

AECL-8183

ATOMIC ENERGY
OF CANADA LIMITED



L'ÉNERGIE ATOMIQUE
DU CANADA LIMITÉE

**UPDATED FOLLOW-UP OF LONG-TERM
CHALK RIVER EMPLOYEES**
**Mise à jour du suivi du personnel employé
à long terme à Chalk River**

M.M. WERNER, D.K. MYERS, and D.P. MORRISON

Chalk River Nuclear Laboratories

Laboratoires nucléaires de Chalk River

Chalk River, Ontario

August 1983 Août

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Résumé

Les données relatives au suivi des employés de Chalk River décédés durant leur emploi ou après leur retraite ont été mises à jour jusqu'au 31 décembre 1982. Ce rapport comprend également la mise à jour des tableaux de mortalité s'appliquant aux employés de l'EACL ayant participé au nettoyage du NRX en 1953 (AECL-7760) et à la décontamination du NRU en 1958 (AECL-7901). On présente des données préliminaires relatives à la mortalité dans deux autres groupes: a) les femmes employées à Chalk River de 1966 à 1982 et b) les hommes employés à Chalk River ayant accumulé durant leur vie professionnelle une dose égale ou supérieure à 0,2 Sv (20 rem). On donne également des données sur différents types de cancers mortels contractés par des hommes employés à long terme à Chalk River: période envisagée 1966-1982. Aucune augmentation significative n'a été révélée par les statistiques en ce qui concerne les décès dus au cancer dans les groupes analysés.

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Abstract

Data on the follow-up of CRNL employees who died during employment or after retirement have been updated to 1982 December 31. Updated tables on mortality for AECL participants in the 1953 NRX clean-up (AECL-7760) and in the 1958 NRU decontamination (AECL-7901) are also included in this report. Preliminary mortality data on two other groups are presented here for (a) female employees of CRNL, 1966-1982 and (b) male employees of CRNL who have accumulated lifetime occupational doses of 0.2 Sv (20 rem) or more. Data on types of fatal cancer recorded for long-term male CRNL employees over the period 1966-1982 are also given. No statistically significant increases in cancer deaths were found in any of the groups analysed.

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1. INTRODUCTION

This report presents an update to 1982 December 31 of the follow-up of employees of the Chalk River Nuclear Laboratories (CRNL). A preliminary report on this study up to 1980 was given in 1982 and, for the convenience of the reader, this earlier report (1) is included as Appendix A in the present document. Two other reports (2,3) dealt with the follow-up of Atomic Energy of Canada Limited (AECL) staff who participated in clean-up activities following the reactor accidents in December 1952 and in May 1958. These studies are also updated to 1982 December 31 in the present document. Details of exposures and methods of analysis are given in the earlier reports (1-3) and will not be repeated here.

Two new items included in the present document are (a) the results of a follow-up of females employees, 1966-1982 and (b) the follow-up of male employees who have accumulated lifetime occupational doses of 0.2 Sv or more. Types of fatal cancer observed in the years 1966-1982 will also be discussed.

2. METHODS

The methods of analysis were the same as those given in Appendix A and other publications (2,3). The observed number of deaths in each age category is compared with the number that would be expected on the basis of vital statistics for persons of the same age and sex in the general population of the province of Ontario. Information on causes of death of CRNL employees and retirees during 1981 and 1982 was obtained from death certificates provided by the offices of the Registrar-General of each of the appropriate provinces in Canada. The cause of death is recorded by ICD (International Classification of Diseases) code number; as in Appendix A, the code numbers used in this report are corrected to conform to those of the 8th revision of the ICDA code (4).

