

1999 Report on Occupational Radiation Exposures in Canada

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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.

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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 one 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.

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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

1997 Final Analysis

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 0.00	0 0.00	8 0.21	3 0.00	50 0.00	388 0.18	19 0.00	3 0.00	29 0.08	29 0.02	0 0.00	0 0.00	531 0.14
Office staff	37 0.01	5 0.14	82 0.02	63 0.03	658 0.03	1989 0.08	230 0.00	64 0.01	176 0.03	265 0.02	12 0.00	1 0.00	3582 0.05
Safety officer	3 0.00	1 0.00	10 0.09	2 0.00	22 0.05	33 0.22	24 0.00	2 0.00	3 1.13	13 0.28	0 0.00	0 0.00	113 0.14
OVERALL	42 0.00	6 0.12	100 0.05	68 0.03	730 0.03	2410 0.10	273 0.00	69 0.01	208 0.05	307 0.03	12 0.00	1 0.00	4226 0.07
Industry and Research													
Industrial radiographer	31 0.56	0 0.00	97 1.53	65 2.46	326 1.95	622 1.89	35 0.76	143 2.54	854 5.59	199 1.93	0 0.00	3 0.00	2375 3.24
Instructor (non-medical)	11 0.00	0 0.00	23 0.06	3 0.00	14 0.02	62 0.06	8 0.00	4 0.00	15 0.02	22 0.03	1 0.30	0 0.00	163 0.04
Instrument technician	89 0.01	1 0.00	60 0.02	53 0.10	404 0.06	786 0.24	55 0.01	25 0.02	176 0.07	184 0.12	0 0.00	0 0.00	1833 0.14
Laboratory technician (industrial)	64 0.07	10 0.11	89 0.10	34 0.01	772 0.08	1621 0.22	234 0.01	222 0.02	522 0.08	289 0.33	0 0.00	0 0.00	3857 0.15
Nuclear fuel processor	0 0.00	0 0.00	0 0.00	0 0.00	1 0.00	170 2.36	1 0.00	0 0.00	3 0.10	2 0.05	0 0.00	0 0.00	177 2.27
Scientist engineer (field)	10 0.00	0 0.00	49 0.15	38 0.25	89 0.24	976 0.35	16 0.13	57 0.11	126 0.55	109 0.17	0 0.00	0 0.00	1470 0.32
Scientist/engineer (laboratory)	128 0.00	3 0.00	146 0.06	17 0.00	1557 0.04	1533 0.06	178 0.01	153 0.04	197 0.08	871 0.05	0 0.00	0 0.00	4783 0.05
Well logger	2 0.05	0 0.00	1 0.00	0 0.00	0 0.00	2 0.00	0 0.00	36 0.02	880 0.47	16 0.02	0 0.00	0 0.00	937 0.44
OVERALL	335 0.07	14 0.08	465 0.38	210 0.83	3163 0.26	5772 0.44	527 0.07	640 0.60	2773 1.92	1692 0.34	1 0.30	3 0.00	15595 0.64
Medicine													
Chiropractor	0 0.00	0 0.00	1 0.00	2 0.00	398 0.02	339 0.04	61 0.01	9 0.03	143 0.02	32 0.21	0 0.00	0 0.00	985 0.03
Dental assistant	84 0.00	16 0.00	219 0.02	139 0.01	1721 0.01	4181 0.01	580 0.01	334 0.01	594 0.01	610 0.01	17 0.00	8 0.00	8503 0.01
Dental hygienist	47 0.02	31 0.00	166 0.01	93 0.01	2227 0.00	2988 0.01	437 0.00	173 0.01	272 0.01	363 0.00	13 0.07	3 0.00	6813 0.01
Dental therapist/nurse	1 0.00	0 0.00	0 0.00	0 0.00	8 0.00	11 0.00	8 0.00	38 0.00	1 0.00	10 0.17	4 0.00	8 0.06	89 0.02
Dentist	86 0.01	11 0.00	144 0.01	90 0.01	2364 0.01	2881 0.01	516 0.02	127 0.01	252 0.01	282 0.00	14 0.02	4 0.00	6771 0.01
Gynaecologist	1 0.00	0 0.00	1 0.00	0 0.00	5 0.00	13 0.28	5 0.04	0 0.00	1 0.00	3 0.07	0 0.00	0 0.00	29 0.14
