Health Canada Santé Canada

1999 Report on Occupational Radiation Exposures in Canada

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Part 1 of 3

Canada

1999 Report on Occupational Radiation Exposures in Canada

Environmental Health Directorate
Health Protection 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 125,883 monitored workers, 4 annual doses exceeded the regulatory limit of 50 mSv in 1998. Out of 43 specified job categories, 18 had a smaller annual average in 1998 than in 1997, 17 had a higher average, and 8 had the same average rounded to 0.01 mSv. The uranium mining job categories are not in this list because the conversion factor for radon progeny exposure to effective dose was changed from 10 to 5 mSv/WLM, precluding a valid comparison of the averages. In all categories of workers, from 1996 to 1997, 19 average annual doses went up, 33 went down, and 4 stayed the same. The figures reflect a sustained effort in keeping the occupational doses low.

Acknowledgements

This document was prepared by Dr. W. Sont and Dr. J.P. Ashmore of the Occupational Radiation Hazards Division, Radiation Protection Bureau.

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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 24 July 1999. 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 given in the specific comments section.

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:

1998: Preliminary analysis

Table 1:

Table 1 gives the annual doses distributions by job category.

1997: 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 1993-1997 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 1988-1997.

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

In anticipation of a new set of regulatory dose limits[8], we now use the factor 5 mSv per WLM to convert radon progeny exposures to equivalent doses. This factor is applied to radon progeny data for all of the years 1988-1998. This means that some tables and graphs will be substantially different from last year's report.

Job category information is not provided by all dosimetry companies. In a number of dose records the job category had to be inferred from earlier information on the same worker. This is expected to be a temporary problem, which will disappear when new regulatory requirements are in force.

References

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8. ICRP publication 47, “Radiation protection of workers in mines”, Annals of the ICRP 16(1), p. 5 (1986).

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1998 Preliminary Analysis

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	334	176	1	0	0	0	0	511	0.12	0.36
Office staff	2953	432	9	6	0	0	0	3400	0.05	0.38
Safety officer	69	21	4	1	0	0	0	95	0.17	0.63
Industry and Research:										
Industrial radiographer	1060	352	181	293	382	46	2	2316	2.90	5.35
Instructor (non-medical)	142	18	0	0	0	0	0	160	0.03	0.31
Instrument technician	1256	365	30	24	27	1	0	1703	0.30	1.15
Laboratory technician (industrial)	2785	816	48	37	13	0	0	3699	0.14	0.58
Nuclear fuel processor	51	41	25	32	23	0	0	172	2.06	2.93
Scientist/engineer (field)	645	589	31	12	6	0	0	1283	0.27	0.55
Scientist/engineer (laboratory)	4016	539	12	8	1	0	0	4576	0.05	0.37
Well logger	512	223	65	29	5	0	0	834	0.39	1.01
Medicine:										
Chiropractor	840	68	3	0	0	0	0	911	0.03	0.41
Dental assistant	8431	261	1	2	2	0	0	8697	0.01	0.34
Dental hygienist	6550	195	6	1	1	0	0	6753	0.01	0.44
Dental therapist/nurse	86	3	0	0	0	0	0	89	0.01	0.30
Dentist	6423	244	2	0	1	0	0	6670	0.01	0.33
Gynaecologist	23	2	2	0	0	0	0	27	0.11	0.78
Laboratory technician (medical)	2556	383	27	17	2	1	0	2986	0.09	0.61
Medical physicist	217	52	3	1	0	1	0	274	0.23	1.12
Medical radiation technologist	9338	2051	88	51	5	1	0	11534	0.09	0.48
Nuclear medicine technologist	372	334	308	367	37	0	0	1418	1.44	1.96
Nurse	3215	882	298	21	6	0	0	4422	0.20	0.75
Physician	1443	424	43	21	7	2	0	1940	0.23	0.90
Radiation therapist	748	262	8	6	2	1	0	1027	0.14	0.52
Radiologist (diagnostic)	1325	382	26	17	3	0	0	1753	0.14	0.56
Radiologist (therapeutic)	123	21	2	0	1	0	0	147	0.12	0.72
Veterinarian	3701	390	16	7	1	2	0	4117	0.06	0.55
Veterinary technician	74	1	0	0	0	0	0	75	0.00	0.20
Ward aid/orderly	1300	181	16	10	1	0	1	1509	0.13	0.94

