Health Canada Santé Canada

2000 Report on Occupational Radiation Exposures in Canada

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Part 1 of 3

Canada

2000 Report on Occupational Radiation Exposures in Canada

Safe Environments Programme
Healthy Environments and
Consumer Safety Branch

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Abstract

The report provides statistics on occupational radiation exposures for use by regulatory authorities, organizations and private individuals. Out of a total of 125,880 monitored workers, 6 annual doses exceeded the regulatory limit of 50 mSv in 1999. Out of 57 specified job categories, 30 had a smaller annual average in 1999 than in 1998, 14 had a higher average, and 13 had the same average rounded to 0.01 mSv. A new job category was added in 1999 entitled “Tradesman” and therefore a comparison of the averages is not possible at this time. In all categories of workers, from 1997 to 1998, 20 average annual doses went up, 25 went down, and 11 had the same average rounded to 0.01 mSv. The figures reflect a sustained effort in keeping the occupational doses low.

Acknowledgements

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Introduction

This series of reports provides statistics on occupational radiation exposures of monitored workers in Canada. The statistics are intended to assist regulatory authorities, organizations, and private individuals in comparing incurred occupational radiation exposures with national or provincial/territorial averages and trends in similar occupations. Previous issues of the report can be obtained from the authors[1-5].

The information is based on the data in the National Dose Registry (NDR) maintained by the Radiation Protection Bureau of Health Canada[6]. The Registry is a centralized record-keeping system containing dose information on all monitored workers in Canada. It includes records from the National Dosimetry Services (NDS), as well as data submitted by nuclear power generating stations, Atomic Energy of Canada Ltd., uranium mines, and private dosimeter processing companies. About 80 percent of the records are from the NDS.

Information for input into the NDR is received in a number of different physical forms. Data from the NDS are fed directly from the dosimeter reading stations into a computer, where they are processed, reported and entered into the NDR files. Most other dose records are submitted to the Registry in computer readable form.

The report provides data on the two consecutive years prior to the year in which the data are extracted from the database. The data for the second (i.e. more recent) year will be close to stable at the time of data extraction. Some changes may still occur, for which the most frequent causes are: (1) a high dose to a dosimeter is judged to be non-personal after investigation; (2) a job category of a worker is updated; or, (3) dosimeters or data are returned late. The report therefore contains preliminary data on the second year, and more complete data on the first year.

For a description and a guide to interpretation of the data, the reader is referred to the next section “General comments”. The section “Comments specific to this report” has been included to address situations that do not reoccur from year to year.

General Comments

The statistics include doses as they exist in the database at the time they are extracted for analysis, which in the case of this report is 25 July 2000. All NDS doses are assigned to the year in which the dosimeter was issued, even though some of the dosimeters may actually have been worn during part of the subsequent year. As the statistics are determined in the same manner each year, the annual dose figures are based on a 12-month period, though not necessarily the strict calendar year.

Dose records submitted by outside organizations such as nuclear power generating stations, uranium mines, and commercial processors, are included to the extent that they have been received. The doses are representative of the calendar year only if the fourth quarter records have been received by the time of analysis. When statistics are based on partial data, the fact is indicated in the section “Comments specific to this report”.

All doses are in International System (SI) units and presented to the nearest hundredth of a millisievert (1 mSv = 100 mrem). For the external whole body doses recorded by the NDS there is a minimum reporting level of 0.2 mSv. Organizations submitting their own doses may have lower reporting levels.

The words “dose” and “exposure” are used interchangeably in this report. Doses of different types of radiation are expressed in mSv and added to give the effective dose stated in the report. The following dose types may be included:

- External whole body gamma.
- External whole body high energy beta.
- External whole body X-ray.
- External whole body neutron.
- Internal whole body tritium, as determined by urinalysis.
- Radon progeny exposures, converted from WLM values (see below).

All types of exposure are given in one total. In Tables 3 and 4, the percentage contribution of radon progeny and tritium components are indicated for occupations related to mining and nuclear power generation, respectively. Skin doses and extremity doses are not included in the report but are recorded in the database.

In the NDR database, radon progeny exposures are expressed in Working Level Months (WLM), which are in most cases calculated by the mines on the basis of area monitoring[7]. In the report the radon progeny exposures are converted to equivalent doses (in mSv). The value used in this report is 5 mSv/WLM, in accordance with the new CNSC regulations[8], which came into force on May 31, 2000.

Job category designations are based on a standard list provided by the Registry and are updated when the Registry is notified. The job category is selected by the organization from a standard list maintained by the NDR. The NDR keeps the most recent job category that an organization submits for a worker in a given year. However, a worker can have records under more than one job category for the same year, if he has been monitored by more than one organization. Some organizations have their own job classifications schemes, and translate them into the Registry's standardized list prior to submission of the records.

In this report, the data are tabulated as follows:

1999: Preliminary analysis

Table 1:

Table 1 gives the annual doses distributions by job category.

1998: Final Analysis

Table 2:

In Table 2, statistics are broken down by job category and province or territory.

Table 3:

Table 3 contains dose distributions broken down by age and sex. In these tables job categories have been grouped into "job sectors".

Table 4:

Table 4 contains various dose statistics broken down by job category. The table also shows the parameters of the lognormal or hybrid lognormal distribution for positive doses, as produced by maximum likelihood estimation. From that information, it is possible to calculate estimates and confidence intervals of statistics of the distribution. For a more detailed discussion the reader is referred to the Appendix.

Table 4 also includes an accumulated dose distribution over the 5 year period 1994-1998 for the workers under the given job category.

Finally, Table 4 contains a histogram that shows the trend in average annual doses over the period 1989-1998.

It should be noted that in the tables, a worker is counted more than once if he (she) works in more than one job category, in more than one province, or in more than on job sector in the same year. For this reason the totals in Tables 2-4 may slightly differ.

Comments specific to this report

Job category information is not provided by all dosimetry companies. In the two previous reports, such unreported job categories in the 1996-1998 data were inferred from earlier information on the same worker. Starting with the 1999 data, these job categories will no longer be inferred, in view of the ever increasing likelihood of job changes. This is expected to be a temporary problem which will disappear when the new regulations[8] are fully implemented.

At the time of extracting the data, we had not received full sets of exposure data for 1999 for all mine sites. This affects some of the statistics in Table 1. This problem will have been corrected in final analysis for 1999 in the next report.

References

1. Sont, W.N. and Ashmore, J.P., “1999 Report on Occupational Radiation Exposures in Canada”, Environmental Health Directorate publication 99-EHD-239, Health Canada.