Laboratory technician (medical)	36 0.01	2 0.00	157 0.02	2 0.00	1046 0.08	1277 0.07	152 0.02	127 0.02	254 0.04	323 0.05	0 0.00	0 0.00	3376 0.06
Medical physicist	2 0.25	0 0.00	8 0.00	6 0.17	81 0.06	92 0.13	15 0.07	11 0.02	12 0.07	52 0.03	1 0.00	0 0.00	280 0.08
Medical radiation technologist	284 0.01	69 0.08	283 0.04	359 0.09	2728 0.05	4354 0.12	634 0.05	618 0.06	1222 0.09	1326 0.10	28 0.03	10 0.00	11915 0.09
Nuclear medicine technologist	21 2.11	4 1.18	46 1.24	31 1.02	487 1.43	560 1.20	71 0.87	26 1.06	89 1.01	153 0.65	0 0.00	0 0.00	1488 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 0.03	2 0.00	252 0.01	136 0.08	1043 0.04	2332 0.15	165 0.02	89 0.24	132 0.12	267 0.09	132 0.01	66 0.03	4809 0.10
Physician	40 0.06	5 0.00	63 0.01	34 0.63	630 0.14	832 0.17	56 0.11	51 0.42	150 0.12	184 0.17	9 0.03	3 0.07	2057 0.16
Radiation therapist	11 0.21	0 0.00	32 0.02	27 0.13	236 0.18	416 0.44	56 0.07	55 0.10	62 0.07	171 0.05	0 0.00	0 0.00	1066 0.24
Radiologist (diagnostic)	49 0.07	7 0.00	49 0.23	51 0.28	527 0.07	686 0.17	67 0.09	45 0.01	122 0.19	226 0.13	2 0.00	0 0.00	1831 0.13
Radiologist (therapeutic)	3 0.00	0 0.00	2 0.15	11 0.02	44 0.08	51 0.09	13 0.02	4 0.08	12 0.03	16 0.03	0 0.00	0 0.00	156 0.06
Veterinarian	38 0.01	44 0.08	179 0.02	83 0.16	660 0.02	1359 0.04	227 0.01	188 0.02	727 0.02	691 0.02	0 0.00	8 0.00	4204 0.03
Veterinary technician	0 0.00	0 0.00	0 0.00	0 0.00	1 0.00	2 0.00	0 0.00	1 0.00	2 0.00	3 0.00	0 0.00	0 0.00	9 0.00
Ward aid/orderly	29 0.02	17 0.03	27 0.04	47 0.14	960 0.05	351 0.11	82 0.00	34 0.06	36 0.05	107 0.02	6 0.00	0 0.00	1696 0.06
OVERALL	925 0.07	208 0.07	1629 0.06	1111 0.12	15166 0.08	22725 0.10	3145 0.05	1930 0.06	4083 0.07	4819 0.08	226 0.01	110 0.03	56077 0.09
Nuclear Power													
Reactor - administration	0 0.00	0 0.00	0 0.00	133 0.16	351 0.26	4677 0.25	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	5161 0.25
Reactor - chemical and radiation control	0 0.00	0 0.00	0 0.00	23 0.69	39 1.48	309 1.92	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	371 1.80
Reactor - construction	0 0.00	0 0.00	0 0.00	0 0.00	41 0.07	1313 1.65	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1354 1.60
Reactor - control technician	0 0.00	0 0.00	0 0.00	0 0.00	111 1.30	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	111 1.30
Reactor - electrical maintenance	0 0.00	0 0.00	0 0.00	79 0.82	37 3.87	861 1.04	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	977 1.13
Reactor - fuel handling	0 0.00	0 0.00	0 0.00	26 5.70	11 3.40	2 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	39 4.76
Reactor - general maintenance	0 0.00	0 0.00	0 0.00	223 0.66	86 3.37	977 0.59	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1286 0.79
Reactor - health physics	0 0.00	0 0.00	0 0.00	36 0.69	9 0.00	21 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	66 0.37