3. RESULTS

3.1 Mortality among CRNL current and retired employees

The mortality patterns among CRNL male employees (excluding summer students) during the years 1966-1982, classified into major categories of cause of death are given in Table 1. To calculate expected numbers of deaths each person, either employed at Chalk River or listed as retired on 1 April of each year, contributes one person - year at risk. The comparison group is the general population of Ontario corrected for age and sex. Ontario vital statistics data were available only to 1980 (5). Expected figures for 1981-1982 deaths are based, therefore, on the vital statistics for 1976-1980. The additional 64 deaths among males for the years 1981-1982 have not changed greatly the overall mortality patterns. However, additional cancer deaths brought the standard mortality ratio (SMR) for cancer deaths in male employees up to 0.96 for the period 1966-1982 (Table 1). The 95 percent confidence limits on this value, as calculated by standard statistical methods (6), indicate that the SMR for cancer deaths is not significantly different from 1.0. A possible excess of cardiovascular deaths that appeared in the years 1976-1980 (1) did not continue in the data for 1981-1982.

Table 1

Mortality of male CRNL employees who
died during employment or after retirement
1966 - 1982

Cause of death	Observed	Expected	SMR*
Cancer	94	98.2	0.96 (0.78-1.18)
Cardiovascular diseases	201	217.1	0.93 (0.81-1.07)
Accidents and other external causes	25	40.3	0.62** (0.40-0.91)
All other causes	51	70.9	0.72** (0.54-0.96)
All causes	371	426.5	0.87** (0.78-0.97)

* SMR is the standard mortality ratio, i.e., the ratio of observed to expected numbers of deaths. The range given in brackets represents the 95 percent confidence limits on the SMR value.

** Value is significantly lower than 1.0 as judged by the 95 percent confidence limits.

The types of cancer causing death among male employees are shown in Table 2. While the numbers are too small for detailed analysis as indicated by the confidence intervals, some general observations can be made. As expected, lung cancer was responsible for 30 percent of the cancer deaths in males. Cancers of the lymphatic and haematopoietic system, a group of cancers which, in some studies (7-11) have been associated with radiation exposure accounted for 6 deaths where 8.65 were expected (Table 2). The 15 observed cancer deaths from 'other and unspecified sites' in Table 2 include 7 cancers of unspecified locations, 2 brain cancers, 1 each of thyroid, bile ducts, testes, kidney, bladder and a soft tissue sarcoma. There is no statistically significant increase in cancer deaths in any of the categories.

Causes of death among female employees of CRNL are shown in Table 3. There have been 21 deaths among females in the years 1966-1982, while 16.2 deaths were expected. Eleven of the 21 deaths were among women who were employed by AECL in Deep River and who had no occupational exposure to radiation. The remaining ten had a collective lifetime accumulated dose of under 0.05 Sv. The excess deaths were mainly in the cardiovascular diseases category. However, none of the observed values are significantly different from those expected.

3.2 Follow-up of AECL clean-up participants

The two follow-up studies (2,3) which are being carried out on the AECL staff who participated in clean-up activities after the reactor accidents in 1952 and 1958 are cohort studies. The cohort is defined as that group of employees who worked specifically in each clean-up. Person-years at risk were calculated from the year of the clean-up operations in both cases. Those members of the cohort who left AECL before retirement to work elsewhere are not readily traceable by the methods used in these studies. The data presented in this report are, therefore, limited to those members of the cohort who are currently employed with AECL, who have retired from AECL, or who died during employment or after retirement. As there were few overexposures in the cohorts and the total collective dose accumulated in the clean-ups was low, no unusual patterns in mortality would be anticipated due to any whole body radiation exposures received during the clean-up operations. This prediction was confirmed by the observed data.

Table 2
Types of cancer causing death among male CRNL
employees and retirees
1966 - 1982