2. Sont, W.N. and Ashmore, J.P., “1998 Report on Occupational Radiation Exposures in Canada”, Environmental Health Directorate publication 98-EHD-223, Health Canada.

3. Sont, W.N. and Ashmore, J.P., “1997 Report on Occupational Radiation Exposures in Canada”, Environmental Health Directorate publication 97-EHD-213, Health Canada.

4. Sont, W.N. and Ashmore, J.P., “1996 Report on Occupation Radiation Exposures in Canada”, Environmental Health Directorate publication 97-EHD-210, Health Canada.

5. Sont, W.N. and Ashmore, J.P., “Occupational radiation exposures in Canada - 1994", Environmental Health Directorate publication 95-EHD-195, Health Canada.

6. Ashmore, J.P. and Grogan, D. “The National Dose Registry for radiation workers in Canada”, Radiation Protection Dosimetry 11(2) pp. 95-100 (1985).

7. ICRP publication 65, “Protection against Radon-222 at home and at work.”, Annals of the ICRP 23(2), p.4 (1993).

8. Regulations of the Nuclear Safety and Control Act, Canada Gazette, June 21, 2000, part 2. For more information see the web site of the CNSC (formerly AECB): http://www.nuclearsafety.gc.ca/eng/index.htm

9. Kumazawa, S. And Numakunai, T. “A new theoretical analysis of occupational dose distributions indicating the effect of dose limits.”, Health Physics 41(3) pp. 465-475 (1981).

Table 1
Breakdown of annual doses by job category for all of Canada

Job Category	Distribution of workers over dose intervals							Number of Workers	Avg. Dose (mSv)	Avg. of Positive Doses
	0 mSv	>0-1 mSv	>1-2 mSv	>2-5 mSv	>5-20 mSv	>20-50 mSv	>50 mSv			
Administration:										
Administrator	330	174	3	0	0	0	0	507	0.13	0.37
Office staff	3109	316	9	4	0	0	0	3438	0.04	0.45
Safety officer	79	18	0	0	0	0	0	97	0.07	0.37
Industry and Research:										
Industrial radiographer	1293	321	164	273	312	45	2	2410	2.67	5.76
Instructor (non-medical)	159	5	2	0	0	0	0	166	0.02	0.59
Instrument technician	1574	246	27	18	5	0	0	1870	0.12	0.79
Laboratory technician (industrial)	2717	400	33	30	5	0	0	3185	0.11	0.73
Nuclear fuel processor	46	29	16	19	10	0	0	120	1.48	2.40
Scientist/engineer (field)	649	478	26	12	9	2	0	1176	0.35	0.77
Scientist/engineer (laboratory)	4099	142	14	2	2	0	0	4259	0.02	0.56
Tradesman	27	1	0	0	0	0	0	28	0.01	0.30
Well logger	343	146	35	23	13	0	0	560	0.50	1.29
Medicine:										
Chiropractor	935	14	4	1	1	0	0	955	0.02	1.01
Dental assistant	9543	99	2	3	2	0	0	9649	0.01	0.54
Dental hygienist	7118	77	0	4	0	0	0	7199	0.01	0.47
Dental therapist/nurse	84	6	0	0	0	0	0	90	0.02	0.25
Dentist	6808	99	2	2	0	1	0	6912	0.01	0.65
Gynaecologist	17	1	0	0	0	0	0	18	0.01	0.20
Laboratory technician (medical)	2492	88	14	13	1	0	1	2609	0.08	1.89
Medical physicist	253	10	1	1	0	0	0	265	0.03	0.60
Medical radiation technologist	9757	627	53	43	1	2	0	10483	0.05	0.68
Nuclear medicine technologist	420	260	206	302	31	0	0	1219	1.35	2.06
Nurse	3353	234	30	6	1	0	0	3624	0.04	0.54
Physician	1421	145	28	16	6	0	0	1616	0.12	0.96
Radiation therapist	876	108	8	6	3	1	0	1002	0.12	0.92
Radiologist (diagnostic)	1327	144	18	9	8	0	0	1506	0.13	1.06
Radiologist (therapeutic)	151	14	0	0	0	0	0	165	0.04	0.45
Veterinarian	3781	191	10	4	1	0	0	3987	0.02	0.48
Veterinary technician	739	27	1	0	0	0	0	767	0.02	0.47
Ward aid/orderly	1386	65	4	6	0	0	0	1461	0.03	0.64

Table 1 (Cont'd)
Breakdown of annual doses by job category for all of Canada

Job Category	Distribution of workers over dose intervals							Number of Workers	Avg. Dose (mSv)	Avg. of Positive Doses
	0 mSv	>0-1 mSv	>1-2 mSv	>2-5 mSv	>5-20 mSv	>20-50 mSv	>50 mSv			
Nuclear Power:										
Reactor - administration	3615	584	139	109	50	0	0	4497	0.24	1.20
Reactor - chemical and radiation control	92	156	31	41	38	0	0	358	1.58	2.13
Reactor - construction	756	314	126	176	226	0	0	1598	1.82	3.46
Reactor - control technician	55	36	17	18	7	0	0	133	1.22	2.08
Reactor - electrical maintenance	396	282	129	135	43	0	0	985	1.04	1.73
Reactor - fuel handling	1	9	1	11	23	0	0	45	6.31	6.46
Reactor - general maintenance	771	281	62	86	100	0	0	1300	1.03	2.54
Reactor - health physics	46	18	3	9	0	0	0	76	0.50	1.27
Reactor - industrial radiographer	5	1	3	5	3	0	0	17	2.42	3.43
Reactor - mechanical maintenance	345	303	139	227	272	0	0	1286	2.53	3.46
Reactor - operations	676	725	222	185	120	0	0	1928	1.15	1.77
Reactor - scientific/professional	1147	221	47	69	59	0	0	1543	0.54	2.12
Reactor - training	68	11	5	2	7	0	0	93	0.83	3.10
Reactor - visitor	2357	110	45	67	87	1	0	2667	0.40	3.46
Uranium Mining:										
Uranium mine electrician	3	13	1	0	0	0	0	17	0.29	0.36
Uranium mine mill maintenance	10	114	16	2	0	0	0	142	0.57	0.62
Uranium mine mill worker	24	125	19	10	0	0	0	178	0.66	0.76
Uranium mine nurse	19	3	0	0	0	0	0	22	0.03	0.25
Uranium mine office staff	83	73	0	0	0	0	0	156	0.10	0.21
Uranium mine support worker	51	212	74	10	0	0	0	347	0.61	0.71
Uranium mine surface maintenance	59	120	4	0	0	0	0	183	0.22	0.32
Uranium mine surface miner	33	39	0	0	0	0	0	72	0.08	0.15
Uranium mine surface personnel	70	88	7	1	0	0	0	166	0.23	0.39
Uranium mine surface support worker	88	103	4	1	0	0	0	196	0.13	0.24
Uranium mine underground maintenance	15	100	19	5	0	0	0	139	0.57	0.64
Uranium mine underground miner	17	134	119	43	8	0	0	321	1.33	1.41
Uranium mine underground personnel	33	80	19	5	0	0	0	137	0.53	0.70
Uranium mine visitor	78	116	0	0	0	0	0	194	0.09	0.16
Miscellaneous/Unknown										
Miscellaneous/unknown	31292	9426	888	697	297	20	3	42623	0.24	0.89