Reactor - industrial radiographer	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	11 1.30	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	11 1.30
Reactor - mechanical maintenance	0 0.00	0 0.00	0 0.00	136 2.56	178 4.56	997 2.19	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1311 2.55
Reactor - operations	0 0.00	0 0.00	0 0.00	93 0.78	113 1.45	1659 1.66	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1865 1.60
Reactor - scientific/professional	0 0.00	0 0.00	0 0.00	330 1.00	134 0.97	1110 0.62	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1574 0.73
Reactor - training	0 0.00	0 0.00	0 0.00	27 0.28	18 0.43	5 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	50 0.31
Reactor - visitor	0 0.00	0 0.00	0 0.00	0 0.00	11 0.79	43 0.34	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	54 0.44
OVERALL	0 0.00	0 0.00	0 0.00	1106 1.07	1139 1.66	11985 0.92	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	14230 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 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1 0.40	0 0.00	159 2.87	0 0.00	0 0.00	0 0.00	0 0.00	160 2.86
Uranium mine mill worker	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	4 0.13	0 0.00	223 2.96	0 0.00	0 0.00	0 0.00	0 0.00	227 2.91
Uranium mine nurse	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	10 0.16	0 0.00	0 0.00	0 0.00	0 0.00	10 0.16
Uranium mine office staff	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	132 0.21	0 0.00	0 0.00	0 0.00	0 0.00	132 0.21
Uranium mine support worker	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1 0.00	0 0.00	150 3.40	0 0.00	0 0.00	0 0.00	0 0.00	151 3.37
Uranium mine surface maintenance	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	12 0.23	0 0.00	190 0.57	0 0.00	0 0.00	0 0.00	0 0.00	202 0.55
Uranium mine surface miner	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	244 0.94	0 0.00	0 0.00	0 0.00	0 0.00	244 0.94
Uranium mine surface personnel	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	4 0.13	0 0.00	98 0.33	0 0.00	0 0.00	0 0.00	0 0.00	102 0.32
Uranium mine surface support worker	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	8 0.15	0 0.00	320 0.68	0 0.00	0 0.00	0 0.00	0 0.00	328 0.66
Uranium mine underground maintenance	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	3 0.10	0 0.00	100 1.52	0 0.00	0 0.00	0 0.00	0 0.00	103 1.48
Uranium mine underground miner	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	3 0.10	0 0.00	351 5.58	0 0.00	0 0.00	0 0.00	0 0.00	354 5.53
Uranium mine underground personnel	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	50 0.09	0 0.00	431 0.75	0 0.00	0 0.00	0 0.00	0 0.00	481 0.68
Uranium mine visitor	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	243 0.12	0 0.00	0 0.00	0 0.00	0 0.00	243 0.12
OVERALL	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	86 0.12	0 0.00	2651 1.78	0 0.00	0 0.00	0 0.00	0 0.00	2737 1.72