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	3909	859	149	131	27	0	0	5075	0.21	0.90
Reactor - chemical and radiation control	122	146	41	24	32	0	0	365	1.41	2.12
Reactor - construction	502	250	103	179	114	0	0	1148	1.60	2.84
Reactor - control technician	54	24	11	15	13	0	0	117	1.49	2.77
Reactor - electrical maintenance	389	320	125	77	44	0	0	955	0.95	1.60
Reactor - fuel handling	3	7	3	14	28	0	0	55	4.73	5.01
Reactor - general maintenance	679	242	58	95	73	0	0	1147	0.90	2.20
Reactor - health physics	39	12	4	1	2	0	0	58	0.51	1.55
Reactor - industrial radiographer	4	3	0	1	0	0	0	8	0.80	1.60
Reactor - mechanical maintenance	393	296	140	208	184	0	0	1221	2.13	3.14
Reactor - operations	628	735	257	163	129	0	0	1912	1.24	1.84
Reactor - scientific/professional	1056	218	53	55	53	0	0	1435	0.53	2.01
Reactor - training	45	9	1	0	3	0	0	58	0.60	2.69
Reactor - visitor	63	16	5	6	4	0	0	94	0.82	2.49
Uranium Mining:										
Uranium mine electrician	1	6	0	0	0	0	0	7	0.15	0.18
Uranium mine mill maintenance	9	86	46	14	3	0	0	158	1.08	1.15
Uranium mine mill worker	15	79	75	39	4	0	0	212	1.37	1.47
Uranium mine nurse	11	5	0	0	0	0	0	16	0.04	0.14
Uranium mine office staff	79	74	2	0	0	0	0	155	0.16	0.34
Uranium mine support worker	33	166	41	31	18	0	0	289	1.28	1.44
Uranium mine surface maintenance	63	97	7	2	0	0	0	169	0.37	0.58
Uranium mine surface miner	12	60	14	9	0	0	0	95	0.80	0.92
Uranium mine surface personnel	30	81	5	4	0	0	0	120	0.39	0.52
Uranium mine surface support worker	117	147	14	5	1	0	0	284	0.37	0.63
Uranium mine underground maintenance	22	79	24	9	5	0	0	139	0.93	1.10
Uranium mine underground miner	14	134	99	55	42	0	0	344	2.04	2.13
Uranium mine underground personnel	179	117	23	16	9	0	0	344	0.55	1.15
Uranium mine visitor	189	96	0	0	0	0	0	285	0.05	0.16
Miscellaneous/Unknown:										
Miscellaneous/unknown	28280	6687	761	585	345	24	1	36683	0.25	1.07

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	2	0	8	3	50	388	19	3	29	29	0	0	531
	0.00	0.00	0.21	0.00	0.00	0.18	0.00	0.00	0.08	0.02	0.00	0.00	0.14
Office staff	37	5	82	63	658	1989	230	64	176	265	12	1	3582
	0.01	0.14	0.02	0.03	0.03	0.08	0.00	0.01	0.03	0.02	0.00	0.00	0.05
Safety officer	3	1	10	2	22	33	24	2	3	13	0	0	113
	0.00	0.00	0.09	0.00	0.05	0.22	0.00	0.00	1.13	0.28	0.00	0.00	0.14
OVERALL	**42**	**6**	**100**	**68**	**730**	**2410**	**273**	**69**	**208**	**307**	**12**	**1**	**4226**
	0.00	**0.12**	**0.05**	**0.03**	**0.03**	**0.10**	**0.00**	**0.01**	**0.05**	**0.03**	**0.00**	**0.00**	**0.07**
Industry and Research													
Industrial radiographer	31	0	97	65	326	622	35	143	854	199	0	3	2375
	0.56	0.00	1.53	2.46	1.95	1.89	0.76	2.54	5.59	1.93	0.00	0.00	3.24
Instructor (non-medical)	11	0	23	3	14	62	8	4	15	22	1	0	163
	0.00	0.00	0.06	0.00	0.02	0.06	0.00	0.00	0.02	0.03	0.30	0.00	0.04
Instrument technician	89	1	60	53	404	786	55	25	176	184	0	0	1833
	0.01	0.00	0.02	0.10	0.06	0.24	0.01	0.02	0.07	0.12	0.00	0.00	0.14
Laboratory technician (industrial)	64	10	89	34	772	1621	234	222	522	289	0	0	3857
	0.07	0.11	0.10	0.01	0.08	0.22	0.01	0.02	0.08	0.33	0.00	0.00	0.15
Nuclear fuel processor	0	0	0	0	1	170	1	0	3	2	0	0	177
	0.00	0.00	0.00	0.00	0.00	2.36	0.00	0.00	0.10	0.05	0.00	0.00	2.27
Scientist engineer (field)	10	0	49	38	89	976	16	57	126	109	0	0	1470
	0.00	0.00	0.15	0.25	0.24	0.35	0.13	0.11	0.55	0.17	0.00	0.00	0.32
Scientist/engineer (laboratory)	128	3	146	17	1557	1533	178	153	197	871	0	0	4783
	0.00	0.00	0.06	0.00	0.04	0.06	0.01	0.04	0.08	0.05	0.00	0.00	0.05
Well logger	2	0	1	0	0	2	0	36	880	16	0	0	937
	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.47	0.02	0.00	0.00	0.44
OVERALL	**335**	**14**	**465**	**210**	**3163**	**5772**	**527**	**640**	**2773**	**1692**	**1**	**3**	**15595**
	0.07	**0.08**	**0.38**	**0.83**	**0.26**	**0.44**	**0.07**	**0.60**	**1.92**	**0.34**	**0.30**	**0.00**	**0.64**
Medicine													
Chiropractor	0	0	1	2	398	339	61	9	143	32	0	0	985
	0.00	0.00	0.00	0.00	0.02	0.04	0.01	0.03	0.02	0.21	0.00	0.00	0.03
Dental assistant	84	16	219	139	1721	4181	580	334	594	610	17	8	8503
	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Dental hygienist	47	31	166	93	2227	2988	437	173	272	363	13	3	6813
	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.07	0.00	0.01
Dental therapist/nurse	1	0	0	0	8	11	8	38	1	10	4	8	89
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.06	0.02
Dentist	86	11	144	90	2364	2881	516	127	252	282	14	4	6771
	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.02	0.00	0.01
Gynaecologist	1	0	1	0	5	13	5	0	1	3	0	0	29
	0.00	0.00	0.00	0.00	0.00	0.28	0.04	0.00	0.00	0.07	0.00	0.00	0.14
Laboratory technician (medical)	36	2	157	2	1046	1277	152	127	254	323	0	0	3376
	0.01	0.00	0.02	0.00	0.08	0.07	0.02	0.02	0.04	0.05	0.00	0.00	0.06
Medical physicist	2	0	8	6	81	92	15	11	12	52	1	0	280
	0.25	0.00	0.00	0.17	0.06	0.13	0.07	0.02	0.07	0.03	0.00	0.00	0.08
Medical radiation technologist	284	69	283	359	2728	4354	634	618	1222	1326	28	10	11915
	0.01	0.08	0.04	0.09	0.05	0.12	0.05	0.06	0.09	0.10	0.03	0.00	0.09
Nuclear medicine technologist	21	4	46	31	487	560	71	26	89	153	0	0	1488
	2.11	1.18	1.24	1.02	1.43	1.20	0.87	1.06	1.01	0.65	0.00	0.00	1.20