Table 2
Number of workers (top) and average whole body dose in mSv (bottom) by job category and province/territory

Job Sector and Category	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	N.W.T.	Yukon	Canada
Administration													
Administrator	3	0	9	3	50	383	17	2	30	29	0	0	526
	0.00	0.00	0.06	0.00	0.02	0.16	0.00	0.00	0.01	0.02	0.00	0.00	0.12
Office staff	33	5	75	63	655	1923	233	67	171	261	10	0	3496
	0.01	0.00	0.01	0.02	0.03	0.07	0.03	0.03	0.03	0.03	0.04	0.00	0.05
Safety officer	3	1	9	2	18	33	12	2	3	13	0	0	96
	0.00	0.00	0.30	0.00	0.03	0.26	0.00	0.00	0.57	0.29	0.00	0.00	0.18
OVERALL	**39**	**6**	**93**	**68**	**723**	**2339**	**262**	**71**	**204**	**303**	**10**	**0**	**4118**
	0.01	**0.00**	**0.04**	**0.02**	**0.03**	**0.08**	**0.03**	**0.02**	**0.03**	**0.04**	**0.04**	**0.00**	**0.06**
Industry and Research													
Industrial radiographer	33	0	85	83	376	636	31	158	927	183	0	3	2515
	1.38	0.00	1.37	1.26	1.86	2.04	0.74	1.72	4.57	1.23	0.00	0.00	2.79
Instructor (non-medical)	11	3	27	3	14	58	8	4	15	23	2	0	168
	0.00	0.00	0.06	0.00	0.01	0.06	0.00	0.10	0.01	0.01	0.00	0.00	0.04
Instrument technician	79	1	55	48	421	779	58	26	162	167	0	0	1796
	0.03	0.20	0.13	0.40	0.62	0.26	0.05	0.11	0.29	0.15	0.00	0.00	0.32
Laboratory technician	58	11	89	42	846	1572	234	228	488	251	0	0	3819
(industrial)	0.12	0.09	0.08	0.06	0.15	0.18	0.08	0.01	0.09	0.37	0.00	0.00	0.16
Nuclear fuel processor	0	0	0	0	1	168	1	0	2	2	0	0	174
	0.00	0.00	0.00	0.00	0.00	4.20	0.00	0.00	0.25	0.00	0.00	0.00	4.06
Scientist engineer (field)	9	0	31	43	66	917	15	49	90	101	2	0	1323
	0.00	0.00	0.19	0.26	0.41	0.30	0.18	0.09	0.51	0.10	0.00	0.00	0.29
Scientist/engineer	117	3	125	23	1708	1436	154	149	199	825	0	0	4739
(laboratory)	0.03	0.07	0.04	0.07	0.03	0.06	0.02	0.03	0.07	0.06	0.00	0.00	0.05
Well logger	3	0	1	0	1	0	0	36	802	15	1	0	859
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.46	0.15	0.00	0.00	0.43
OVERALL	**310**	**18**	**413**	**242**	**3433**	**5566**	**501**	**650**	**2685**	**1567**	**5**	**3**	**15393**
	0.19	**0.08**	**0.35**	**0.58**	**0.34**	**0.51**	**0.10**	**0.44**	**1.77**	**0.26**	**0.00**	**0.00**	**0.64**
Medicine													
Chiropractor	1	0	1	3	422	311	63	8	112	26	0	0	947
	0.00	0.00	0.00	0.00	0.09	0.03	0.04	0.00	0.02	0.06	0.00	0.00	0.06
Dental assistant	106	34	244	131	1822	4487	596	332	598	612	18	6	8986
	0.02	0.01	0.02	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.01
Dental hygienist	46	18	163	91	2283	3030	445	155	289	340	11	3	6874
	0.05	0.00	0.01	0.02	0.01	0.02	0.00	0.00	0.01	0.01	0.06	0.00	0.01
Dental therapist/nurse	1	0	0	0	8	17	11	37	0	8	5	9	96
	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.06	0.00	0.01
Dentist	90	10	146	90	2441	2848	535	127	255	263	21	3	6829
	0.04	0.00	0.01	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01
Gynaecologist	1	0	1	0	3	13	6	0	1	3	0	0	28
	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.11
Laboratory technician	37	1	143	2	1017	1064	133	120	242	323	0	0	3082
(medical)	0.56	0.00	0.03	0.00	0.07	0.12	0.02	0.06	0.06	0.06	0.00	0.00	0.09
Medical physicist	3	0	10	7	87	85	13	10	11	57	1	0	284
	0.13	0.00	0.14	0.10	0.08	0.11	0.14	4.24	0.00	0.02	0.00	0.00	0.23
Medical radiation	288	70	259	355	2627	4312	638	606	1243	1327	27	11	11763
technologist	0.10	0.12	0.11	0.12	0.07	0.11	0.06	0.07	0.12	0.08	0.03	0.14	0.09
Nuclear medicine	20	4	47	33	464	551	74	24	75	151	0	0	1443
technologist	2.00	0.58	1.78	1.09	1.82	1.34	0.93	1.92	1.38	0.72	0.00	0.00	1.43

Table 2 (Cont'd)
Number of workers (top) and average whole body dose in mSv (bottom) by job category and province/territory