1997 Final Analysis

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

Job Sector	Age	Statistic	Sex			Overall
			Male	Female	Unknown	
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.

Job Sector	Age	Statistic	Sex			Overall
			Male	Female	Unknown	
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

1997 Final Analysis

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

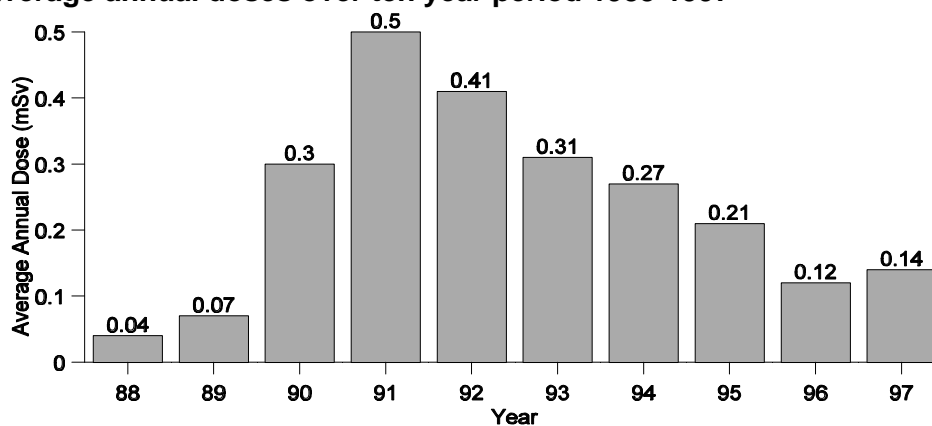
μ : 8.0313

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

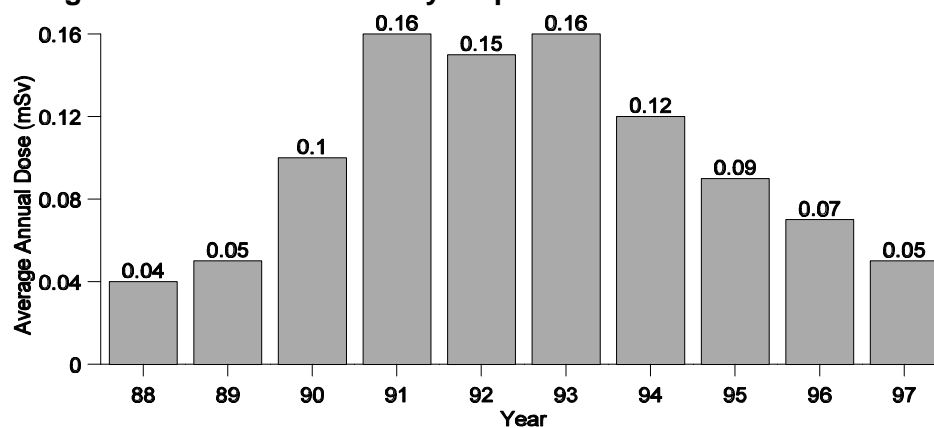


Table 4 (Cont'd)
Safety Officer