Type of cancer	Observed	Expected	SMR
Buccal cavity & pharynx	3	3.03	0.99 (0.20-2.89)
Oesophagus	1	2.59	0.39 (0.01-2.17)
Stomach	5	6.76	0.74 (0.24-1.73)
Intestines	7	9.40	0.74 (0.30-1.52)
Rectum	6	4.16	1.44 (0.53-3.14)
Larynx	0	1.59	--
Lung	32	31.97	1.00 (0.70-1.43)
Bone	0	0.39	--
Skin	1	1.38	0.72 (0.02-4.00)
Breast	1	0.14	7.04 (0.18-39.10)
Prostate	9	5.82	1.54 (0.71-2.93)
Pancreas*	8	5.79	1.38 (0.59-2.72)
Lymph & blood forming systems*			
Leukemia	1	3.46	0.29 (0.01-1.61)
Multiple myeloma	0	1.27	--
Other (lymphoma, etc)	5	3.91	1.28 (0.41-2.99)
Other & unspecified site	15	15.99	0.94 (0.52-1.55)
Benign & unspecified nature	0	0.66	--
TOTAL	94	98.2	0.96 (0.78-1.18)

*Expected figures based on Canadian data.

Table 3

Mortality of female CRNL employees who died during employment or after retirement 1966 - 1982

Cause of death	Observed	Expected	SMR
Cancer	6	5.27	1.14 (0.42-2.48)
Cardiovascular diseases	9	6.40	1.41 (0.65-2.67)
Accidents and other external causes	2	1.58	1.27 (0.15-4.55)
All other causes	4	2.96	1.35 (0.37-3.45)
All causes	21	16.21	1.29 (0.80-1.97)

Tables 4 and 5 give the updated figures to 1982 December 31 for the two cohorts of clean-up participants. There are few changes in the overall mortality patterns (2,3) with the addition of two years' data.

Table 4

Mortality among 562 AECL participants in the NRX clean-up 1952 December to 1954 February

Cause of death	Observed	Expected	SMR
Cancer	35	38.96	0.90 (0.62-1.25)
Cardiovascular diseases	96	91.83	1.04 (0.85-1.28)
Accidents and other external causes	12	15.36	0.78 (0.40-1.36)
All other causes	19	29.00	0.65 (0.39-1.02)
All causes	162	175.15	0.92 (0.79-1.08)

Table 5

Mortality among 537 AECL participants
in the 1958 NRU clean-up

Cause of death	Observed	Expected	SMR
Cancer	31	27.67	1.12 (0.78-1.56)
Cardiovascular diseases	62	61.01	1.02 (0.79-1.32)
Accidents and other external causes	9	12.21	0.74 (0.34-1.40)
All other causes	19	20.00	0.95 (0.57-1.48)
All causes	121	120.89	1.00 (0.83-1.20)

3.3 Follow-up of CRNL employees with 0.2 Sv or more occupational radiation dose

Causes of death in the group of CRNL employees who have recorded lifetime occupational doses of 0.2 Sv (20 rem) or more were examined. All the employees in this group were male. Recorded lifetime doses have not been extrapolated for those persons who were employed prior to 1956 February when most dose records were destroyed in a fire. The dose records do include, however, any high doses acquired during the 1953 NRX clean-up; these latter records were traced through internal CRNL memoranda (2). To the end of 1982, 413 long-term traceable CRNL employees and retired employees had accumulated 0.2 Sv or more. The average lifetime occupational dose for this group was about 0.42 Sv (42 rem). The average date at which these 413 persons commenced employment at CRNL was 1956, and their average length of employment was 23.5 years. An additional 23 men in the same category left AECL for other employment. We have anecdotal evidence, usually based on someone's personal knowledge of the individual in question, that 21 of these men are alive and two have died. However, this group of 23 individuals was not included in our present calculations. For the calculation of expected numbers of deaths from vital statistics for Ontario, person-years at risk were calculated from the date that each individual in this group was hired at CRNL. Table 6 gives the causes of death for the 64 members of this cohort of 413 males who have died. There was no excess of cancer deaths in this group taken as a whole (Table 6), even though worker's compensation was awarded for one of these cancer deaths on the basis that occupational exposure may have contributed to the occurrence of this particular cancer (12). An apparent slight excess of cardiovascular fatalities (heart attacks, strokes, etc) in this group was not statistically significant (Table 6).