Job Sector and Category	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	N.W.T.	Yukon	Canada
Medicine (cont'd**)**													
Nurse	154	4	174	130	1032	2227	176	86	131	278	125	65	4582
	0.51	0.25	0.08	0.09	0.06	0.32	0.02	0.07	0.16	0.06	0.01	0.08	0.20
Physician	35	5	61	32	632	809	62	51	136	178	6	3	2010
	0.25	0.14	0.09	0.24	0.18	0.24	0.72	0.55	0.15	0.24	0.07	0.10	0.24
Radiation therapist	11	0	39	26	248	402	56	56	60	177	0	0	1075
	0.27	0.00	0.15	0.06	0.15	0.13	0.05	0.09	0.06	0.21	0.00	0.00	0.14
Radiologist (diagnostic)	48	7	44	52	512	663	69	44	134	218	1	0	1792
	0.15	0.16	0.25	0.11	0.10	0.19	0.08	0.07	0.16	0.13	0.00	0.00	0.15
Radiologist (therapeutic)	4	0	3	8	47	44	11	4	10	21	0	0	152
	0.10	0.00	0.20	0.03	0.14	0.05	0.03	0.00	0.01	0.41	0.00	0.00	0.12
Veterinarian	33	36	180	77	694	1354	231	180	709	698	0	7	4199
	0.08	0.17	0.03	0.82	0.03	0.05	0.02	0.04	0.04	0.03	0.00	0.00	0.06
Veterinary technician	2	1	11	1	35	50	7	2	21	40	0	0	170
	0.00	0.00	0.02	0.00	0.01	0.04	0.00	0.00	0.01	0.03	0.00	0.00	0.02
Ward aid/orderly	18	14	20	45	839	315	93	29	39	124	5	0	1541
	0.08	0.24	0.12	1.45	0.05	0.22	0.04	0.17	0.04	0.03	0.04	0.00	0.13
OVERALL	**898**	**204**	**1546**	**1083**	**15213**	**22582**	**3219**	**1871**	**4066**	**4844**	**220**	**107**	**55853**
	0.22	**0.11**	**0.11**	**0.22**	**0.10**	**0.12**	**0.06**	**0.11**	**0.09**	**0.09**	**0.02**	**0.06**	**0.11**
Nuclear Power													
Reactor - administration	0	0	0	163	344	4572	0	0	0	0	0	0	5079
	0.00	0.00	0.00	0.07	0.25	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Reactor - chemical and radiation control	0	0	0	29	36	300	0	0	0	0	0	0	365
	0.00	0.00	0.00	0.32	0.91	1.58	0.00	0.00	0.00	0.00	0.00	0.00	1.41
Reactor - construction	0	0	0	0	55	1093	0	0	0	0	0	0	1148
	0.00	0.00	0.00	0.00	0.35	1.66	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Reactor - control technician	0	0	0	0	116	1	0	0	0	0	0	0	117
	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49
Reactor - electrical maintenance	0	0	0	86	45	824	0	0	0	0	0	0	955
	0.00	0.00	0.00	0.65	5.45	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Reactor - fuel handling	0	0	0	46	9	2	0	0	0	0	0	0	57
	0.00	0.00	0.00	5.06	3.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.57
Reactor - general maintenance	0	0	0	212	96	839	0	0	0	0	0	0	1147
	0.00	0.00	0.00	0.62	2.89	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.90
Reactor - health physics	0	0	0	37	6	15	0	0	0	0	0	0	58
	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
Reactor - industrial radiographer	0	0	0	0	0	8	0	0	0	0	0	0	8
	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.80
Reactor - mechanical maintenance	0	0	0	164	207	850	0	0	0	0	0	0	1221
	0.00	0.00	0.00	0.94	2.51	2.26	0.00	0.00	0.00	0.00	0.00	0.00	2.13
Reactor - operations	0	0	0	100	116	1696	0	0	0	0	0	0	1912
	0.00	0.00	0.00	0.37	1.45	1.27	0.00	0.00	0.00	0.00	0.00	0.00	1.24
Reactor - scientific/ professional	0	0	0	338	147	952	0	0	0	0	0	0	1437
	0.00	0.00	0.00	0.32	0.70	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.53
Reactor - training	0	0	0	34	19	5	0	0	0	0	0	0	58
	0.00	0.00	0.00	0.65	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Reactor - visitor	0	0	0	0	55	610	0	0	0	0	0	0	665
	0.00	0.00	0.00	0.00	0.99	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.52
OVERALL	**0**	**0**	**0**	**1209**	**1251**	**11767**	**0**	**0**	**0**	**0**	**0**	**0**	**14227**
	0.00	**0.00**	**0.00**	**0.65**	**1.37**	**0.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.84**

Table 2 (cont'd)
Number of workers (top) and average whole body dose in mSv (bottom) by job category and province/territory

Job Sector and Category	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	N.W.T.	Yukon	Canada
Uranium Mining													
Uranium mine electrician	0	0	0	0	0	0	0	9	0	0	0	0	9
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.16
Uranium mine mill maintenance	0	0	0	0	0	0	0	161	0	0	0	0	161
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	1.09
Uranium mine mill workers	0	0	0	0	0	4	0	208	0	0	0	0	212
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	1.37
Uranium mine nurse	0	0	0	0	0	0	0	17	0	0	0	0	17
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04
Uranium mine office staff	0	0	0	0	0	0	0	160	0	0	0	0	160
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
Uranium mine support worker	0	0	0	0	0	2	0	288	0	0	0	0	290
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.00	0.00	1.28
Uranium mine surface maintenance	0	0	0	0	0	3	0	173	0	0	0	0	176
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.36
Uranium mine surface miner	0	0	0	0	0	0	0	96	0	0	0	0	96
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.80
Uranium mine surface personnel	0	0	0	0	0	2	0	124	0	0	0	0	126
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.37
Uranium mine surface support worker	0	0	0	0	0	19	0	274	0	0	0	0	293
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.36
Uranium mine underground maintenance	0	0	0	0	0	1	0	138	0	0	0	0	139
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.93
Uranium mine underground miner	0	0	0	0	0	1	0	361	0	0	0	0	362
	0.00	0.00	0.00	0.00	0.00	0.20	0.00	1.98	0.00	0.00	0.00	0.00	1.97
Uranium mine underground personnel	0	0	0	0	0	37	0	314	0	0	0	0	351
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.54
Uranium mine visitor	0	0	0	0	0	0	0	295	0	0	0	0	295
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.05
OVERALL	**0**	**0**	**0**	**0**	**0**	**69**	**0**	**2618**	**0**	**0**	**0**	**0**	**2687**
	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.84**	**0.00**	**0.00**	**0.00**	**0.00**	**0.82**

Table 3
Dose distribution broken down by job sector, age and sex.