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	193	2	252	136	1043	2332	165	89	132	267	132	66	4809
	0.03	0.00	0.01	0.08	0.04	0.15	0.02	0.24	0.12	0.09	0.01	0.03	0.10
Physician	40	5	63	34	630	832	56	51	150	184	9	3	2057
	0.06	0.00	0.01	0.63	0.14	0.17	0.11	0.42	0.12	0.17	0.03	0.07	0.16
Radiation therapist	11	0	32	27	236	416	56	55	62	171	0	0	1066
	0.21	0.00	0.02	0.13	0.18	0.44	0.07	0.10	0.07	0.05	0.00	0.00	0.24
Radiologist (diagnostic)	49	7	49	51	527	686	67	45	122	226	2	0	1831
	0.07	0.00	0.23	0.28	0.07	0.17	0.09	0.01	0.19	0.13	0.00	0.00	0.13
Radiologist (therapeutic)	3	0	2	11	44	51	13	4	12	16	0	0	156
	0.00	0.00	0.15	0.02	0.08	0.09	0.02	0.08	0.03	0.03	0.00	0.00	0.06
Veterinarian	38	44	179	83	660	1359	227	188	727	691	0	8	4204
	0.01	0.08	0.02	0.16	0.02	0.04	0.01	0.02	0.02	0.02	0.00	0.00	0.03
Veterinary technician	0	0	0	0	1	2	0	1	2	3	0	0	9
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ward aid/orderly	29	17	27	47	960	351	82	34	36	107	6	0	1696
	0.02	0.03	0.04	0.14	0.05	0.11	0.00	0.06	0.05	0.02	0.00	0.00	0.06
OVERALL	**925**	**208**	**1629**	**1111**	**15166**	**22725**	**3145**	**1930**	**4083**	**4819**	**226**	**110**	**56077**
	0.07	**0.07**	**0.06**	**0.12**	**0.08**	**0.10**	**0.05**	**0.06**	**0.07**	**0.08**	**0.01**	**0.03**	**0.09**
Nuclear Power													
Reactor - administration	0	0	0	133	351	4677	0	0	0	0	0	0	5161
	0.00	0.00	0.00	0.16	0.26	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Reactor - chemical and radiation control	0	0	0	23	39	309	0	0	0	0	0	0	371
	0.00	0.00	0.00	0.69	1.48	1.92	0.00	0.00	0.00	0.00	0.00	0.00	1.80
Reactor - construction	0	0	0	0	41	1313	0	0	0	0	0	0	1354
	0.00	0.00	0.00	0.00	0.07	1.65	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Reactor - control technician	0	0	0	0	111	0	0	0	0	0	0	0	111
	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30
Reactor - electrical maintenance	0	0	0	79	37	861	0	0	0	0	0	0	977
	0.00	0.00	0.00	0.82	3.87	1.04	0.00	0.00	0.00	0.00	0.00	0.00	1.13
Reactor - fuel handling	0	0	0	26	11	2	0	0	0	0	0	0	39
	0.00	0.00	0.00	5.70	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.76
Reactor - general maintenance	0	0	0	223	86	977	0	0	0	0	0	0	1286
	0.00	0.00	0.00	0.66	3.37	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.79
Reactor - health physics	0	0	0	36	9	21	0	0	0	0	0	0	66
	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Reactor - industrial radiographer	0	0	0	0	0	11	0	0	0	0	0	0	11
	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	1.30
Reactor - mechanical maintenance	0	0	0	136	178	997	0	0	0	0	0	0	1311
	0.00	0.00	0.00	2.56	4.56	2.19	0.00	0.00	0.00	0.00	0.00	0.00	2.55
Reactor - operations	0	0	0	93	113	1659	0	0	0	0	0	0	1865
	0.00	0.00	0.00	0.78	1.45	1.66	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Reactor - scientific/ professional	0	0	0	330	134	1110	0	0	0	0	0	0	1574
	0.00	0.00	0.00	1.00	0.97	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.73
Reactor - training	0	0	0	27	18	5	0	0	0	0	0	0	50
	0.00	0.00	0.00	0.28	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
Reactor - visitor	0	0	0	0	11	43	0	0	0	0	0	0	54
	0.00	0.00	0.00	0.00	0.79	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.44
OVERALL	**0**	**0**	**0**	**1106**	**1139**	**11985**	**0**	**0**	**0**	**0**	**0**	**0**	**14230**
	0.00	**0.00**	**0.00**	**1.07**	**1.66**	**0.92**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.99**