Table 6

Mortality among 413 CRNL employees
with lifetime occupational doses to
1982 December of 0.2 Sv* or more

Cause of death	Observed	Expected	SMR
Cancer	12	17.58	0.68 (0.35-1.19)
Cardiovascular diseases	41**	36.86	1.11 (0.81-1.52)
Accidents and other external causes	4	9.97	0.40 (0.11-1.02)
All other causes	7	12.78	0.56 (0.22-1.15)
All causes	64	77.20	0.83 (0.65-1.06)

* Lifetime doses were taken to be those given on official AECL records. No corrections were made for potential underestimation or overestimation of doses recorded prior to 1964 (Appendix G in reference 13).

** One death certificate from this group has not been received. The available evidence indicates that death was due to cardiovascular disease, and it was included as such in the calculations.

4. DISCUSSION

The follow-up data continue to show that the mortality patterns of long-term CRNL employees, including retired personnel, are approximately the same as those expected on the basis of age and sex-specific vital statistics for the general population of Ontario. Average death rates from various causes in Renfrew County do not differ significantly from Canadian averages (13). No statistically significant increase in cancer mortality was observed in any of the analyses that were carried out on long-term CRNL employees (Table 1-6).

The average annual cumulative occupational exposure of all CRNL employees over the past 20 years since 1962 has been approximately 11 Sv (Appendix G in reference 14). On the basis of currently accepted international risk estimates (15), this cumulative exposure might be expected to cause one cancer fatality every nine years or roughly two in the 17 years of detailed follow-up represented by the data in Table 1. This hypothetical number would be slightly reduced by the fact that some employees leave AECL for other employment and are, therefore, not included in the present study; data on personnel who have left AECL will be included in the larger AECL Health Study (14) which is currently in progress. However, this factor should not have a major impact on the results. According to data provided by Dr. R.M. Holford, Health Physics Branch, CRNL, the cumulative annual exposure of all CRNL employees over the last 5 years and the total lifetime recorded doses of persons retiring from CRNL in the last 5 years are as follows:

Years	Cumulative dose for all CRNL employees 1978-1982	Total lifetime dose for all employees retiring 1978-1982
1978-1982	54.77 Sv	37.19 Sv

It would thus appear that about 70 percent of the cumulative doses received by all CRNL employees are retained within the group of retired employees who are included in the present analysis. This suggestion is supported by the fact noted above that 95 percent or 413 out of the 436 past and current employees with recorded lifetime doses of 0.2 Sv or more were in fact long-term employees who remained with CRNL. One can, therefore, conclude (a) that the absence of excess cancer deaths in the present analysis does not conflict with the currently accepted risk estimates and (b) that the absence of excess cancer deaths in this study provides some reason to believe that these risk estimates (15) cannot be too low by as much as an order of magnitude.

The absence of a significant excess of cancer mortality in Tables 1, 2, 3 and 6 also does not conflict with the theory (16,17) behind the concept of awarding workers' compensation in certain individual cases where it is believed that the employee's long-term occupational exposure to radiation or other agents may have caused or contributed to development of this disease in a particular case (12). Because the numbers involved in the above analysis are small, the 95 percent confidence limits on the standard mortality ratios are frequently large (Tables 1-6). One cannot exclude the possibility that one or

two cancer deaths in the total number observed might be attributable in part to occupational exposure. The data do, however, provide some reassurance that large numbers of cancer deaths which might be related to occupational radiation exposure do not exist in the groups of CRNL employees studied to the end of 1982.

It should be understood that the time between radiation exposure and the appearance of an overt cancer may be 2-25 years in the case of leukemia and 20-30 years or more for solid tumours (7,18). Continued observation of long-term CRNL employees is therefore required in order to be confident that conclusions based on data available to the end of 1982 are well-founded.

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APPENDIX A

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FOLLOW-UP OF PAST EMPLOYEES OF THE CHALK RIVER
NUCLEAR LABORATORIES

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ABSTRACT

Data on 307 CRNL male employees who died before or after retirement during the period 1966-1980 were examined. The standard mortality ratios for deaths from cancer, cardiovascular diseases, accidents and all other causes were 0.85, 0.94, 0.63 and 0.70, respectively, with an average standard mortality ratio of 0.85 for deaths from all causes.