			Sex			
Job Sector	Age	Statistic	Male	Female	Unknown	Overall
Administration	Below 25	Number of Workers	8	209	1	218
		Average dose (mSv)	0.00	0.01	0.00	0.01
	25-34	Number of Workers	47	912	2	961
		Average dose (mSv)	0.11	0.02	0.00	0.03
	35-44	Number of Workers	163	1262	2	1427
		Average dose (mSv)	0.25	0.04	0.00	0.07
	45-54	Number of Workers	189	913	1	1103
		Average dose (mSv)	0.23	0.06	0.00	0.09
	55-up	Number of Workers	79	264	3	346
		Average dose (mSv)	0.13	0.03	0.00	0.06
	Unknown	Number of Workers	18	42	0	60
		Average dose (mSv)	0.27	0.07	0.00	0.13
	Overall	**Number of Workers**	**504**	**3602**	**9**	**4115**
		Average dose (mSv)	**0.21**	**0.04**	**0.00**	**0.06**
Industry and Research	Below 25	Number of Workers	726	439	5	1170
		Average dose (mSv)	1.70	0.06	0.30	1.08
	25-34	Number of Workers	3050	1379	11	4440
		Average dose (mSv)	1.12	0.11	0.00	0.81
	35-44	Number of Workers	4030	1115	8	5153
		Average dose (mSv)	0.66	0.12	0.03	0.54
	45-54	Number of Workers	2709	520	3	3232
		Average dose (mSv)	0.68	0.11	3.37	0.59
	55-up	Number of Workers	934	117	9	1060
		Average dose (mSv)	0.31	0.19	0.02	0.29
	Unknown	Number of Workers	179	20	1	200
		Average dose (mSv)	0.30	0.02	0.00	0.27
	Overall	**Number of Workers**	**11628**	**3590**	**37**	**15255**
		Average dose (mSv)	**0.82**	**0.11**	**0.32**	**0.65**
Medicine	Below 25	Number of Workers	287	3378	5	3670
		Average dose (mSv)	0.15	0.06	0.00	0.07
	25-34	Number of Workers	2983	14295	19	17297
		Average dose (mSv)	0.17	0.09	0.03	0.11
	35-44	Number of Workers	5033	13060	16	18109
		Average dose (mSv)	0.16	0.11	0.00	0.13
	45-54	Number of Workers	4484	7373	7	11864
		Average dose (mSv)	0.12	0.11	0.06	0.11
	55-up	Number of Workers	2396	1370	31	3797
		Average dose (mSv)	0.09	0.10	0.02	0.09
	Unknown	Number of Workers	323	333	0	656
		Average dose (mSv)	0.07	0.08	0.00	0.08
	Overall	**Number of Workers**	**15506**	**39809**	**78**	**55393**
		Average dose (mSv)	**0.14**	**0.10**	**0.02**	**0.11**

Table 3 (Cont'd)
Dose distribution broken down by job sector, age and sex.

			Sex			
Job Sector	Age	Statistic	Male	Female	Unknown	Overall
Nuclear Power	Below 25	Number of Workers	183	49	0	232
		Average dose (mSv)	0.49	0.27	0.00	0.44
		% tritium	14.0	4.5	0.0	12.8
	25-34	Number of Workers	1717	414	0	2131
		Average dose (mSv)	1.22	0.27	0.00	1.03
		% tritium	23.1	24.7	0.0	23.1
	35-44	Number of Workers	4676	759	0	5435
		Average dose (mSv)	1.12	0.26	0.00	1.00
		% tritium	19.4	16.4	0.0	19.3
	45-54	Number of Workers	4358	397	0	4755
		Average dose (mSv)	0.79	0.11	0.00	0.73
		% tritium	16.8	23.8	0.0	16.9
	55-up	Number of Workers	1009	31	0	1040
		Average dose (mSv)	0.54	0.39	.00	0.54
		% tritium	17.2	9.5	0.0	17.0
	Unknown	Number of Workers	245	11	0	256
		Average dose (mSv)	0.55	0.38	0.00	0.54
		% tritium	20.7	34.9	0.0	21.1
	Overall	**Number of Workers**	**12188**	**1661**	**0**	**13849**
		Average dose (mSv)	**0.95**	**0.23**	**0.00**	**0.86**
		% tritium	**19.1**	**19.2**	**0.0**	**19.1**
Mining	Below 25	Number of Workers	174	37	2	213
		Average dose (mSv)	0.87	0.40	0.05	0.78
		% radon progeny	63.6	74.8	100.0	64.6
	25-34	Number of Workers	595	82	8	685
		Average dose (mSv)	1.10	0.22	0.07	0.98
		% radon progeny	77.8	86.8	45.5	78.0
	35-44	Number of Workers	751	71	5	827
		Average dose (mSv)	1.04	0.36	0.11	0.98
		% radon progeny	71.9	88.6	100.0	72.4
	45-54	Number of Workers	492	23	9	524
		Average dose (mSv)	0.90	0.11	0.17	0.85
		% radon progeny	80.1	100.0	100.0	80.3
	55-up	Number of Workers	172	6	3	181
		Average dose (mSv)	0.51	0.12	0.00	0.49
		% radon progeny	82.4	100.0	0.0	82.5
	Unknown	Number of Workers	27	1	0	28
		Average dose (mSv)	0.98	0.00	0.00	0.94
		% radon progeny	79.2	0.0	0.0	79.2
	Overall	**Number of Workers**	**2211**	**220**	**27**	**2458**
		Average dose (mSv)	**0.97**	**0.28**	**0.10**	**0.90**
		% radon progeny	**75.3**	**85.4**	**89.1**	**75.6**

Table 4
Dose Statistics by job category
Administrator

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	348	0.00	0.00
>0-1	176	61.12	0.35
>1-2	1	1.74	1.74
>2-5	0	0.00	0.00
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	525	62.86	0.12
			Five year period 1994-1998
0	469	0.00	0.00
>0-5	392	377.88	0.96
>5-25	1	8.60	8.60
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	862	386.48	0.45

Hybrid lognormal parameters for positive doses in 1998:
ρ: 11.6257
μ: 5.3202
σ^2: 9.0661
Sample size: 177
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