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 mill maintenance	0	0	0	0	0	1	0	159	0	0	0	0	160
	0.00	0.00	0.00	0.00	0.00	0.40	0.00	2.87	0.00	0.00	0.00	0.00	2.86
Uranium mine mill worker	0	0	0	0	0	4	0	223	0	0	0	0	227
	0.00	0.00	0.00	0.00	0.00	0.13	0.00	2.96	0.00	0.00	0.00	0.00	2.91
Uranium mine nurse	0	0	0	0	0	0	0	10	0	0	0	0	10
	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 office staff	0	0	0	0	0	0	0	132	0	0	0	0	132
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.21
Uranium mine support worker	0	0	0	0	0	1	0	150	0	0	0	0	151
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.00	0.00	0.00	0.00	3.37
Uranium mine surface maintenance	0	0	0	0	0	12	0	190	0	0	0	0	202
	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.57	0.00	0.00	0.00	0.00	0.55
Uranium mine surface miner	0	0	0	0	0	0	0	244	0	0	0	0	244
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.94
Uranium mine surface personnel	0	0	0	0	0	4	0	98	0	0	0	0	102
	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.33	0.00	0.00	0.00	0.00	0.32
Uranium mine surface support worker	0	0	0	0	0	8	0	320	0	0	0	0	328
	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.68	0.00	0.00	0.00	0.00	0.66
Uranium mine underground maintenance	0	0	0	0	0	3	0	100	0	0	0	0	103
	0.00	0.00	0.00	0.00	0.00	0.10	0.00	1.52	0.00	0.00	0.00	0.00	1.48
Uranium mine underground miner	0	0	0	0	0	3	0	351	0	0	0	0	354
	0.00	0.00	0.00	0.00	0.00	0.10	0.00	5.58	0.00	0.00	0.00	0.00	5.53
Uranium mine underground personnel	0	0	0	0	0	50	0	431	0	0	0	0	481
	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.75	0.00	0.00	0.00	0.00	0.68
Uranium mine visitor	0	0	0	0	0	0	0	243	0	0	0	0	243
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.12
OVERALL	**0**	**0**	**0**	**0**	**0**	**86**	**0**	**2651**	**0**	**0**	**0**	**0**	**2737**
	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.12**	**0.00**	**1.78**	**0.00**	**0.00**	**0.00**	**0.00**	**1.72**

1997 Final Analysis

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	11	195	1	207
		Average dose (mSv)	0.09	0.00	0.00	0.01
	25-34	Number of Workers	60	972	4	1036
		Average dose (mSv)	0.18	0.03	0.00	0.04
	35-44	Number of Workers	176	1293	8	1477
		Average dose (mSv)	0.27	0.05	0.04	0.07
	45-54	Number of Workers	205	878	3	1086
		Average dose (mSv)	0.25	0.07	0.00	0.10
	55-up	Number of Workers	68	260	5	333
		Average dose (mSv)	0.16	0.03	0.04	0.06
	Unknown	Number of Workers	29	53	0	82
		Average dose (mSv)	0.21	0.06	0.00	0.11
	Overall	**Number of Workers**	**549**	**3651**	**21**	**4221**
		Average dose (mSv)	**0.23**	**0.04**	**0.02**	**0.07**
Industry and Research	Below 25	Number of Workers	684	390	3	1077
		Average dose (mSv)	2.02	0.05	0.10	1.30
	25-34	Number of Workers	3268	1409	15	4692
		Average dose (mSv)	1.12	0.09	0.00	0.81
	35-44	Number of Workers	4130	1112	14	5256
		Average dose (mSv)	0.72	0.10	0.04	0.59
	45-54	Number of Workers	2655	480	10	3145
		Average dose (mSv)	0.53	0.16	1.20	0.48
	55-up	Number of Workers	916	119	13	1048
		Average dose (mSv)	0.26	0.07	0.02	0.24
	Unknown	Number of Workers	181	21	0	202
		Average dose (mSv)	0.34	0.60	0.00	0.37
	Overall	**Number of Workers**	**11834**	**3531**	**55**	**15420**
		Average dose (mSv)	**0.82**	**0.10**	**0.24**	**0.65**
Medicine	Below 25	Number of Workers	286	3324	5	3615
		Average dose (mSv)	0.11	0.04	0.00	0.05
	25-34	Number of Workers	3255	14762	32	18049
		Average dose (mSv)	0.13	0.07	0.33	0.09
	35-44	Number of Workers	5104	12821	35	17960
		Average dose (mSv)	0.13	0.09	0.03	0.10
	45-54	Number of Workers	4361	6956	28	11345
		Average dose (mSv)	0.09	0.08	0.03	0.08
	55-up	Number of Workers	2398	1481	72	3951
		Average dose (mSv)	0.11	0.06	0.03	0.09
	Unknown	Number of Workers	341	349	4	694
		Average dose (mSv)	0.07	0.07	0.00	0.07
	Overall	**Number of Workers**	**15745**	**39693**	**176**	**55614**
		Average dose (mSv)	**0.11**	**0.08**	**0.08**	**0.09**