1. INTRODUCTION

An empirical method to determine the effectiveness of measures taken to protect workers against occupational health hazards is provided by a follow-up of the health of past employees. Previous studies of the mortality of employees in various nuclear facilities have indicated that these employees were healthier than persons of the same age and sex in the general population (1-4). A similar study is proceeding at Atomic Energy of Canada Limited (AECL) (5). A preliminary report is now presented on one portion of this study, namely, on deaths during employment and after retirement of employees at the Chalk River Nuclear Laboratories (CRNL).

2. STUDY GROUP

The total number of AECL employees currently exceeds 7360. Of this total, about 2300 are employed at CRNL (5). The Chalk River laboratories started operations in 1945, while other AECL sites were established more recently. Most of the collective occupational radiation exposure of AECL employees occurs at the

CRNL site (Table 1), where all employees are classified as radiation workers. Dosimetry practices and radiation exposure records have been described in detail elsewhere (6,7). Most of the exposure records at CRNL prior to 1956 were lost when a building was destroyed by fire in February of that year; thus the cumulative lifetime exposures described are largely restricted to the period 1956-80. The average annual occupational dose for CRNL employees is about 5 mSv (8) and the average lifetime dose for current employees is about 68 mSv, most of which can be attributed to external γ -radiation (Table 1). At the end of 1980, the recorded lifetime occupational doses of current CRNL employees were distributed as follows: 41% of employees 0-9.99 mSv, 40% 10-99.9 mSv and the remainder between 100 and 1000 mSv.

Table 1. Collective lifetime occupational exposures of all AECL employees on 1980 December 31

Site	Collective lifetime dose in Sv*		
	External gamma	Tritiated water	Neutrons
CRNL	146.6	9.0	0.007
Other AECL sites	32.0	0.1	0.003

(*1 Sv = 100 rem. Values given represent whole body doses.)

Non-occupational radiation exposures received by CRNL employees are unknown. However, it is expected that on average by age 50 employees will have received an additional 100 mSv from natural background and medical diagnosis, plus an appreciable lung dose resulting from the inhalation of radon daughters from non-occupational sources.

The age distribution of CRNL employees is shown in Fig.1. The number of employees in each 5-year age category between ages 25 and 60 is fairly uniform, with no marked shift in the age distribution between 1973 and 1980. The total number of employees in each year prior to 1973 was known but the age distribution by 5-year increments was not known (although the age distribution by 10-year increments was available for 1971); for the years 1966 to 1972, it was assumed to be similar to that in 1973-75. The errors introduced by this assumption are believed to be relatively small. The age distribution of retired employees (Fig.2) could be calculated for each year since 1966 from the computer listings of all pensioned retired employees. The basic study group thus consisted of all employees in service (Fig.1) plus retired employees (Fig.2) over the years 1966-80. For convenience and to see if any trends in mortality were apparent, the data were sub-divided into three groups covering the years 1966-70, 1971-75 and 1976-80 respectively.

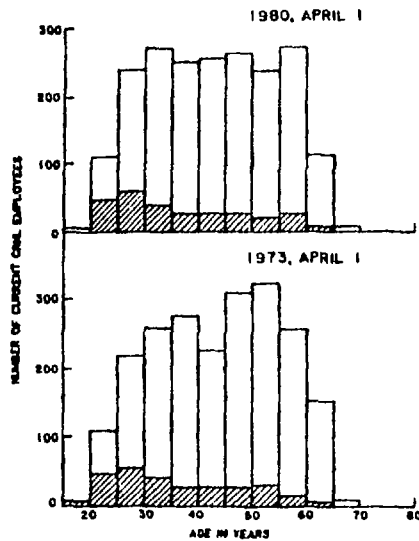


Fig.1. Age distribution of CRNL employees as of April 1, 1973 and 1980. The total height of the open rectangles indicates numbers of male employees in each age group while the hatched rectangles represent female employees.