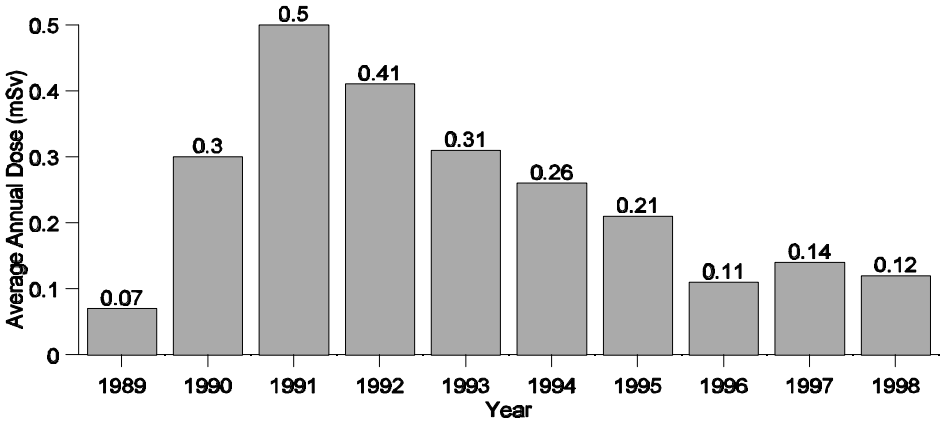

Table 4 (Cont'd)
Office Staff

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	3038	0.00	0.00
>0-1	439	140.27	0.32
>1-2	11	14.67	1.33
>2-5	6	17.26	2.88
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	3494	172.20	0.05
			Five year period 1994-1998
0	5094	0.00	0.00
>0-5	1424	1375.65	0.97
>5-25	17	140.13	8.24
>25-100	1	35.00	35.00
>100	0	0.00	0.00
Total	6536	1550.78	0.24

Hybrid lognormal parameters for positive doses in 1998:
ρ: 0.2903
μ: -2.4282
σ^2: 0.9112
Sample size: 456
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

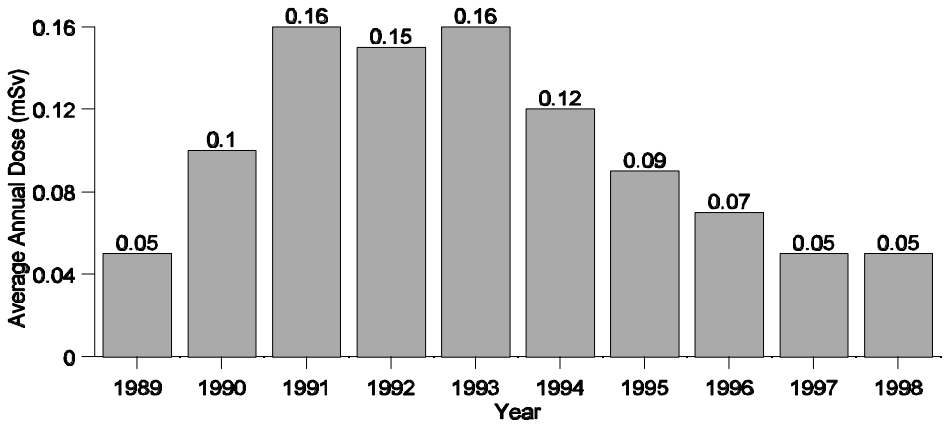

Table 4 (Cont'd)
Safety Officer

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	69	0.00	0.00
>0-1	22	7.96	0.36
>1-2	4	6.70	1.68
>2-5	1	2.60	2.60
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	96	17.26	0.18
			Five year period 1994-1998
0	96	0.00	0.00
>0-5	67	63.03	0.94
>5-25	1	16.30	16.30
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	164	79.33	0.48

Lognormal parameters for positive doses in 1998:
μ: -0.8849
σ^2: 0.9768
Sample size: 27
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

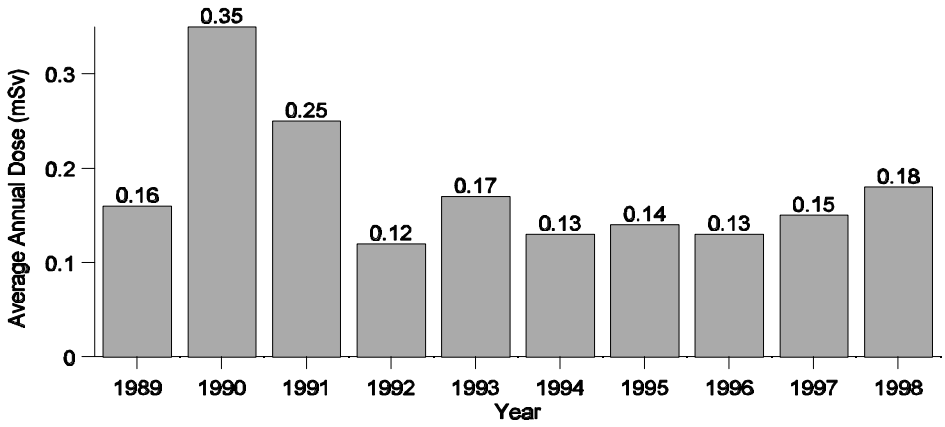

Table 4 (Cont'd)
Industrial Radiographer

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	1113	0.00	0.00
>0-1	372	178.45	0.48
>1-2	184	275.96	1.50
>2-5	309	1053.67	3.41
>5-20	402	4086.29	10.16
>20-50	47	1291.26	27.47
>50	2	143.90	71.95
Total	2429	7029.53	2.89
			Five year period 1994-1998
0	1299	0.00	0.00
>0-5	1110	1589.27	1.43
>5-25	734	9835.72	13.40
>25-100	473	21922.85	46.35
>100	37	4966.09	134.22
Total	3653	38313.93	10.49

Hybrid lognormal parameters for positive doses in 1998:
ρ: 0.0419
μ: -2.0553
σ^2: 2.6046
Sample size: 1316
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