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	198	60	0	258
		Average dose (mSv)	0.68	0.07	0.00	0.54
		% tritium	14.2	42.1	0.0	15.1
	25-34	Number of Workers	1977	474	0	2451
		Average dose (mSv)	1.50	0.34	0.00	1.28
		% tritium	22.9	19.7	0.0	22.7
	35-44	Number of Workers	4760	718	2	5480
		Average dose (mSv)	1.29	0.25	0.00	1.16
		% tritium	19.4	25.5	0.0	19.6
	45-54	Number of Workers	4134	369	2	4505
		Average dose (mSv)	0.89	0.16	0.00	0.83
		% tritium	17.7	31.4	0.0	17.9
	55-up	Number of Workers	919	26	0	945
		Average dose (mSv)	0.72	0.25	0.00	0.71
		% tritium	14.1	0.0	0.0	13.9
	Unknown	Number of Workers	208	10	0	218
		Average dose (mSv)	0.53	0.79	0.00	0.54
		% tritium	19.4	15.1	0.0	19.1
	Overall	**Number of Workers**	**12196**	**1657**	**4**	**13857**
		Average dose (mSv)	**1.12**	**0.25**	**0.00**	**1.02**
		% tritium	**19.4**	**23.7**	**0.0**	**19.5**
Mining	Below 25	Number of Workers	184	49	0	233
		Average dose (mSv)	1.36	0.75	0.00	1.23
		% radon progeny	46.1	29.6	0.0	44.0
	25-34	Number of Workers	606	97	3	706
		Average dose (mSv)	2.35	0.78	0.22	2.13
		% radon progeny	39.6	31.8	100.0	39.2
	35-44	Number of Workers	749	63	5	817
		Average dose (mSv)	2.16	0.61	0.39	2.03
		% radon progeny	38.3	41.7	89.7	38.4
	45-54	Number of Workers	485	22	1	508
		Average dose (mSv)	2.13	0.25	0.35	2.04
		% radon progeny	39.5	52.7	100.0	39.6
	55-up	Number of Workers	176	9	6	191
		Average dose (mSv)	1.16	0.04	0.12	1.07
		% radon progeny	43.3	100.0	28.6	43.4
	Unknown	Number of Workers	29	2	0	31
		Average dose (mSv)	1.07	0.00	0.00	1.00
		% radon progeny	57.9	0.0	0.0	57.9
	Overall	**Number of Workers**	**2229**	**242**	**15**	**2486**
		Average dose (mSv)	**2.04**	**0.65**	**0.24**	**1.90**
		% radon progeny	**39.8**	**34.6**	**80.8**	**39.6**

Table 4
Dose Statistics by job category
Administrator

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	351	0.00	0.00
>0-1	179	73.42	0.41
>1-2	1	1.70	1.70
>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	531	75.12	0.14
			Five year period 1993-1997
0	413	0.00	0.00
>0-5	396	422.89	1.07
>5-25	3	22.30	7.43
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	812	445.19	0.55

Hybrid lognormal parameters for positive doses in 1997:
D: 15.4719
μ: 8.0313
F^2: 17.7197
Sample size: 180
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

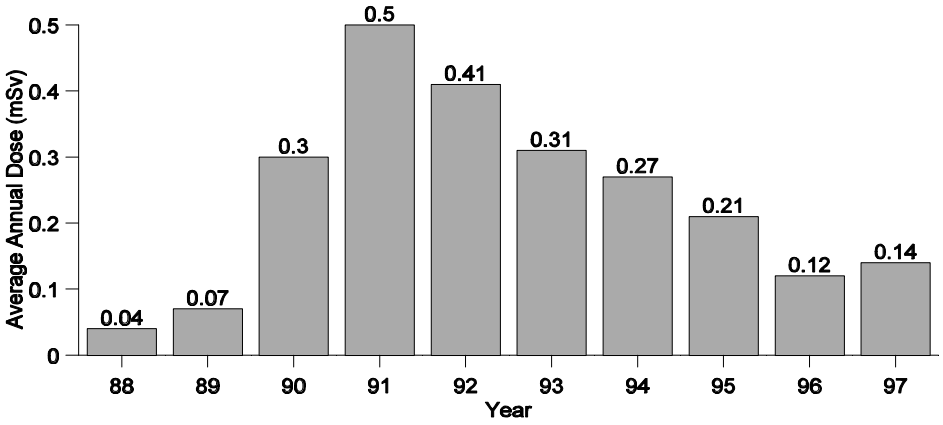

Table 4 (Cont'd)
Office Staff

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	3116	0.00	0.00
>0-1	446	163.84	0.37
>1-2	10	13.96	1.40
>2-5	7	18.55	2.65
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	3579	196.35	0.05
			Five year period 1993-1997
0	5178	0.00	0.00
>0-5	1535	1782.69	1.16
>5-25	23	179.55	7.81
>25-100	3	112.12	37.37
>100	0	0.00	0.00
Total	6739	2074.36	0.31

Hybrid lognormal parameters for positive doses in 1997:
D: 1.2715
μ: -0.4293
F^2: 1.7465
Sample size: 463
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

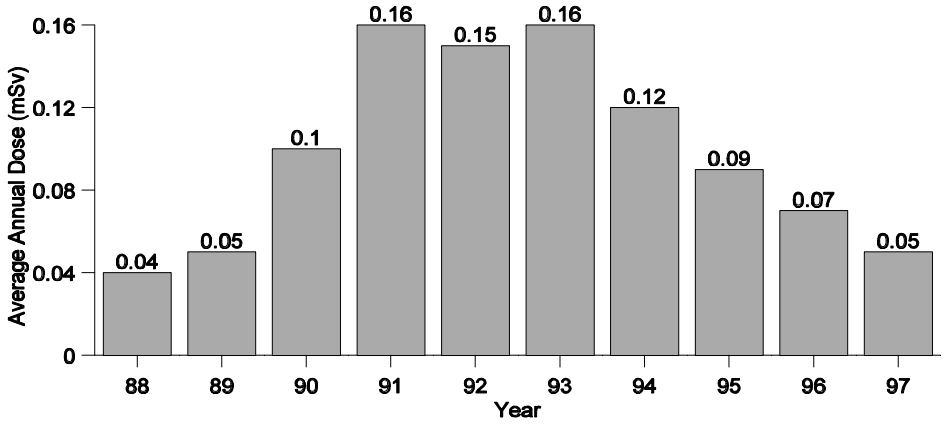

Table 4 (Cont'd)
Safety Officer

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	89	0.00	0.00
>0-1	21	10.20	0.49
>1-2	2	2.60	1.30
>2-5	1	3.40	3.40
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	113	16.20	0.14
			Five year period 1993-1997
0	88	0.00	0.00
>0-5	67	55.97	0.84
>5-25	2	20.22	10.11
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	157	76.19	0.49