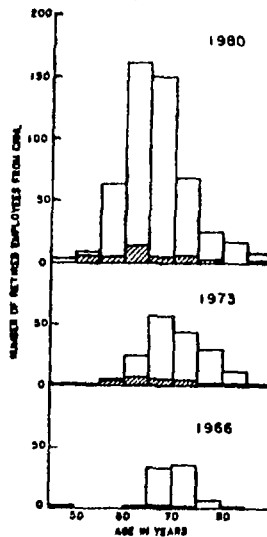


Fig.2. Age distribution of living retired employees from CRNL as of April 1, 1966, 1973 and 1980. Males and females indicated as in Fig.1. The rectangles that are nominally indicated as age 85-90 actually represent all past employees who were 85+ years of age, a grouping corresponding to that in the vital statistics for Ontario.

The present report does not include a follow-up of the large number of past employees who terminated employment at CRNL for reasons other than retirement, e.g., persons who moved to take up a position with another employer (including other AECL sites). Information on this group of past employees is being collected and will be analysed as part of the continuing study of all AECL employees (5).

3. MORTALITY DATA

Most of the information on date of death was derived from computer records that included all deaths occurring during employment at CRNL since 1945, and all known deaths of employees who retired from CRNL on a federal pension plan since 1945. These combined records disclosed 465 deaths, of which 307 had occurred during the period 1966-80. A manual search of all personnel files on past CRNL employees led to the identification of a few more deaths, none of which affected the data for 1966-80. One recorded death occurring within three months after termination of employment was arbitrarily included in the category of deaths during employment since 1966. The observed fatalities for 1945-80 listed in Table 2 included two caused by industrial non-radiation accidents prior to 1966.

Causes of death were determined by a manual search of death records at Statistics Canada (9) and at the Office of the Registrar-General for the province of Ontario. Data from Statistics Canada were made available in tabular form. The results, which are summarised in Table 2, are thought to be complete for the 1966-80 deaths, though minor revisions of the data in future cannot be ruled out. Six presumed deaths prior to 1966 could not be confirmed from the Mortality Data Base at Statistics Canada. These are included in the category of (unconfirmed) deaths due to unknown cause in Table 2.

In all cases, the cause of death was taken to be that recorded by ICD code number on the Mortality Data Base (9) or the death certificate. These code numbers were corrected to conform with the categories given in the 8th revision of the ICDA code (10). This revision was used for reporting of vital statistics in Canada over the years 1969-78.

Most of the deaths of past CRNL employees occurred in the province of Ontario. Values for expected numbers of deaths from 1966 Jan. 1 to 1980 Dec. 31 were therefore derived from the vital statistics available for 1966-78 for the province of Ontario (11). To calculate the expected number of deaths for past CRNL employees in any given year, the number of employees in each 5-year age category during that year was multiplied by the fraction of Ontario residents of the same age and sex who died during that same year. Since the exact age distribution of past CRNL employees was not known precisely for the years

Number of deaths 1945-80		Number of deaths among males who died in service or after retirement			
Male	Female	1966-70	1971-75	1976-80	Total 1966-80
		Obs/Exp	Obs/Exp	Obs/Exp	Obs/Exp
All cancers (ICDA 140-239)					
93	7	21/22.1	19/26.2	30/33.7	70/82.0
Cardiovascular diseases (ICDA 390-458)					
248	6	46/54.1	46/59.0	81/70.7	173/183.8
Accidents (ICDA 800-999)					
43	1	7/11.9	8/11.8	7/11.5	22/35.2
Other causes (ICDA 000-136, 240-389, 460-796)					
63	4	6/16.8	16/19.9	20/23.0	42/59.7
Unknown cause					
5	1	-	-	-	-
Total					
452	19	80/104.9	89/116.9	138/138.9	307/360.8