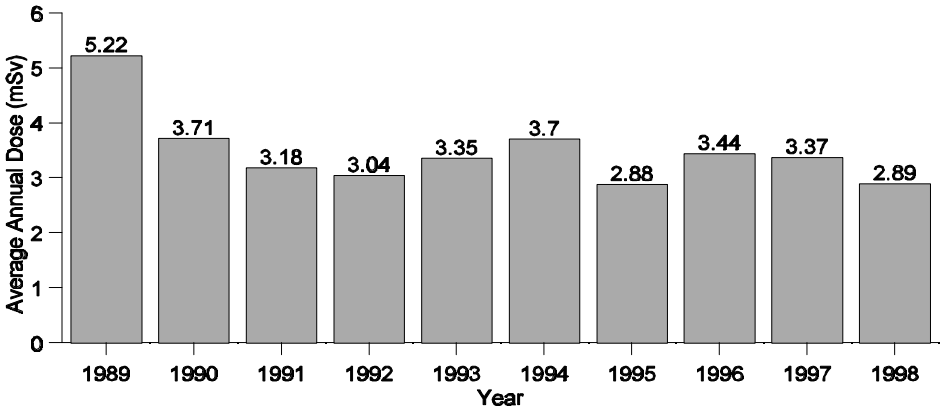

Table 4 (Cont'd)
Instructor (Non Medical)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	148	0.00	0.00
>0-1	20	5.90	0.30
>1-2	0	0.00	0.00
>2-5	0	0.00	0.00
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	168	5.90	0.04
			Five year period 1994-1998
0	207	0.00	0.00
>0-5	76	50.30	0.66
>5-25	0	0.00	0.00
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	283	50.30	0.18

Lognormal parameters for positive doses in 1998:
μ: -1.3905
σ^2: 0.3207
Sample size: 20
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

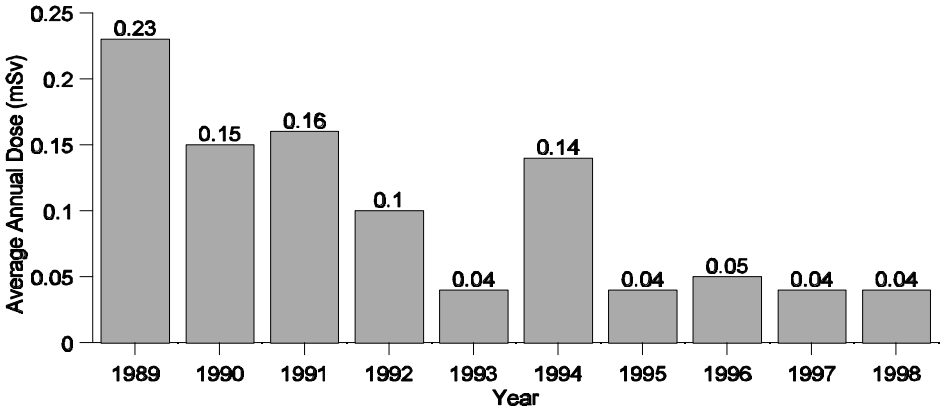

Table 4 (Cont'd)
Instrument Technician

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	1321	0.00	0.00
>0-1	375	139.04	0.37
>1-2	31	44.30	1.43
>2-5	27	83.58	3.10
>5-20	30	259.33	8.64
>20-50	2	52.20	26.10
>50	0	0.00	0.00
Total	1786	578.45	0.32
			Five year period 1994-1998
0	1670	0.00	0.00
>0-5	1051	1032.91	0.98
>5-25	109	1074.65	9.86
>25-100	11	406.23	36.93
>100	0	0.00	0.00
Total	2841	2513.79	0.88

Lognormal parameters for positive doses in 1998:
μ: -0.7149
σ^2: 1.4277
Sample size: 465
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

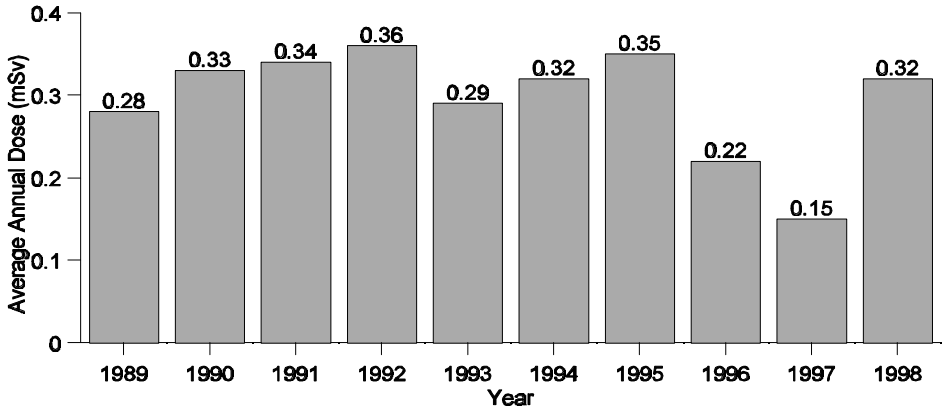

Table 4 (Cont'd)
Laboratory Technician (Industrial)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	2860	0.00	0.00
>0-1	841	275.69	0.33
>1-2	55	79.33	1.44
>2-5	37	110.36	2.98
>5-20	16	117.81	7.36
>20-50	1	21.40	21.40
>50	0	0.00	0.00
Total	3810	604.59	0.16
			Five year period 1994-1998
0	4493	0.00	0.00
>0-5	2315	1779.08	0.77
>5-25	130	1335.05	10.27
>25-100	6	205.17	34.20
>100	1	550.00	550.00
Total	6945	3869.30	0.56

Lognormal parameters for positive doses in 1998:
μ: -1.1140
σ^2: 1.1161
Sample size: 950
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

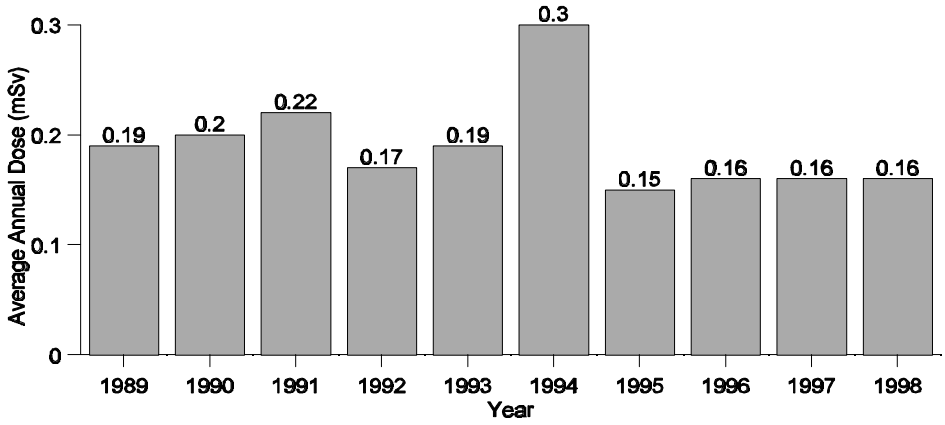

Table 4 (Cont'd)
Nuclear Fuel Processor

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	53	0.00	0.00
>0-1	41	21.30	0.52
>1-2	24	34.40	1.43
>2-5	32	110.90	3.47
>5-20	23	186.00	8.09
>20-50	0	0.00	0.00
>50	1	354.00	354.00
Total	174	706.60	4.06
			Five year period 1994-1998
0	31	0.00	0.00
>0-5	89	203.90	2.29
>5-25	79	1006.10	12.74
>25-100	27	1009.20	37.38
>100	1	371.40	371.40
Total	227	2590.60	11.41