Lognormal parameters for positive doses in 1997:
μ: -0.6289
F^2: 0.3802
Sample size: 24
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

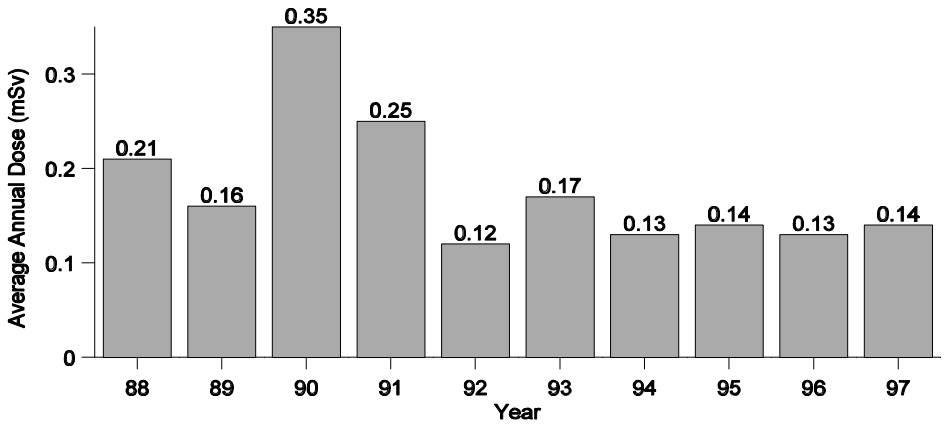

Table 4 (Cont'd)
Industrial Radiographer

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	1039	0.00	0.00
>0-1	329	173.02	0.53
>1-2	153	234.34	1.53
>2-5	265	894.76	3.38
>5-20	414	4099.75	9.90
>20-50	80	2185.85	27.32
>50	2	108.90	54.45
Total	2282	7696.62	3.37
			Five year period 1993-1997
0	1169	0.00	0.00
>0-5	1114	1562.52	1.40
>5-25	687	9131.83	13.29
>25-100	484	23074.91	47.68
>100	37	5108.18	138.06
Total	3491	38877.44	11.14

Hybrid lognormal parameters for positive doses in 1997:
D: 0.0374
μ: -2.2826
F^2: 2.7088
Sample size: 1243
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

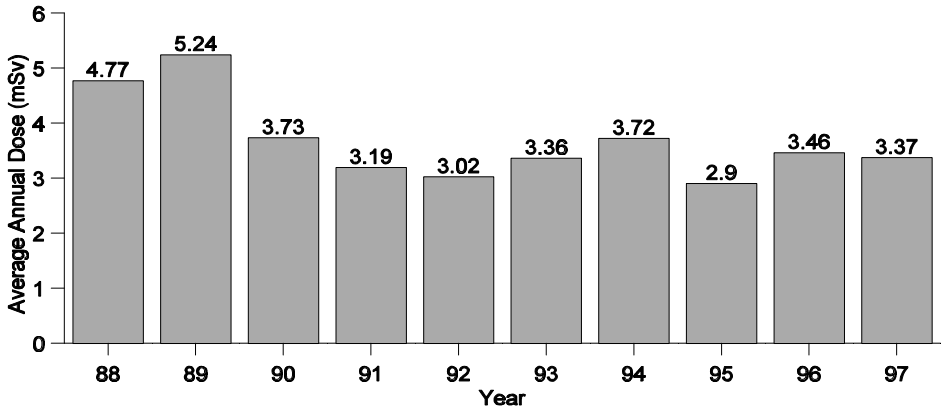

Table 4 (Cont'd)
Instructor (Non Medical)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	149	0.00	0.00
>0-1	13	5.30	0.41
>1-2	1	1.10	1.10
>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	163	6.40	0.04
			Five year period 1993-1997
0	201	0.00	0.00
>0-5	73	49.24	0.67
>5-25	0	0.00	0.00
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	274	49.24	0.18

Lognormal parameters for positive doses in 1997:
μ: -0.9186
F^2: 0.2548
Sample size: 14
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