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

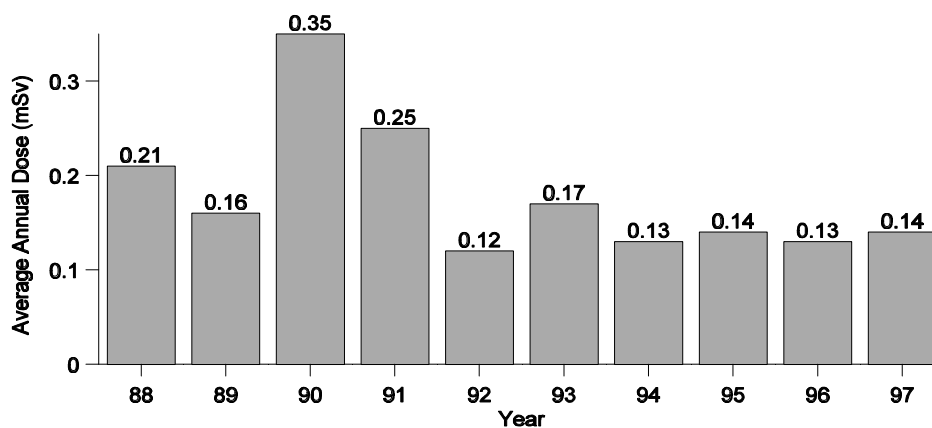


Table 4 (Cont'd)
Industrial Radiographer

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

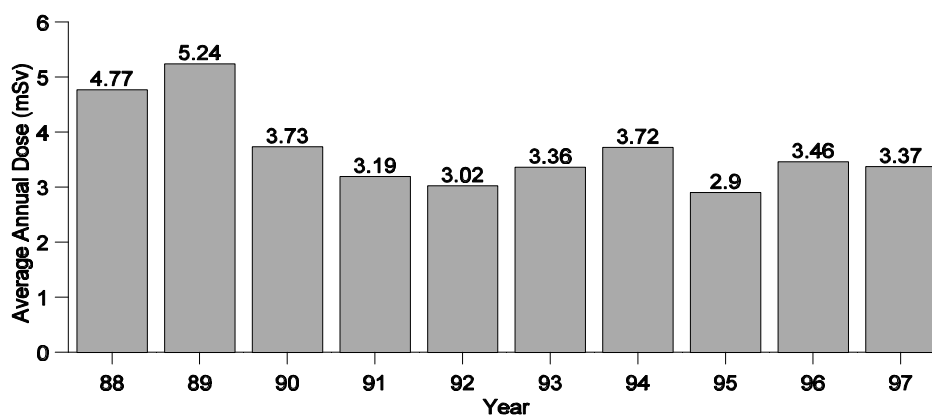


Table 4 (Cont'd)
Instructor (Non Medical)

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

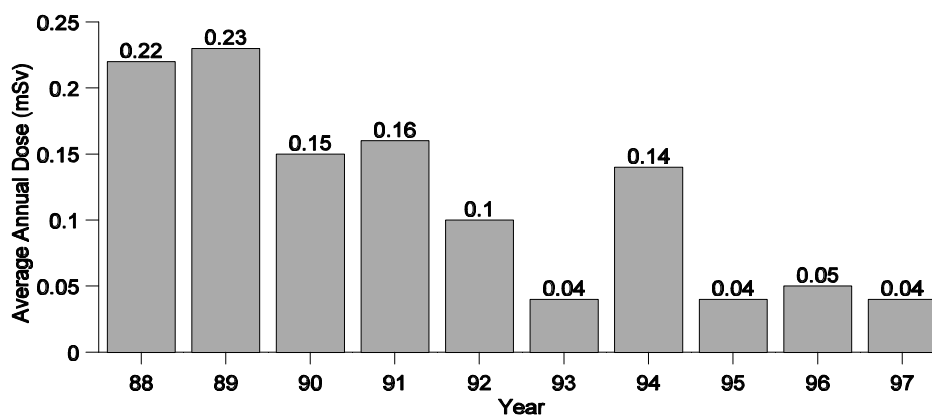


Table 4 (Cont'd)
Instrument Technician

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

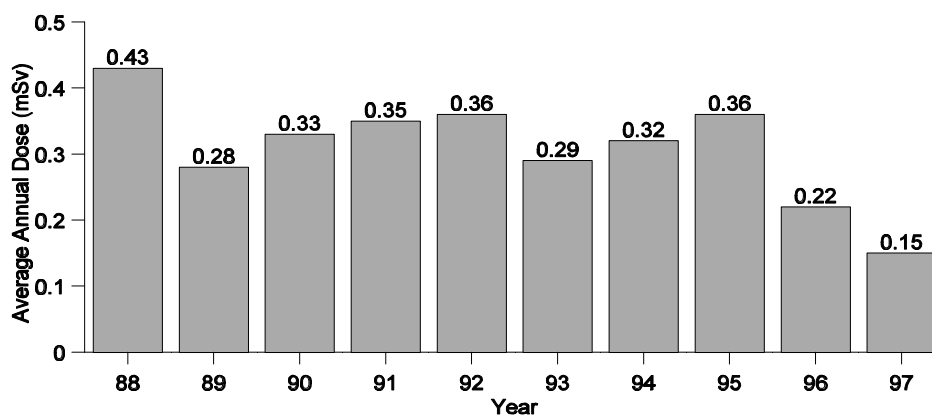


Table 4 (Cont'd)
Laboratory Technician (Industrial)