Lognormal parameters for positive doses in 1998:
μ: 0.5721
σ^2: 1.4737
Sample size: 121
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

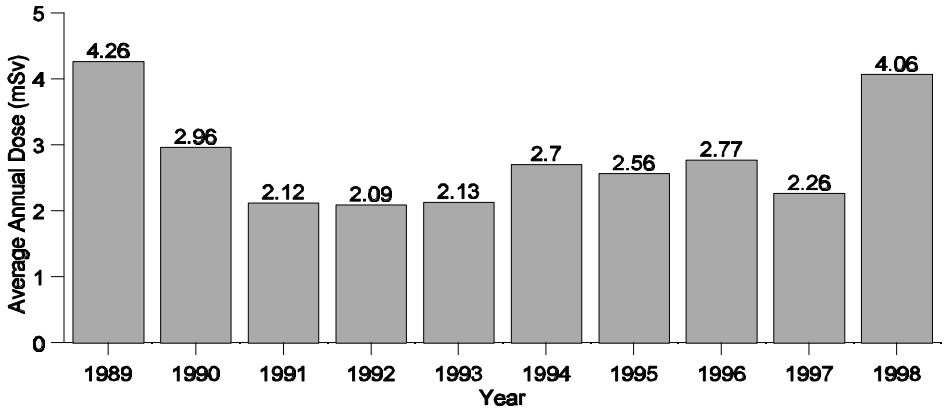

Table 4 (Cont'd)
Scientist/Engineer (Field)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	665	0.00	0.00
>0-1	603	226.10	0.37
>1-2	32	43.64	1.36
>2-5	14	44.56	3.18
>5-20	7	70.89	10.13
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	1321	385.19	0.29
			Five year period 1994-1998
0	830	0.00	0.00
>0-5	1394	1622.74	1.16
>5-25	78	847.15	10.86
>25-100	6	199.44	33.24
>100	0	0.00	0.00
Total	2308	2669.33	1.16

Lognormal parameters for positive doses in 1998:
μ: -1.1161
σ^2: 1.1794
Sample size: 656
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

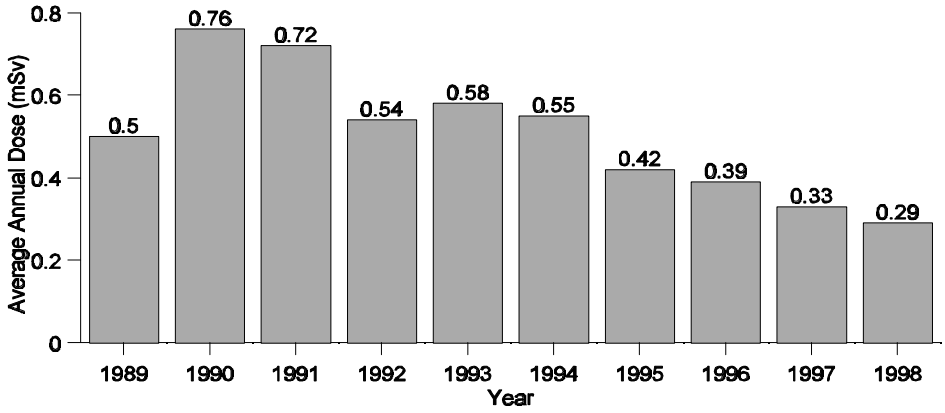

Table 4 (Cont'd)
Scientist/Engineer (Laboratory)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	4146	0.00	0.00
>0-1	545	163.31	0.30
>1-2	17	23.30	1.37
>2-5	9	27.00	3.00
>5-20	1	7.30	7.30
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	4718	220.91	0.05
			Five year period 1994-1998
0	5850	0.00	0.00
>0-5	2361	1317.28	0.56
>5-25	17	130.77	7.69
>25-100	4	121.00	30.25
>100	0	0.00	0.00
Total	8232	1569.05	0.19

Lognormal parameters for positive doses in 1998:
μ: -1.2729
σ^2: 0.5026
Sample size: 572
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998

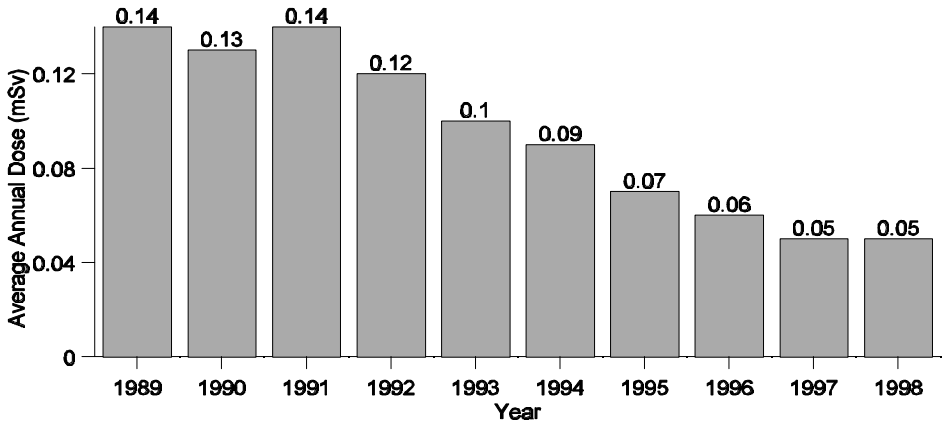

Table 4 (Cont'd)
Well Logger

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1998
0	515	0.00	0.00
>0-1	232	101.10	0.44
>1-2	65	98.50	1.52
>2-5	36	117.20	3.26
>5-20	7	55.70	7.96
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	855	372.50	0.44
			Five year period 1994-1998
0	559	0.00	0.00
>0-5	914	1237.27	1.35
>5-25	152	1442.00	9.49
>25-100	4	138.00	34.50
>100	0	0.00	0.00
Total	1629	2817.27	1.73

Lognormal parameters for positive doses in 1998:
μ: -0.4244
σ^2: 0.9312
Sample size: 340
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1989-1998