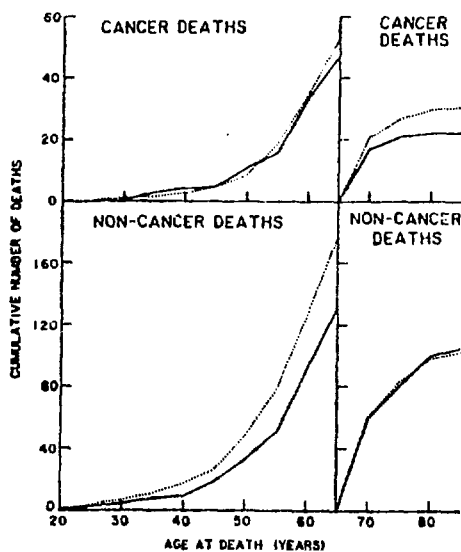


Fig.3. Accumulated number of deaths of male employees who died in service or after retirement in the years 1966-80 inclusive. The dotted line represents expected number of deaths by age while the solid line represents the observed number. In order to facilitate comparisons of early and late mortality, deaths were accumulated over two broad age categories, i.e., those occurring before and after the 65th birthday. Data are shown for (a) cancer deaths and (b) non-cancer deaths.

1966-70, the expected numbers of deaths during this period will be less certain than those for the years 1971-80. The vital statistics on causes of death, and therefore the expected numbers of deaths from various causes (Table 2), are again dependent on the cause of death that is recorded on the death certificate.

Data on all known deaths of past CRNL employees over the period 1945-80 are included in Table 2; 21.5% of all confirmed deaths were due to cancer, a proportion similar to that found provincially and nationally for persons over age 18. Since the total number of deaths of females is too small to yield significant results and since data from the earlier years appear to be less certain, we have concentrated the analysis of standard mortality ratios (i.e. ratio of observed to expected numbers of deaths) on the 307 deaths occurring during the period 1966-80 among males who died in service or after retirement (Table 2). In this group, the standard mortality ratios by four broad categories of causes of death were as follows: cancer 0.85, cardiovascular diseases 0.94, accidents 0.63, and all other causes 0.70. Fig.3 summarises the observed and expected numbers of deaths by age at death for this same group. There was no evidence of excess cancer mortality in old age that might be attributed to delayed effects of occupational exposures.

Preliminary data on observed and expected numbers of deaths from various types of cancer were also tabulated. Because the numbers are small, it would be premature to discuss in detail apparent small differences in the observed and expected values. As expected, the major cause of cancer mortality among males was lung cancer (23 cases observed, 26.5 expected for 1966-80). The preliminary data that are currently available for 1966-80 suggest that the observed/expected numbers of deaths due to pancreatic cancer (ICDA 157), multiple myeloma (ICDA 203) and leukemia (ICDA 204-207) were 7/4.85, 0/1.07, and 0/2.89, respectively. However, as in any study of this kind, the question of the accuracy of the cause of death as recorded on the death certificate is a major problem which remains to be resolved.

4. DISCUSSION

The proportion of deaths from various causes appears to be reasonably consistent in each of the 5-year periods between 1966 and 1980 (Table 2) with one exception: an excess number of deaths from cardiovascular diseases amongst past CRNL employees was observed during 1976-80. All of this excess occurred among males who were over age 65 at death. The reason for this unusual result is not known; although mortality from cardiovascular diseases in the local district (Renfrew County) around CRNL is slightly higher than the average for all of Canada, this latter difference is not statistically significant (12). The apparent excess of cardiovascular deaths among past

CRNL employees in 1976-80 was not observed in 1966-75 (Table 2) and it remains to be seen whether this result will be confirmed in future extensions of the present study.

The total number of deaths among past male employees during the period 1966-80 is about 0.85 times that expected for males of the same age in the general population (Table 2). When total deaths are examined on the basis of age (Fig.3), the ratio of observed to expected deaths proved to be 0.78 for (male) employees under age 65 and 0.96 for past employees over age 65. These data are consistent with the existence of a healthy worker effect among CRNL employees.

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