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

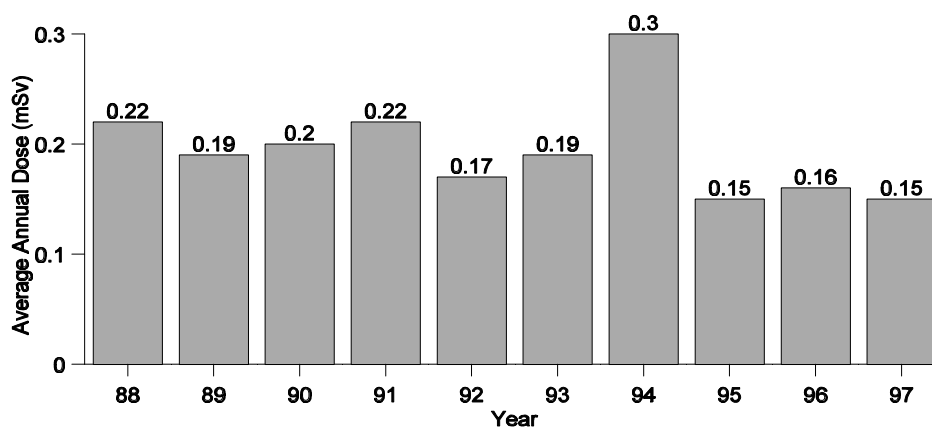


Table 4 (Cont'd)
Nuclear Fuel Processor

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

F²: 2.5587

Sample size: 138

(See Appendix for explanation)

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

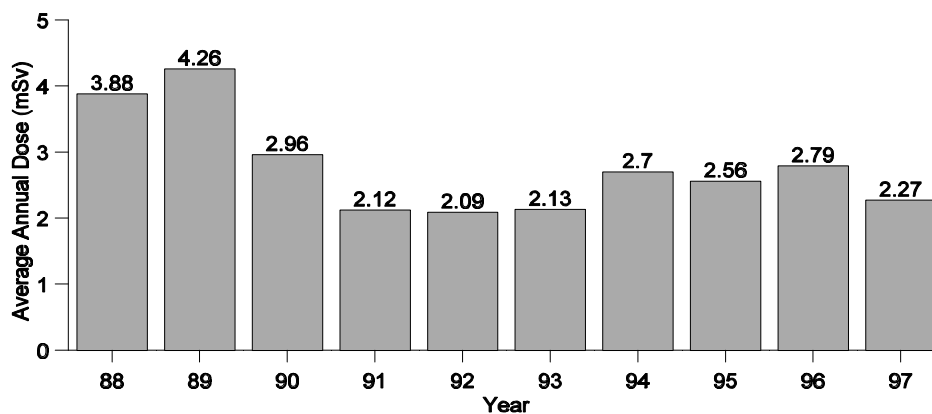


Table 4 (Cont'd)
Scientist/Engineer (Field)

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

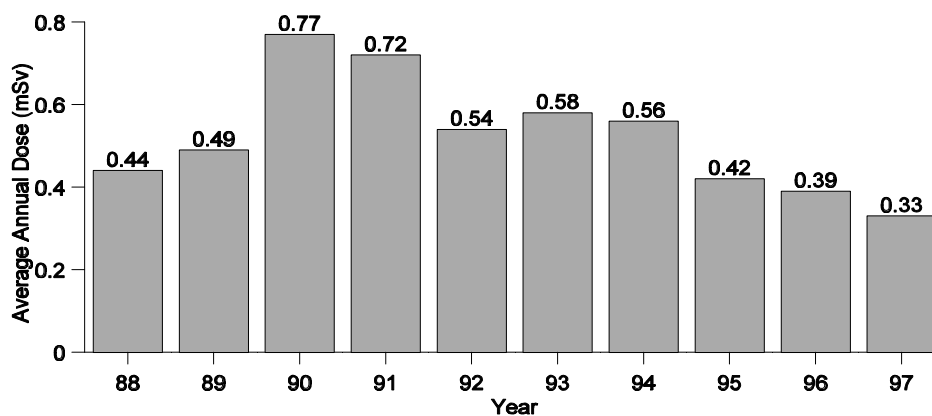


Table 4 (Cont'd)
Scientist/Engineer (Laboratory)

