.4	0.7	<0.001
Kidney cancer	17	22.1	0.8	0.4	1.2	0.326
Bladder and other urinary cancer	14	41.2	0.3	0.2	0.6	<0.001
Brain and other CNS cancer	11	13.7	0.8	0.4	1.4	0.563
Non-Hodgkins Lymphoma	22	27.2	0.8	0.5	1.2	0.371
Leukaemia	20	18.4	1.1	0.7	1.7	0.763
All cancers	581	677.8	0.9	0.8	0.9	<0.001

Adjusted for age (five-year intervals) and calendar year at risk (five-year intervals).

Table 16 - Lung cancer deaths and person-years by cumulative exposure (WLM) for sub-cohorts of Eldorado cohort (1950-1999)

Exposure (WLM)

		0.0	0.001-	3.58-	14.83-	53.12-	164.51-	614.38+	Total
Port Hope, Males	Cases	17	33	31	11	7	-	-	101
	Person-years	30 596	28 829	12 625	6 575	3 699	-	-	83 397
Port Radium, Males	Cases	46	7	12	23	28	38	76	230
	Person-years	37 187	9 391	10 782	12 709	13 986	18 207	8960	111 222
Beaverlodge, Males	Cases	41	43	43	53	47	44	8	279
	Person-years	82 183	90 740	46 856	35 771	20 948	8 673	793	285 964
Other Sites, Males	Cases		-	-	-	-	-	-	8
	Person-years		-	-	-	-	-	-	28 160
Females, all facilities	Cases		-	-	-	-	-	-	21
	Person-years		-	-	-	-	-	-	44 865
Total	Cases	123	88	89	87	83	84	85	639
	Person-years	209 470	136 722	73 807	56 985	38 855	27 952	9817	553 608

- indicates cells with potentially < 5 cases

*Table 17 - Excess relative risk estimates for radon decay products (per 100 WLM) for various sub-cohorts of Eldorado cohort (1950-1999)**

	Cases N	Estimate	95% Lower Limit	95% Upper Limit	$X^2(1)$	p-value
Males**	618	0.55	0.37	0.78	130.6	<0.0001
Port Hope, Males	101	0.18	-0.10	1.49	0.29	0.59
Port Radium, Males	230	0.37	0.23	0.59	78.22	<0.0001
Beaverlodge, Males	279	0.96	0.56	1.56	55.42	<0.0001

* All models adjusted for sub-cohort, age at risk (five-year intervals), calendar year at risk (five-year intervals) and duration of employment by less than six months vs greater than six months stratification.

** Including lung cancer cases occurring in the "Other Sites" sub-cohort.

*Table 18 - Relative risks by exposure for various sub-cohorts**

(Males only)

Entire Cohort

Exposure (WLM)	Cases	%	Person Years	%	Relative Risk	Lower Bound	Upper Bound	X^2	DOF	p-value
0	110	17.8	175 143	34.4	1.00			98.05	1	<0.0001
0.001-	83	13.4	130 688	25.7	0.85	0.62	1.17			
3.58-	86	13.9	70 919	13.9	1.30	0.96	1.75			
14.83-	87	14.1	55 349	10.9	1.51	1.12	2.03			
53.12-	83	13.4	38 776	7.6	1.79	1.31	2.43			
164.51-	84	13.6	27 976	5.5	2.50	1.82	3.42			
614.38+	85	13.8	9822	1.9	7.34	5.13	10.53			
Total	618	100.0	508 673	100.0						

Port Hope

Exposure (WLM)	Cases	%	Person Years	%	Relative Risk	Lower Bound	Upper Bound	X^2	DOF	p-value
0	17	16.8	30 565	36.7	1.00			2.75	1	0.0973
0.001-	33	32.7	28 811	34.6	0.76	0.4	1.51			
3.58-	31	30.7	12,638	15.2	1.61	0.84	3.23			
14.83-	11	10.9	6571	7.9	1.30	0.55	3.02			
53.12+	9	8.9	4776	5.7	1.35	0.49	3.54			
Total	101	100.0	83 362	100.0						