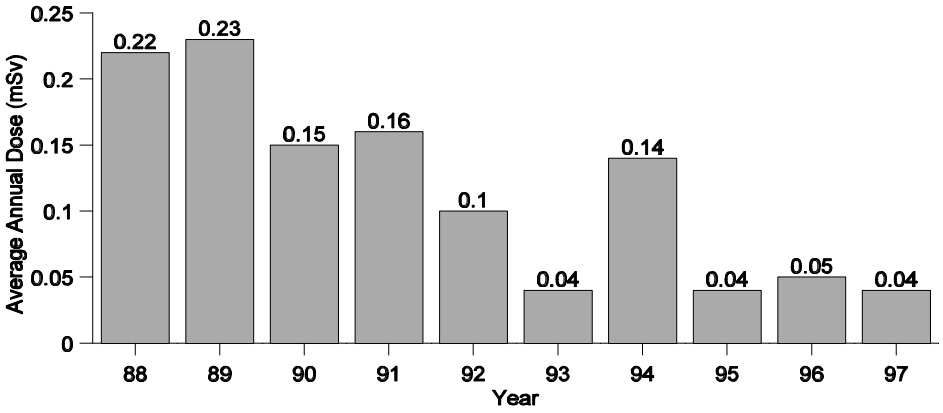

Table 4 (Cont'd)
Instrument Technician

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	1450	0.00	0.00
>0-1	315	124.48	0.40
>1-2	35	47.66	1.36
>2-5	17	50.90	2.99
>5-20	6	43.00	7.17
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	1823	266.04	0.15
			Five year period 1993-1997
0	1601	0.00	0.00
>0-5	1069	1074.09	1.00
>5-25	94	922.75	9.82
>25-100	12	422.80	35.23
>100	0	0.00	0.00
Total	2776	2419.64	0.87

Lognormal parameters for positive doses in 1997:
μ: -0.9022
F^2: 1.0193
Sample size: 373
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

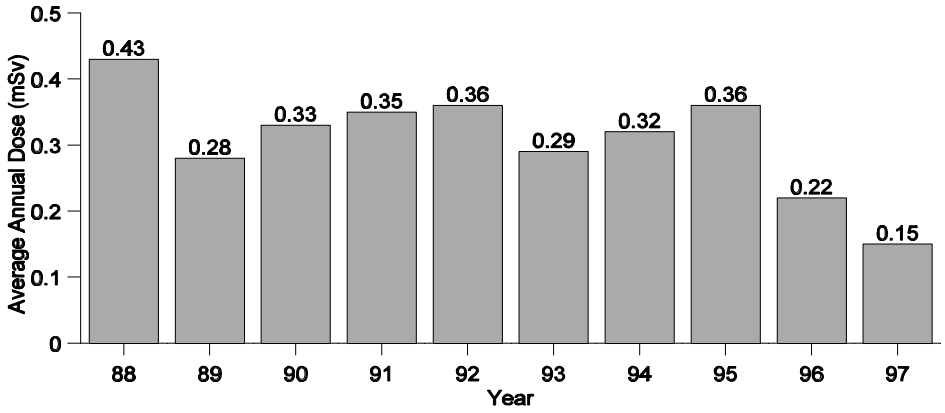

Table 4 (Cont'd)
Laboratory Technician (Industrial)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	2958	0.00	0.00
>0-1	772	261.41	0.34
>1-2	59	79.41	1.35
>2-5	48	155.78	3.25
>5-20	12	91.68	7.64
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	3849	588.28	0.15
			Five year period 1993-1997
0	5010	0.00	0.00
>0-5	2428	1855.83	0.76
>5-25	133	1476.30	11.10
>25-100	8	292.08	36.51
>100	1	550.00	550.00
Total	7580	4174.21	0.55

Lognormal parameters for positive doses in 1997:
μ: -1.0848
F^2: 1.1863
Sample size: 891
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

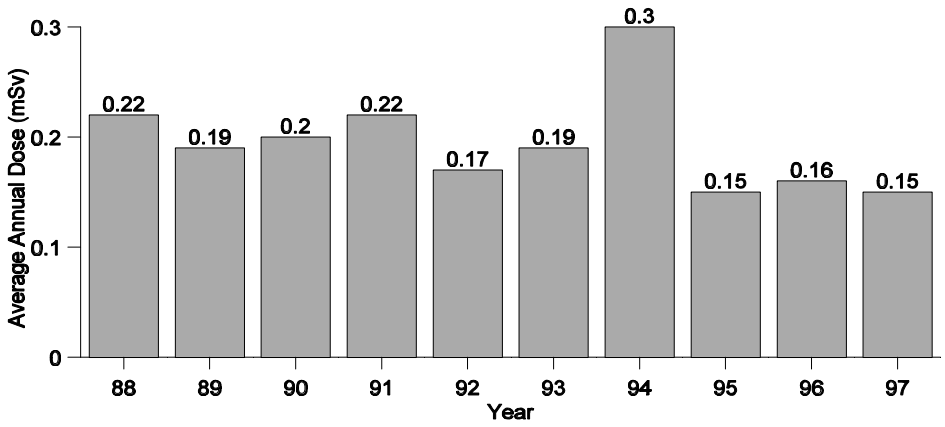

Table 4 (Cont'd)
Nuclear Fuel Processor

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	39	0.00	0.00
>0-1	56	24.90	0.44
>1-2	22	34.90	1.59
>2-5	32	112.90	3.53
>5-20	28	229.60	8.20
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	177	402.30	2.27
			Five year period 1993-1997
0	30	0.00	0.00
>0-5	82	172.71	2.11
>5-25	98	1189.20	12.13
>25-100	24	867.50	36.15
>100	0	0.00	0.00
Total	234	2229.41	9.53

Lognormal parameters for positive doses in 1997:
D: 0.1139
μ: -1.4675
F^2: 2.5587
Sample size: 138
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