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:

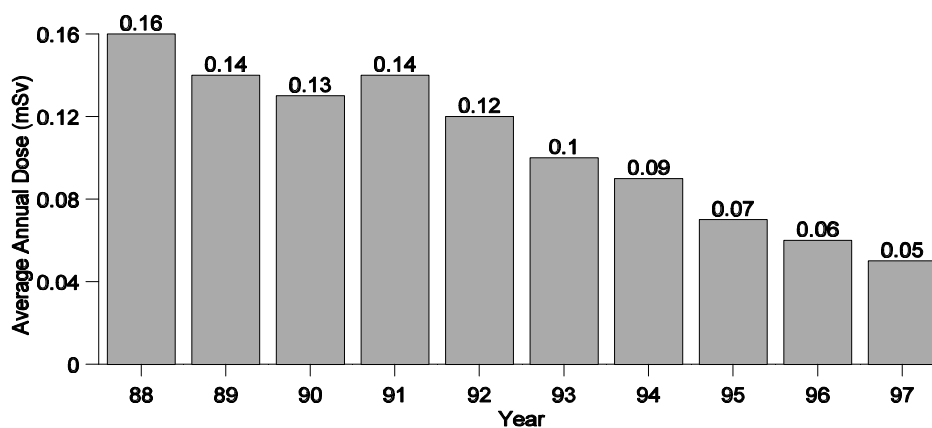
μ : -1.2261

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:

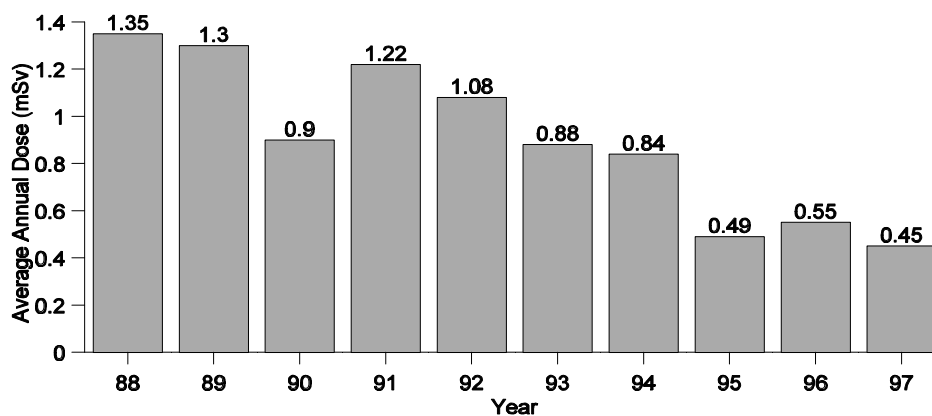
μ : -0.4426

F^2 : 0.9788

Sample size: 336

(See Appendix for explanation)

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



**Table 4 (Cont'd)
Chiropractor**

Dose Interval (mSv)	Number of Workers	Collective Dose	Average Dose
			Year 1997
0	938	0.00	0.00
>0-1	41	16.90	0.41
>1-2	3	4.30	1.43
>2-5	2	8.80	4.40
>5-20	0	0.00	0.00
>20-50	0	0.00	0.00
>50	0	0.00	0.00
Total	984	30.00	0.03
Five year period 1993-1997			
0	1072	0.00	0.00
>0-5	256	142.70	0.56
>5-25	7	80.30	11.47
>25-100	0	0.00	0.00
>100	0	0.00	0.00
Total	1335	223.00	0.17

Lognormal parameters for positive doses in 1997:

μ : -0.8355

F^2 : 0.6136

Sample size: 46

(See Appendix for explanation)

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