Port Radium

Exposure (WLM)	Cases	%	Person Years	%	Relative Risk	Lower Bound	Upper Bound	X^2	DOF	p-value
0	46	20.0	37 158	33.4	1.00			42.38	1	<0.0001
0.001-	7	3.0	9414	8.5	0.72	0.29	1.56			
3.58-	12	5.2	10 802	9.7	0.95	0.47	1.76			
14.83-	23	10.0	12 758	11.5	1.43	0.84	2.37			
53.12-	28	12.2	13 992	12.6	1.38	0.85	2.22			
164.51-	38	16.5	18 221	16.4	1.43	0.91	2.24			
614.38+	76	33.0	8951	8.0	5.35	3.54	8.2			
Total	230	100.0	111 297	100.0						

Beaverlodge

Exposure (WLM)	Cases	%	Person Years	%	Relative Risk	Lower Bound	Upper Bound	X^2	DOF	p-value
0	41	14.7	82 135	28.7	1.00			52.44	1	<0.0001
0.001-	43	15.4	90 674	31.7	1.13	0.73	1.77			
3.58-	43	15.4	46 853	16.4	1.44	0.93	2.24			
14.83-	53	19.0	35 739	12.5	1.82	1.19	2.79			
53.12-	47	16.8	20 957	7.3	2.36	1.5	3.72			
164.51-	44	15.8	8681	3.0	4.62	2.91	7.37			
614.38+	8	2.9	807	0.3	9.19	3.91	19.17			
Total	279	100.0	285 846	100.0						

* Adjusted for cohort, age, years and days worked

Table 19 - Deviances and X2 tests for various interaction models (1950-1999)

Model	Terms	Deviance	X^2	DOF	p-value
1	WLM	3248.18			
2	WLM 5, WLM 15, WLM 25	3233.8	14.37	2	0.0008
3	WLM 5, WLM 15, WLM 25, rate (2), rate (3), rate (4), rate (5), rate (6)	3213.63	20.17	5	0.0012
4	WLM5, WLM 15,WLM 25, rate (2), rate (3), rate (4), rate (5), rate (6), age (2), age (3), age (4)	3206.62	7.01	3	0.0715

WLM = Total WLM (per 100 WLM) lagged by 5 years
WLM 5 = WLM 5-14 years previously (per 100 WLM)
WLM 15 = WLM 15-24 years previously (per 100 WLM)
WLM 25 = WLM 25 years+ previously (per 100 WLM)

Rate (2) = WL 0.5-1.0
Rate (3) = WL 1.0-3.0
Rate (4) = WL 3.0-5.0
Rate (5) = WL 5.0-15.0
Rate (6) = WL 15+

Age (2) = age at risk 55-64
Age (3) = age at risk 65-74
Age (4) = age at risk 75+

Table 20 - Parameter estimates for full interaction model and comparison with BEIR VI model estimates for males in the Eldorado cohort (1950-1999)

Parameter	Estimate	95% Lower Limit	95% Upper Limit	Estimate for BEIR VI
WLM 5	5.23	1.33	14.52	7.68
WLM 15	2.5	0.63	7.05	5.99
WLM 25	1.37	0.36	3.99	3.92
rate(1)	1			1
rate (2)	1.02	0.39	2.67	0.49
rate (3)	0.49	0.2	1.21	0.37
rate (4)	0.35	0.12	1.01	0.32
rate (5)	0.33	0.13	0.84	0.17
rate (6)	0.16	0.06	0.44	0.11
age (1)	1			1
age (2)	1.94	0.77	4.89	0.57
age (3)	1	0.37	2.72	0.29
age (4)	0.05	0	6266.67	0.09

Parameters as specified in footnotes to Table 19

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