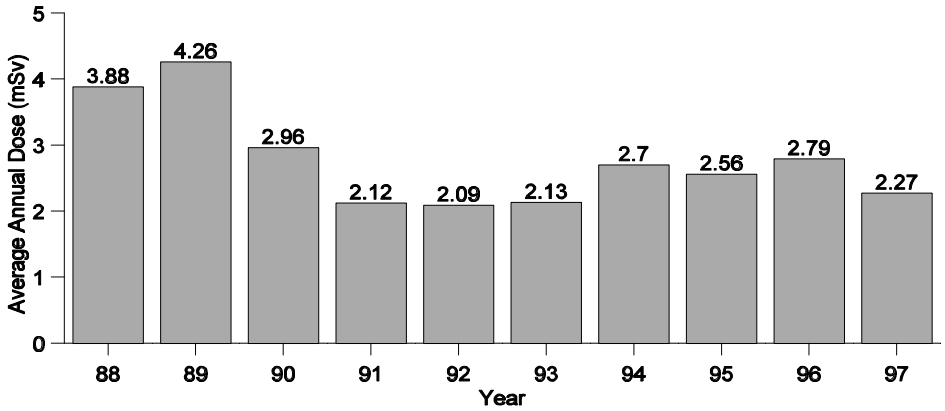

Table 4 (Cont'd)
Scientist/Engineer (Field)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	745	0.00	0.00
>0-1	633	249.31	0.39
>1-2	47	65.93	1.40
>2-5	24	78.96	3.29
>5-20	7	61.83	8.83
>20-50	1	27.70	27.70
>50	0	0.00	0.00
Total	1457	483.73	0.33
			Five year period 1993-1997
0	811	0.00	0.00
>0-5	1374	1636.19	1.19
>5-25	89	963.04	10.82
>25-100	11	369.86	33.62
>100	0	0.00	0.00
Total	2285	2969.09	1.30

Lognormal parameters for positive doses in 1997:
μ: -1.0194
F^2: 1.2290
Sample size: 712
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

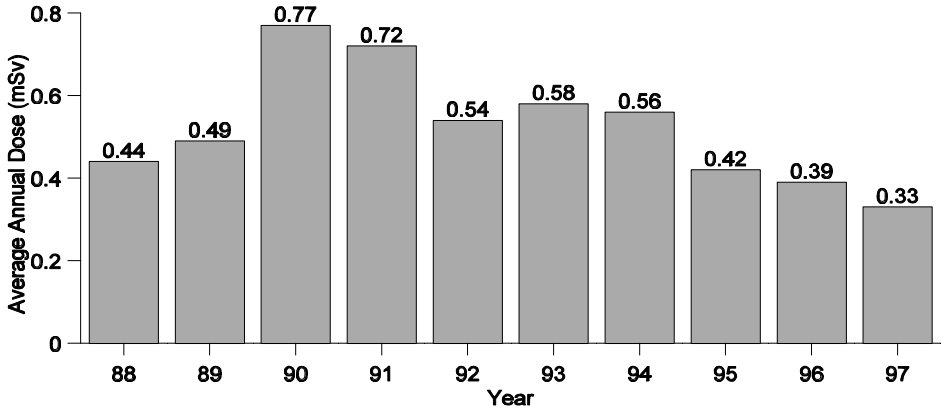

Table 4 (Cont'd)
Scientist/Engineer (Laboratory)

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	4198	0.00	0.00
>0-1	516	163.41	0.32
>1-2	25	36.90	1.48
>2-5	6	20.20	3.37
>5-20	2	12.40	6.20
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	4747	232.91	0.05
			Five year period 1993-1997
0	5693	0.00	0.00
>0-5	2388	1491.17	0.62
>5-25	25	211.32	8.45
>25-100	4	123.00	30.75
>100	0	0.00	0.00
Total	8110	1825.49	0.23

Lognormal parameters for positive doses in 1997:
μ: -1.2261
F^2: 0.5654
Sample size: 549
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997

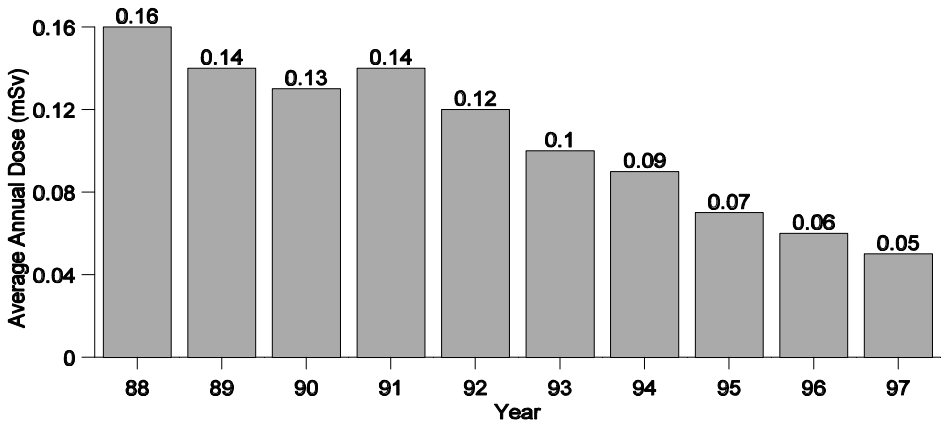

Table 4 (Cont'd)
Well Logger

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	594	0.00	0.00
>0-1	219	97.50	0.45
>1-2	55	81.60	1.48
>2-5	54	172.00	3.19
>5-20	8	64.10	8.01
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	930	415.20	0.45
			Five year period 1993-1997
0	548	0.00	0.00
>0-5	930	1357.47	1.46
>5-25	177	1664.30	9.40
>25-100	7	232.40	33.20
>100	0	0.00	0.00
Total	1662	3254.17	1.96

Lognormal parameters for positive doses in 1997:
μ: -0.4426
F^2: 0.9788
Sample size: 336
(See Appendix for explanation)

Histogram of average annual doses over ten year period 1988-1997